Safety in the Field: Assessing the Impact of Stress and Fatigue on Situation Awareness in Irish and British Farmers

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Abstract. Situation awareness (SA) is a cognitive safety-critical skill, consisting of three levels – perception, comprehension, and anticipation. SA lapses have been associated with many incidents and accidents across high-risk industries. Stress and fatigue can negatively impact SA, leading to some of these lapses. More recently, the importance of SA has also been acknowledged in agriculture, the most dangerous industry in Ireland and the United Kingdom by injury and fatality rate. The current study aimed to explore SA lapses and the impact of stress and fatigue on SA in agriculture. Fifteen Irish and British farmers were interviewed using the critical incident technique followed by general questions on stress and fatigue in farming. In the critical incident section, interviewees were asked to verbally recall a recent negative farming experience, an error that occurred, or adverse conditions which they had to manage on the farm while feeling tired or stressed. Additional questions were asked to uncover implicit knowledge on SA lapses, stress, and fatigue. Interviews were analysed using qualitative content analysis. SA lapses were reportedly involved in all accidents and incidents. Many occurred at the perception level, as a failure to monitor or observe data, usually because of attentional narrowing. Several lapses also occurred at the comprehension level as an incomplete or an inaccurate mental model, usually in the context of a recent change in equipment or machinery. Stress and fatigue had a negative impact on SA through cognitive impairments. A twofold strategy is suggested, focused on strengthening SA and managing stress and fatigue.

Keywords: Situation awareness · Stress · Fatigue · Safety · Agriculture

1 Introduction

Situation awareness (SA) is a cognitive safety-critical skill, essential for reducing the likelihood of errors in high-risk industries. Conversely, failures in SA have been associated with major incidents and disasters such as Deepwater Horizon (Sneddon et al. 2013). A widely accepted definition of SA is “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (Endsley 1995a). The triadic model

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by Endsley (1995a) will hereby be adopted as theoretical background. Thus, Level 1 SA involves perceiving relevant aspects in the environment, whilst Level 2 SA relies on a synthesis of separate Level 1 data and encompasses a subsequent understanding of the situation by considering such patterns in the light of operator goals. Finally, Level 3 SA consists of the ability to predict the future state of the system and is founded on both Level 1 and Level 2 SA. Errors of SA can occur at all three levels and can be classified according to an SA error taxonomy developed in aviation (Endsley 1995b; Jones and Endsley 1995).

Stress represents one of the factors which can negatively affect SA (Endsley 1995a). Whilst a certain amount of stress may have a beneficial effect by directing attention to important aspects of the situation, a higher amount may impair SA by demanding a portion of limited attentional resources. The most common ways in which stressors can decrease SA are attentional narrowing and premature closure i.e., reaching a decision without considering all available information. These cognitive lapses can lead to Level 1 “failure to monitor or observe data” errors. In novel situations where a mental model does not exist, stress is also likely to lead to inaccurate or incomplete Level 2 SA through reductions in working memory capacity. Alongside stress, fatigue could also impair SA by reducing alertness levels (HSE 2006).

Research across high-risk industries using the original SA error taxonomy or an adapted version to analyse and quantify SA lapses has consistently shown that a large proportion of incidents and accidents are caused by failures in SA. In most studies, Level 1 lapses were identified most frequently, followed by Level 2 and Level 3 lapses, respectively. Nevertheless, since errors are typically coded at the lowest level, comprehension and projection lapses may have been underestimated. In studies which reported factors affecting SA at each of its three levels, the most common single type of error was failure to scan or observe data, typically due to attentional narrowing or distraction and low vigilance (e.g., Endsley 1995b; Sandhåland et al. 2015; Sneddon et al. 2006). Various sources of data were analysed, including accident reports in aviation and bridge operations (Endsley 1995b; Sandhåland et al. 2015); incident reports in anaesthesia and offshore drilling (Schulz et al. 2016; Sneddon et al. 2006); patient records in primary care (Singh et al. 2012); and closed malpractice claims in anaesthesia (Schulz et al. 2017). However, an acknowledged limitation of many of these narratives is the incomplete information available on SA. Consequently, some studies also employed semi-structured qualitative interviews with subject-matter experts to explore SA aspects further (Singh et al. 2012).

