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Developing a Prototype Behavioural Marker System for Farmer Non-Technical Skills (FLINTS)

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ABSTRACT

Objective: Non-technical skills, the social and cognitive skills thought necessary for safe and effective working, have been studied within the farming context over the past six years. However, these skills are not yet taught as part of a safety curriculum for farmers, due, in part, to a lack of defined framework and assessment system. The current paper describes the development of the FLINTS behavioral marker system for discussion, observation, evaluation and feedback on non-technical skills for farmers.

Method: The development of the behavioral marker system proceeded through three key stages. First, the current research knowledge on non-technical skills was synthesized to compile a list of non-technical skill categories and elements. Second, a series of discussion groups with subject matter experts was conducted to develop behavioral markers for each element. Lastly, refinement and review of the system was undertaken by academics and experts.

Results: The prototype FLINTS taxonomy containing five non-technical skill categories and 16 elements was produced. The non-technical skill categories comprised situation awareness, teamwork & communication, leadership, task management and decision-making each with specific elements and behavioral markers.

Conclusion: FLINTS represents the first behavioral marker system for farmer non-technical skills, constructed through expert knowledge and advice via discussion and review groups, combined with underpinning research findings. This represents the first step towards the development of non-technical training and assessment for farmers. The current version of the FLINTS system is freely available to all potential users (https://research.abdn.ac.uk/nts-farming/flints/).

KEYWORDS

non-technical skills; FLINTS; safety; behavioural marker system

Introduction

Farming is a high-risk occupation, with a current fatality rate 18 times that of general industry in the UK.[1] Farmers must deal with multiple hazards including livestock and heavy machinery[2] often working alone and for long hours.[3] Typically, agricultural work involves a range of activities, many of which are conducted under time pressure and are associated with high workload,[4] particularly those that are weather dependent such as bringing in a harvest. As such farmers must develop a high level of technical knowledge to enable them to effectively manage their varied task load. However, technical knowledge alone may not be sufficient for safe work performance; farmers also need non-technical skills.

Non-technical skills

Non-technical skills are the cognitive (thinking skills such as situation awareness and decision-making) and social (interaction skills such as teamwork and leadership) considered necessary for safe and effective work practice.[5] These skills have been studied across a range of industries, including aviation[6] (where the study of these skills originated), offshore drilling[7] and healthcare.[8] More recently these skills have also been examined within agriculture, with work conducted to identify the key skill categories and elements required for safe farm work.[3] However, these specific skills are not currently taught within any farm safety training program.

Work in other industries has identified that lapses in non-technical skills can be a key cause of accidents and injuries, rather than a lack of technical knowledge.[9] Similarly, farmers identified lapses in situation awareness as being linked to adverse incidents when operating tractors,[10] and reported issues with decision-making, communication and teamwork when describing critical farming incidents.[3] To develop a training program

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behavioral marker system as the framework and common language for training and assessment of non-technical skills.

Behavioral marker systems

Behavioral marker systems are used to support the observation, evaluation, and training of key skills within high-risk industries and professions.[11] Each system has unique components that are context and/or role specific and should be developed through a rigorous research process with the workers who will be using the system.[11,12] Typically, a behavioral marker system will encompass a skill taxonomy, with defined skill categories, elements and behaviors, together with user guidance and a rating scale for assessment purposes.[12] The NOTECHS behavioral marker system was one of the first such systems for training and assessing non-technical skills, developed for use in aviation.[6] Following the methods reported for NOTECHS a series of systems were developed for surgeons (NOTSS[11]), scrub practitioners (SPLINTS[9]), anesthetists (ANTS[13]) and anesthetic practitioners (ANTS-AP[14]). In each case the steps towards development encompassed a literature review, interviews with practitioners, and a series of focus/discussion groups alongside academic or expert review. Once the prototype taxonomy is published further research is then conducted to assess the reliability and validity of the tool.[13]