Specific factors leading to SA lapses have also been studied in offshore drilling, leading to mixed results. Thus, through interviews with oil and gas drilling personnel, Sneddon et al. (2006) found that stress and fatigue were amongst the largest contributory factors to decreased SA quality. A subsequent study investigated the impact of stress and fatigue on SA as measured through a self-report scale and the relationship with safety behaviour and accident involvement (Sneddon et al. 2013). Expectedly, higher levels of stress and fatigue were negatively associated with SA. Nevertheless, stress remained the sole significant predictor of poor SA after the regression analysis.

Agriculture is the most dangerous industry in Ireland and the United Kingdom, with a fatality and injury rate much higher than any other industrial sector (HSA 2020; HSE

2020). A recent series of studies has revealed that failures in SA, especially because of fatigue or stress, significantly contribute to agricultural accidents. In an initial interview study with British farmers, lack of SA was identified in many reported incidents and was frequently associated with impaired attention due to rushing or fatigue (Irwin and Poots 2015). Most participants also identified stress due to task pressure as a potential cause of accidents. Several farmers also acknowledged the importance of experience in developing mental models and enhancing their higher levels of SA. In a subsequent investigation of risk perception in tractor-based scenarios, most farmers decided not to proceed with the task when tired, expressing concern about the detrimental effects of fatigue on awareness (Irwin and Poots 2018). Finally, an analysis of error types and factors impacting SA in British and Irish agricultural machinery operators found that the most frequent lapse occurred at Level 1 due to information not being observed (Irwin et al. 2019), mirroring the results from other high-risk industries. This type of error was commonly linked with individual performance limitations or task-based pressures such as fatigue, distraction, rushing or stress. Level 2 errors were also reported, either in the form of a poor mental model in unfamiliar situations or of complacency and overconfidence.

Some studies conducted outside of the UK have also analysed the impact of stress and fatigue on farm safety. Thus, high levels of perceived stressors including financial issues and time pressure, stress symptoms and poor safety behaviours predicted farm accidents in a sample of Danish farmers (Glasscock et al. 2006). An interaction was observed, so that higher levels of stress symptoms and not performing safety checks increased the risk of injury. The authors argued that farmers with poor safety habits cannot manage risks when stressed, due to impaired attention and concentration. Hagel et al. (2013) also identified an association between economic worry and accident risk. Financial stress associated with conditions on Saskatchewan farms impacted safety indirectly through behavioural changes linked to fatigue. Long working hours and subsequent limited sleep duration as factors leading to fatigue have also been shown to increase the risk of workplace injury in farming (Choi et al. 2006; Day et al. 2009; Lilley et al. 2012; Sprince et al. 2003; Stallones et al. 2006).

In the light of the above, the current study was conducted to identify SA lapses and to determine the impact of stress and fatigue on SA and safety in agriculture, through a qualitative content analysis of semi-structured interviews with Irish and British farmers. Expanding our emergent knowledge of SA in agriculture and understanding underlying psychosocial causes of farm accidents can help inform future safety interventions.

2 Method

2.1 Participants

Farmers (N = 15; 1 female, 14 males; aged 25–59) were recruited from Ireland (n = 10) and the United Kingdom (n = 5) in February-March & June-August 2020. Participants worked on several types of farm: dairy (n = 7), animals and arable crops (n = 3), mixed animals (sheep & beef cattle) (n = 2), dairy & beef cattle (n = 1), sheep (n = 1), arable crops (n = 1). Recruitment criteria were farming as main occupation and age over 18.

2.2 Design

Interview. The critical incident technique (Flanagan 1954) was employed in the first part of each qualitative semi-structured interview. The method had been previously used to elicit detailed information from domain experts on non-technical skills (Irwin and Poots 2015), including SA.

In the critical incident section, participants (all but one who could not recall a critical incident) were asked to verbally recall from memory a recent negative farming experience, an error that occurred, or adverse conditions which they had to manage on the farm while feeling tired or stressed. The interviewees were asked to provide as many details as possible surrounding the critical incident, from the lead up to the consequences of the event. Participants were asked to describe their thoughts and behaviours, as well the actions of any other individuals present. Additional questions were asked to uncover implicit knowledge with a focus on SA lapses, stress, and fatigue. These questions were adapted from an interview schedule exploring critical incidents in helicopter pilots (Hamlet et al. 2018) and from SA literature.

In the second and third part of the interview, participants were asked more general questions on stress and fatigue in agriculture, including on the potential impact of these factors on SA. These were based on a literature review conducted on the topic.

Demographic Survey. Farmers were asked to report their age, gender, role, work schedule, average number of hours worked, any off-farm employment, number of hours worked per week in off-farm employment, number of hours of sleep per 24h, and the type and size of current farm. This information was collected to describe the sample.

2.3 Data Collection

This research project was approved in January 2020 by the Psychology Ethics Committee, University of Aberdeen. Participants were recruited through an email invitation sent to contacts within agricultural organisations or from a farming background. Recruitment was also conducted online via Twitter and specialized farming forums. All participants from Ireland were recruited through two organisational contacts within Teagasc. Both the invitation letter and the information sheet offered potential participants information about the study and indicated the opportunity to ask additional questions before participation. Suitable dates and times were arranged for the interviews, either through organisational contacts or directly.

Informed consent was obtained prior to the interview. Consent forms were stored separately from interview transcripts to maintain anonymity. Audio recorded interviews lasting between 20 and 50 min (30 min on average) were conducted by the first author in March (13 interviews) & August (2 interviews) 2020. The interviews were conducted over the telephone, due to the remote geographical location of participants and COVID restrictions and were followed by the demographic survey. Due to the semi-structured nature of the interview schedule, existing questions were omitted or altered where relevant to accommodate information already provided by the participant. Similarly, additional questions were asked if necessary. Participants were fully debriefed at the end of the study. All interview recordings were transcribed verbatim by the first author and subsequently deleted. To maintain anonymity, personally identifiable details were removed from the interview transcripts.

An initial minimum sample size of 12 participants was established based on relevant literature (Guest et al. 2006) and similar studies (Irwin and Poots 2015). Since most participants in the initial sample had been recruited from Ireland (n = 9) and since data saturation had not yet been reached (i.e., the point where no new concepts or behaviours are identified), a second wave of data collection occurred in August 2020. After this stage, data saturation was reached.

2.4 Data Analysis

The interview transcripts were coded using qualitative content analysis (Hsieh and Shannon 2005). All coding and analysis were conducted using qualitative analysis software NVivo 12.

Stage 1 of coding involved the first author reading the transcripts and then coding using primarily manifest, descriptive coding, each code capturing what the interviewees had said. Latent coding was also used for certain codes where further interpretation was necessary. For example, fragments describing cognitive lapses were interpreted and coded according to SA theory (Endsley 1995a). The first three interviews coded were from British farmers; these were then compared to four of the interviews from Irish farmers to determine any differences between geographical regions. As similar patterns were observed and given the small number of British farmers, data from both locations was considered as a single sample. Stage 2 of coding required codes to be streamlined and then their meaning was checked for accuracy. The first seven interviews coded, alongside the codebook derived from this analysis were also checked by the second author to ensure the consistency of the coding strategy. Minor amendments to the code names and meanings were made. Codes were then grouped into broad categories and several levels of sub-categories, describing underlying trends within the data. Some of these sub-categories were informed by relevant models and theories, for instance the taxonomy of SA errors (Endsley 1995b).

Data from the two interviews collected later was analysed using the existing framework, whilst allowing for minor amendments to the structure. When preparing the current chapter, data from all interviews was reconsidered and recoded where necessary.