The process of developing a behavioral marker system for farmer non-technical skills began 6 years ago with an interview study[3] that identified five key team non-technical skill categories – situation awareness, decision-making, leadership, teamwork and task management, together with a subset of those skills – situation awareness, decision-making, and task management for the lone worker. This was followed by a questionnaire-based study which reported a link between safety climate, motivation, financial concerns and non-technical skills.[15] A mixed measures vignette study was undertaken to examine factors influencing, and supporting, farmer decision-making when working with heavy machinery.[16] The results suggested that management of fatigue and stress were crucial for maintaining safety and illustrated the importance of risk assessment and management for safe decision making in the farming context.[16] A fourth qualitative study focused on situation awareness requirements and lapses when driving a tractor[10] providing further detail on the skill elements, and behaviors, within the farming context. Finally, a second mixed measures vignette study investigated farmer decision-making across livestock vignettes[17] providing further insight into the elements and behaviors associated with decision-making, situation awareness, task management, communication, and teamwork.

Study AIM

Building on the studies reported above, the next step in the development of a prototype farmer behavioral marker system was to confirm the core non-technical skill categories and elements identified in the research, alongside production of observable behavioral markers for each element. At this stage a single generic system encompassing skills relevant for those working in groups, and alone, across multiple farm contexts was planned. This is reflective of both the need for farmers to manage multiple tasks within their job role, and the multifaceted research (spanning multiple farm contexts) conducted to date. The current paper describes this stage of system development via a research synthesis, a series of subject matter expert discussion groups, combined with expert and academic review, to produce the prototype version of FLINTS – the Farmer LIst of Non-Technical Skills behavioral marker system.

Methods

Stages of development

The study was conducted over three key stages:

(1) Synthesis of farming non-technical skills research combined with academic review to produce a list of skills and elements.
(2) Discussion groups with subject matter experts (farmers, farm safety professionals, members of farming organizations) to confirm the key skills and elements, alongside generating observable behavioral markers.
(3) Refinement of the system via expert and academic review.

Synthesis and academic review

The first author undertook the initial exercise whereby a list of key non-technical skills and associated elements were compiled from the five research projects[3,10,15–17] undertaken by the research group previously to identify and assess farmer non-technical skills. The combined research projects provided qualitative and quantitative data describing non-technical skills, elements and associated behaviors gathered from a sample of 463 UK farmers. The list was drawn directly from the core skills and elements reported across the research studies. Only those skills and elements that were reported in at least two of the previous studies were included in the final list. The skill taxonomy was developed according to the design criteria commonly used for the development of behavioral marker systems,[6,12] which state that a system should:

- Be based on a hierarchical structure with three levels: category, element, behavior.
- Focus on skills that are observable through behavior.
- Use appropriate language and terminology suitable for the specific sector (i.e. farming).
- Be parsimonious and seek to explain non-technical skills using as few categories and elements as possible.

Following this initial compilation, the taxonomy was reviewed by all three co-authors to ensure the skills were relevant and matched the core research findings, followed by category and element definition development. The final framework contained five skill categories and 17 elements (see Table 1).

Discussion groups

Facilitated discussion groups have been previously reported as a recognized method for the development of behavioral marker systems.[9] Participants should be selected on the basis of their being subject matter experts within the defined field of interest; in the current paper this meant all participants should have a thorough understanding of both farming (including tasks and hazards) and farm safety requirements. The focus of the current discussion groups was to encourage participants to discuss a presented subset of skills (no single group attempted to cover all five non-technical skills). The discussion was facilitated by two of the co-authors who encouraged participants to exchange ideas, use personal experience and perspective to suggest observable behaviors and comment on the suggested skill categories, elements and associated terminology. The discussion groups were primarily focused on ensuring the skills and elements were relevant, and the terminology used for definitions was appropriate. They were also asked to generate behavioral marker suggestions for good and poor performance. These suggestions were collated across discussion groups to produce a comprehensive list of behavioral markers for the prototype FLINTS system.