3 Results

3.1 Demographic Characteristics

Most participants (n = 13) were aged 40–59, with the remainder (n = 2) aged 25–29. All participants were farm owners, except for one farm tenant. All participants worked full-time, with one participant working part-time on their own farm and full-time in off-farm employment. Participants reported working a minimum of either 49h per week (n = 8) (M = 64) or 8.5h per day (n = 7) (M = 10.6). Two participants currently held off-farm employment, in which they spent 30-40h and 55-60h per week, respectively.

Typical reported sleep duration varied between 5.5 and 7.8h (M = 6.6). The size of the farms (n = 14) ranged between 79 and 800ac (M = 272), with one significant outlier of 2200ac.

3.2 Situation Awareness

SA lapses were reportedly involved in all accidents and incidents. These were broadly described as a general loss of concentration or focus. Some participants mentioned specific elements of which they lost awareness, such as own location, personal status, or safety aspects including risks and hazards. For example, the following interviewee reported a complete loss of spatial awareness leading up to the critical incident: *"I don't know where I am anymore." (P2).* Another participant reported a lack of self-awareness prior to the accident, especially of fatigue levels: *"I didn't know I was tired and rushing at all." (P4).* For some participants, the realisation of what was going on only occurred in hindsight: *"I did realize afterwards." (P6).* The general role of good SA as a protective factor and of poor SA as a contributing factor to errors, incidents and accidents was also mentioned by many participants who solely described adverse circumstances: *"Not as aware of your surroundings and obviously that can lead to accidents." (P8).*

Of the SA lapses which could be accurately classified, many occurred at Level 1 SA, as a failure to monitor or observe data which was otherwise readily available and discernible in the environment: "*I didn't see any risk at all." (P1).* For instance, one participant failed to notice that a shed door was not closed properly, which led to an incident involving cattle. In most of these instances, participants demonstrated attentional narrowing, whereby they focused excessively on one element whilst ignoring others: *"I was just totally focused on his nostrils." (P1).* Some interviewees also exhibited premature closure: "*I just saw the bucket and I reacted." (P4).* These cognitive failures were compounded by the addition of heavy workload and rushing.

Many SA lapses also occurred at Level 2 in the form of poor comprehension of perceived data in the light of operator goals. Most participants explicitly expressed an inability to understand the situation, either in the form of an incomplete or an inaccurate mental model: *"I didn't realize how serious the situation was" (P6).* Some interviewees also reported a recent change in equipment or machinery or over-familiarity with existing equipment. For instance, the following participant used an outdated mental model when operating a new tractor, formed through their experience with the old one: *"Possibly because of that I was not used to the operation of it." (P6).*

3.3 Stress and Fatigue

The contribution of fatigue to farm safety was widely acknowledged, both in general terms and as a causal factor in the context of critical incidents: *"Fatigue was the problem there." (P2).* Participants took more risks and shortcuts to complete tasks quicker when fatigued: "*You would definitely cut corners." (P12).* In most critical incidents, long working hours, high workload, and lack of sleep were the main contributory factors to this extreme tiredness. Many participants reported that fatigue led to decreased alertness, which in extreme cases meant that the operator was falling asleep on the job. In terms of cognitive lapses, fatigue caused impaired concentration and poor SA. For instance, several participants described their actions when fatigued as *"going through the motions",* resulting in SA failures in both their perception and comprehension.

Similarly, stress was regarded as a contributory factor to errors, incidents and lapses on the farm. What is more, many participants also reported disregarding safety when stressed. At a cognitive level, stress led to impaired concentration and internal focus on worries and concerns, contributing to many of the previously outlined SA lapses: *"You're on the job, but your mind is not there, that's stress for me." (P13).*

4 Discussion

The results of the current study highlight the importance of SA within agriculture, adding to the existing literature in other high-risk industries and to more recent findings in farming (Irwin and Poots 2015; 2018; Irwin et al. 2019). Thus, general SA failures and lapses at Level 1 (perception) and Level 2 (comprehension) were present in all accidents and incidents reported. The data also indicated the potential negative impact of stress and fatigue on SA, both generally and in the context of critical incidents, mirroring previous results from offshore drilling (Sneddon et al. 2006; 2013) and farming (Irwin and Poots 2015; 2018; Irwin et al. 2019). Stress and fatigue were regarded as main contributory factors to errors, incidents, and accidents, in line with studies on accident and injury risk within agriculture (Choi et al. 2006; Day et al. 2009; Glasscock et al. 2006; Hagel et al. 2013; Lilley et al. 2012; Sprince et al. 2003; Stallones et al. 2006).