Participants

A total of nine (five female, four male) participants were recruited to participate in four discussion groups. There were three types of participants:

- Farmers (one full-time farmer and two farmers who also had roles within farming organizations). All three farmers were livestock farmers, with one farmer also having experience of crop farming. All three farmers were engaged in farm safety activities, including speaking at farming events.
- Farm safety professionals (n = 4). All four professionals had experience of conducting UK farm safety inspections, with two continuing to conduct regular inspections at the time of participation.
- Professionals from farming organizations (n= 2). Both professionals were engaged in farm safety activities at the time of participation, including presentations, research and safety campaigns. Both professionals had more than a decade of experience of working with, and within, the farming industry.

It was important at this stage to gain insight from subject matter experts with experience of multiple farm types (e.g. livestock, crops) to enable them to recognize and discuss multiple behavior and task safety activities over a period

Table 1. Skill categories and elements developed for FLINTS via research synthesis and academic review.

Skill	Definition	Element	Definition
Situation awareness	*Building and maintaining an awareness of the environment, conditions and self. Recognizing and understanding information and cues in the environment, then using that information effectively to anticipate future states.*	Gathering information	*Collecting data about a situation or circumstances through monitoring the environment and checking a variety of sources.*
		Understanding the situation	*Recognizing the meaning of informational elements to form, and maintain, an accurate mental picture of situations.*
		Anticipating future events	*Using the current mental picture to think ahead about actions, consequences and possible future outcomes.*
Decision-making	*Reaching an appropriate judgment about a situation, selecting the most appropriate actions, solving problems, and managing risk.*	Managing risk	*Evaluating a situation to identify possible threats, considering potential actions and consequences with the overall aim of managing, or minimizing, risk.*
		Identifying and selecting options	*Generating and then weighing up multiple options and deciding on the most appropriate course of action for any given situation.*
		Adapting to circumstances	*The ability to adapt a course of action, or decision, based on a changing, dynamic, situation.*
Leadership	*Building a holistic picture of the environment and team actions, overseeing and guiding task activities, ensuring worker wellbeing and safety.*	Directing or guiding task behaviors	*Organizing work activities of others to achieve work goals.*
		Monitoring staff	*Maintaining oversight of worker location, progress and wellbeing.*
		Leading by example	*Engaging in overt safe and appropriate behaviors in front of workers.*
Teamwork & communication	*Developing effective working mechanisms for group-based scenarios, working well with others by combining activities and effort to reach a shared goal safely and effectively. Ensuring every team member has sufficient information to complete their tasks*	Co-coordinating with others	*Working together with others to achieve a shared goal.*
		Managing handover	*Ensuring work tasks are provided to team-mates at a suitable stage and with appropriate guidance.*
		Sharing tasks	*Sharing tasks appropriately across the team and facilitating support/fatigue management mechanisms.*
Task management	*Organizing activities and resources to maintain safety and quality standards. Managing competing pressures and demands.*	Maintaining quality and equipment	*Ensuring equipment and infrastructure are in safe and working condition.*
		Organizing resources/ infrastructure	*Arranging work areas for maximum safety and efficiency.*
		Managing deadlines	*Arranging work activities to ensure task completion and priorities within a defined timeframe.*
		Preparing	*Engaging in activity prior to a work task to facilitate timely and appropriate performance.*

of at least 5 years. Following this initial contact recruitment then proceeded via snowball sampling whereby the initial contacts approached further individuals known to fit the stated criteria. Participants selected from within this network of contacts all had experience with observing farmer behaviors in practice as part of their job role, this could encompass conducting farm inspections, providing training, or conducting observational research. Three of the groups consisted of two participants; the final group consisted of three participants.

Procedure

All discussion groups were held online using the platform Microsoft Teams. Each group was introduced by one of the research facilitators who provided an overview of all five skill categories from the prototype framework and then highlighted the two or three skills the group would focus on during their session. The sessions lasted between 60 and 90 minutes, and were audio recorded to facilitate note taking and accuracy for the suggested behaviors. The participants were asked to discuss the skill categories and elements provided, make suggestions in terms of the terminology used for those aspects, then work on developing observable behaviors for each element. Group 1 discussed decision-making, leadership, and teamwork & communication; Group 2 discussed making and leadership; and Group 4 discussed task management and situation awareness.

Review and refinement of the system

The behavioral marker and terminology suggestions raised by the discussion groups were subject to further refinement and review by two subject matter expert review groups, alongside academic review by the paper authors. The aim of this review and refinement process was to ensure minimal crossover between elements, remove any extraneous or irrelevant behaviors, generate new behaviors where gaps were noted, and ensure the language used was appropriate.

Participants

Two review sessions were conducted with three subject matter experts (one female, two male), all of whom were farm safety professionals with experience of making farm safety inspections (two participants in the first review group, one of whom had taken part in the original discussion groups, while the other had not, and one participant, who had not taken part in the discussion groups, for the final review). Academic review was undertaken by the three co-authors for this paper.

Procedure

The subject matter expert review groups followed the same procedure as stated above for the discussion groups (online, using Teams, lasting between 60–90 minutes). The reviewers were presented with a subset of skills, elements, and behaviors for review (review Group 1 discussed situation awareness, decision-making, and leadership, the second review session discussed situation awareness, teamwork & communication and task management). The reviewers were asked to consider the language used for each aspect, and the types of behaviors listed for each element. The first step was to ensure all behaviors were observable, removing any considered either unobservable or not relevant within the farming context. The next step was to reduce the number of behaviors for each element to enhance the usability of the system and remove any crossover. Finally, the wording for each category, element and behavior was considered and adjusted to ensure the language was suitable for a farming audience.

Within the academic review process the co-authors of the current paper implemented the suggestions put forward by the review groups where these were agreed via consensus and were consistent with the underpinning research on farming non-technical skills. Where there were gaps in behaviors due to removal of inappropriate behaviors new behaviors were generated, based on research, to ensure the system was balanced. The final revised system was checked by all co-authors and all participants of both the discussion and review groups to ensure accuracy.

Results

The process of discussion and review retained the five skill categories produced via the research synthesis but reduced the number of elements from 17 to 16 (combining managing deadlines and preparing within task management). The definitions for the categories and elements were altered to ensure the wording was appropriate for a farming audience. Each element had a minimum of three, maximum of six, descriptive observable behaviors for good and poor performance. Table 2 details the updated framework along with example good and poor behaviors for each element.

FLINTS v.1 handbook

Following completion of the refinement and review process, the FLINTS taxonomy was combined with guidelines and a rating scale to produce the complete prototype FLINTS v.1 handbook. This format will be suitable for the next stage in the development process, that of evaluating the taxonomy to determine reliability, validity and allow further refinement. The handbook, including guidance for users in terms of making observations, requirements for using the system, and details on the rating scale, is available here: https://research.abdn.ac.uk/nts-farming/flints/

Discussion

The prototype FLINTS behavioral marker system was designed to enable farmers, farm safety

Table 2. Updated FLINTS taxonomy with appropriate terminology and example good and poor practice behaviors.