Many SA lapses which occurred in the reported accidents and incidents were Level 1 "failure to monitor or observe data" errors, which happened because of underlying attentional narrowing or premature closure. SA error analyses in aviation, offshore drilling, bridge operations and farming have frequently identified this single type of lapse, also occurring due to distraction or attentional narrowing (Endsley 1995b; Irwin et al. 2019; Sandhåland et al. 2015; Sneddon et al. 2006). This is an important issue for SA, as certain elements in the environment are attended at the expense of others which are often safety-critical, as it was also the case in the current study. For instance, airplane crashes have occurred due to an excessive focus on landing gear leading to a neglect of fuel usage, due to attentional narrowing on the flight direction indicator or due to a failure to check flap status (Endsley 1995a).

Many SA lapses also occurred at Level 2 as either an incomplete or an incorrect mental model, in the context of a recent change in equipment or machinery or overfamiliarity with existing equipment. This would suggest that operators were using old mental models when dealing with new equipment. The same underlying factors have also been identified through a previous SA error analysis in farming (Irwin et al. 2019). Although these errors are typically less frequently identified in the literature than errors of perception, some studies in anaesthesia and primary care found Level 2 SA lapses to be equally prevalent (Schulz et al. 2016; Singh et al. 2012). It can be argued that like medicine, farming is an unstandardized industry in terms of training and work settings, as opposed to aviation (Schulz et al. 2016).

The current study extended the existing literature in aviation, offshore drilling and farming by exploring the specific impact of stress and fatigue on SA and safety in agriculture. Many participants reported that fatigue led to decreased alertness and to cognitive lapses, such as impaired concentration and poor SA. Stress also reportedly led to impaired concentration and internal focus on worries and concerns, contributing to many SA lapses. In other words, fatigue impacted SA through decreased vigilance, whereas stress demanded a portion of the limited attentional resources of the operator (Endsley 1995a).

A few limitations of the project should be noted. The current data is specific to a purposive sample of farmers from Ireland and the UK predominantly running animal farms. As such, generalizability of results is not advised to farmers outside these geographical regions or in different farm operations. The current study may be subject to self-selection bias, whereby the sample mostly consisted of participants with an interest in safety issues or who had previously sustained workplace accidents or injuries. Participant recruitment was mainly conducted during busy times of the year, namely calving and lambing season, which may also explain the reduced sample size. Despite taking measures to ensure rigor in the data analysis process, such as cross-checking of the coding structure by the second author and data saturation, qualitative analysis is founded on subjectivity and interpretation and multiple meanings are possible within the data. The causality between variables of interest warrants further investigation. What is more, self-reports are subject to individual and recall bias. Furthermore, although self-reports of critical incidents provide valuable insight into cognitive aspects otherwise not available in official accident and incident reports, SA lapses were sometimes not verbalised despite probing efforts. Importantly, lapses in the current study were coded at the lowest identified level, as per similar studies, which might explain the absence of Level 3 errors. Frequency was not reported within the results section as the number of accidents and incidents was too small for reliable statistical inferences. However, the participant quotes provided good descriptive illustrations of the types of SA lapses and contributory factors.

The identified connection between stress and fatigue and SA lapses flags the need for a twofold strategy in agriculture, focused on strengthening SA on the one hand and managing stress and fatigue on the other hand. This is based on the acknowledgement that certain levels of stress and fatigue are sometimes inevitable in the farming industry. Mental models which support higher levels of SA can be improved through training of both technical skills and SA. Furthermore, checklists which have recently been developed based on research with tractor operators can prompt users to complete procedural steps and can further support SA (Irwin et al. 2019).

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