Skill category	Element	Example of good practice	Example of poor practice
Situation awareness: *Building and maintaining an awareness of the environment, conditions and self. Recognizing and understanding information and cues in the environment, then using that information effectively to anticipate future states.*	Gathering information: *Actively collecting data about a situation or circumstances by monitoring the environment, listening, looking for potential issues and checking a variety of sources.*	Carries out regular visual checks of the environment (e.g. regularly watches livestock behavior when in an open field).	Is distracted by external/irrelevant factors while doing complex work (e.g. uses a mobile phone while driving).
	Understanding the situation: *Recognizing and interpreting the meaning of cues and information to form, and maintain, an accurate mental picture of situations.*	Responds to cues within the work environment that may suggest problems (e.g. safely stops tractor to investigate odd noise).	Fails to understand or does not follow rules and regulations (e.g. does not adhere to warning signage/labels on the farm).
	Anticipating future events: *Asking "what if" questions and using the current mental picture to think ahead about actions, consequences and possible future outcomes.*	Warns/advises others of future dangers and possible consequences of actions (e.g. warning visitors that wearing yellow hi vis workwear may agitate livestock).	Loses track of a farming activity (e.g. appears unaware that cattle are becoming restless).
Decision-making: *Reaching an appropriate judgment about a situation, selecting the most appropriate actions, solving problems, and managing risk.*	Managing risk: *Evaluating a situation to identify possible threats, considering potential actions and consequences with the overall aim of managing, or minimizing, risk.*	Implements additional safety precautions when working alone (e.g. shares their location and work plans with others when working alone).	Ignores safety guidelines and protocols that reduce risk (e.g. does not wear appropriate PPE).
	Identifying and selecting options: *Generating and then weighing up multiple options and deciding on the most appropriate course of action for any given situation.*	Takes into consideration other workers opinions/suggestions before starting work (i.e., group-based decision-making).	Proceeds with the first identified option to completing a job, even when time is available to consider other approaches.
	Adapting to circumstances: *Retaining a calm demeanor in the face of change, adapting actions and decisions in response to changing/dynamic circumstances.*	Stays calm and composed when circumstances prevent work from being completed according to the original plan.	Continues with original plan even when the outcome is poor, or an alternative is available.
Teamwork & communication: *Sharing information, goals and understanding to facilitate working well with others. Combining activities and effort to reach a shared goal safely and effectively.*	Co-coordinating with others: *Working with others by collaborating, sharing ideas and combining physical tasks to achieve a shared goal.*	Holds an informal chat before starting work to agree on the actions of the day.	Focuses on their own work to the detriment of the team (e.g. starts action that negatively impacts the work of others).
	Managing handover: *Ensuring work tasks are provided to other workers at a suitable stage and with appropriate guidance.*	Confirms that incoming workers have understood the given information and know what is expected of them.	Withholds critical task or situation relevant information, even when questioned.
	Sharing tasks: *Interacting with others to ensure work is shared appropriately across the team according to skill level and performance influencing factors (such as fatigue or stress).*	Asks for help/passes work on to others when overwhelmed or fatigued.	Displays signs of stress/rushing and works extended hours after colleagues have finished.
	Exchanging information: *Giving and receiving task and safety relevant information. Asking for further information on location, task, activities to ensure shared understanding.*	Informs those who are unfamiliar with the farm (e.g. visitors, contractors, new workers, etc.) about possible dangers.	Ends the conversation without the possibility of communicating feedback (e.g. walks off without allowing the workers/visitors to ask for further clarity or explanation).

(*Continued*)

Table 2. (Continued).

Skill category	Element	Example of good practice	Example of poor practice
Leadership: *Building a holistic picture of the environment and team actions, overseeing and guiding task activities, ensuring worker wellbeing and safety.*	Directing/guiding task behaviors: *Organizing the work activities of others to achieve farming and safety goals.*	Assigns work tasks with consideration for worker capabilities, experience, and training (e.g. promotes work shadowing opportunities when possible).	Directs work which is known to be dangerous or requires resources/ tools which are not available.
	Monitoring staff: *Maintaining oversight of worker location, progress and wellbeing. Providing support (mental and physical) where needed.*	Checks-in with workers regarding their progress, wellbeing and location (either on location or through communication devices).	Ignores risk taking or procedure breaking behavior of workers (e.g. skipping safety procedures in favor of increased productivity or getting the job done).
	Leading by example: *Engaging in overt safe and appropriate behaviors in front of workers.*	Openly takes accountability for personal errors or inappropriate behavior.	Is unaware of the existing safety procedures or precautions when questioned.
Task management: *Organizing activities and resources to maintain safety and quality standards. Managing competing pressures and demands.*	Providing and maintaining standards: *Supporting safety and quality by ensuring equipment and workplace are in safe condition and machinery maintenance guidelines are followed.*	Goes beyond the basic checks (i.e. looks behind the tires, counts wheel nuts, looks at the tread).	Starts or continues to work using equipment that is known to be faulty.
	Organizing resources/infrastructure: *Establishing the necessary requirements for task completion and arranging work areas for maximum safety and efficiency.*	Plans and follows a safe traffic management plan for the farm (e.g. one-way system, minimizes reversing, segregation of equipment/transport and pedestrians).	Keeping unused/faulty/dangerous equipment around the farm.
	Preparing: *Planning work activities to get jobs/tasks done on time and safely, minimizing the risk of rushing, distraction by irrelevant work activities or difficulties finding equipment.*	Walks the land before planned work, checking for possible safety hazards (e.g. open gates, powerlines, ditches).	Misses deadlines due to lack of planning, preparation, or required equipment (e.g. silage harvester not repaired, runs out of diesel).

professionals and farm safety organizations to engage in discussion, observation, assessment and structured feedback of farmer non-technical skills. The system utilizes the standard hierarchical format describing skill categories, elements and behaviors. FLINTS represents a step forward in facilitating the incorporation of non-technical skills within farming safety programs, identifying the skills that could be taught and evaluated, but requires further development and evaluation to ensure the system is usable and valid.[11]

The current system

The current system incorporates the skill of communication as a single skill category in combination with teamwork, an approach similar to that taken within the SPLINTS system.[9] It has been argued that communication should not be included as a specific skill category within a behavioral marker system, because it is inherent across all skill categories, and is often the method of observing the behavior (when an individual verbalizes their thoughts or course of action).[12] However, the farm professionals within the discussion and review groups felt communication was an important skill for farmers, particularly when interacting with visitors, farm workers and contractors. As such, it was important to highlight this safety critical skill within the taxonomy, with observable examples of good practice.

Refinement of the system led to the elements "managing deadlines" and "preparing" being merged. The behavioral examples produced by the discussion groups made it clear that these elements overlapped, with preparation necessary for managing time. Since an aim of the refinement process was to remove any extraneous elements.

Further development

The next step for the development of the FLINTS system is to evaluate the system using standardized

simulation videos.[18] This usually requires subject matter experts to watch a series of videos constructed to illustrate a range of behaviors associated with non-technical skill categories and elements, and rate the behaviors they observe. These ratings can then be evaluated for inter-rater reliability and further feedback on the system can be incorporated.[18] Typically, this type of evaluation will further refine and reduce the system, in addition to providing an avenue for reliability and validity assessment. This may lead to a reduction in the number of skill categories, elements and behaviors encompassed. The current FLINTS system comprises five skill categories and 16 elements, this is longer than the SPLINTS[9] system which is comprised of three skill categories and nine elements. This may indicate that further reduction of the system components is required.

The current system encompasses both cognitive and social non-technical skills relevant to a variety of contexts. However, it is important to note that farmers often work alone[3] and may focus on a subset of the skills covered within the current handbook (e.g. situation awareness, decision-making and task management[3]). As such a more concise version of the current system, designed to focus on those skills most utilized by lone workers, may be helpful to facilitate assessment and observation of farmers operating in isolation.

Limitations

The process of discussion groups and review has proven an effective mechanism for generating prototype behavioral marker systems across a variety of contexts.[6,9] However, it should be acknowledged that this process is subject to possible bias according to varying skill levels and job roles contained within the groups. Further research is required, ideally utilizing the video simulation method described above, to validate and further refine the current FLINTS system.

Conclusion

Non-technical skills, combined with technical know-how, are vital for safe and effective farm work. These safety critical skills are not currently taught to farmers explicitly, partially due to the lack of a defined framework and assessment tool. FLINTS represents a prototype behavioral marker system for farmer non-technical skills. This represents the first step towards the development of non-technical training and assessment for farmers.

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