Avoiding harm on the farm: Human factors

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A.C.McLaughlin, C.B.Mayhorn. Avoiding harm on the farm: Human factors. Gerontechnology 2011; 10(1):26-37; doi:10.4017/gt.2011.10.01.002.00 The high accident rate in agricultural work, especially for older farmers, indicates a need for increased safety and prevention research. This can contribute to increased safety on the farm, from engineering to human factors and ergonomics. **Methods** The current set of studies used two distinctly different research approaches to identify areas most linked to agricultural safety incidents. Focus groups including older farmers and an analysis of archived data produced descriptions of where, when, and how accidents occur, and what hazards contributed to these accidents. The database used was the Fatality Assessment and Control Evaluation (FACE) database of fatal farm-related accidents. This database contains a structured narrative account of each accident. Cases were coded to capture the demographics of the victim, the environmental conditions during the accident, the machinery involved, and other variables related to the accident. The average age of farmers involved in fatal accidents was over fifty years and many of them were using decades-old equipment when they died. These data are presented in terms of frequencies and a cluster analysis was performed to identify patterns of accident types. Focus group discussions identified the knowledge and attitudes of older farmers related to their work and equipment. **Results** In general, older farmers understood that they had slower reaction times than when they were younger; however, the prevailing attitude was that a task must be accomplished by any means necessary. This included working in poor visual conditions, past the point of fatigue, and using equipment for tasks other than for which it was designed. Last, older farmers were aware of numerous accidents related to their profession and expressed an acceptance of risk as well as the attitude that those who had accidents were not careful enough. **Conclusion** The findings from these studies can be used to motivate influential safety research. Older farmers stand to benefit greatly from applied work in this area once their general behavior patterns with farming technology are understood. The goal of the current studies was to link the information from farming accidents with the knowledge, attitudes, and behaviors of older farmers to direct the solving of safety problems through engineering, human factors, and industrial design.

Keywords: aging workforce, focus group, farm safety, archival data

The population of farmers is aging at a higher rate than the USA population[1] and older farmers are more likely to suffer fatal accidents than their younger counterparts[2]. An aging workforce is not just a USA problem: the populations of most countries, particularly farmers, are aging disproportionally as well[3,4].

The physical and cognitive changes that can accompany aging require particular considerations when technologies are being designed[5]. Indeed, one study found that the need for a hearing aid was the best predictor of work-related farm accidents[6]. In terms of interacting with machinery, farmers over age 59 were more likely to suffer differentially more injuries from machinery than younger farmers[7]. Expertise is not an immunization for injury: the most experienced farmers show the highest injury rates[8,9]. Some older farmers have only recently bought equipment and taught themselves the rudiments of farming while others have used many pieces of heavy equipment throughout their lives and were trained informally[10]. Both groups heavily represent farm-related accident statistics. In the available US statistics, older farmers represented over 50% of all farming-related fatalities from 1992–2004[11]. When older farmers are injured, they lose more workdays and are more likely to be hospitalized than younger farmers[11]. Older farmers are more susceptible to non-fatal injuries as well[12]. One example comes from a study of Greek farmers that found percent injury rises from 10% for farmers aged 25-34, 18% for farmers aged 45-54, and up to 28% by the time farmers are over age 65[13]. Similar trends have been found for Canadian farmers[14].

Per capita accident data support that older farmers are a particularly vulnerable group: farmers over 65 represent 45.8 fatalities per 100,000 workers each year compared to the overall fatality rate across occupations of 25.4 fatalities per 100,000 workers/year[11]. The problem with fatal accident statistics is that most come from death certificates and do not give insight into why the accident occurred[15]. Data on non-fatal injuries are even more difficult to assess, as many farmers go without medical care for their injuries due to the lack of medical services in rural communities[16].

The most common farming hazards involve tractors, augers (devices for moving solid or liquid material by means of a rotating helical flighting; the material is moved along the axis of rotation), and grain silos. Tractors are one of the most common forms of technology used in agricultural work and also the most dangerous: more fatalities have occurred due to tractors than all other hazards combined[12]. Disturbingly, older workers accounted for an even higher percentage of tractor related deaths than younger workers[12]. On every farm, workers and owners interact daily with multiple systems and machines in a frequently changing environment[8,11].

Though there are accident data identifying roll-overs, run-overs, collisions, electrocution, and falling as major causes of injury, there is little information on the causes (and therefore potential preventative measures) of these accidents[9,11,17,18]. On the farm, what change to technology would have the most impact on accident rates? What kinds of individual differences are there in the farming population versus the samples commonly used in research? The purpose of the current project was to generate descriptive data of the kinds of farm technologies related to injury and whether there are specific environments or situations in which those accidents are more likely to occur. The second goal of the current work was to augment this information with the reasons behind the decisions farmers made that resulted in near misses, injury, or loss of life. To answer these questions we analyzed archival accident data for human factors issues and conducted focus groups with experienced farmers about their typical tasks and which tasks and machinery they considered the most dangerous.

Methods

Quantitative and qualitative data were gathered and analyzed to understand the safety issues facing today's farmers. Qualitative data came from focus groups with experienced farmers and was complemented by quantitative data from the Fatality Assessment and Control Evaluation (FACE) database of fatal farm-related accidents[19]. Differences between the focus group method and the coding of archival data were that the archival analysis spanned many states, while the focus groups contained only central and eastern North Carolina farmers. Also, the archival analysis contained reports of fatal accidents, while the focus groups provided information on near misses and non-fatal accidents.

Focus group

Two focus groups were conducted with local farmers at Farm Bureau offices in North Carolina, USA. Sessions were guided by a structured script (available from the authors on request) composed of questions concerning farm accidents, known hazards on the farm, and hidden or non-intuitive hazards. Focus groups were audio-taped for transcription and a note-taker augmented any difficult to understand speech. Each participant's response to questions was written on a large easel pad to facilitate further discussion. Analyses in this report are based on the transcriptions of the focus groups, whiteboard notes, and the notes of a scribe attending the session. This effort achieved the first goal of this research -- to discover opportune areas of human factors research in agriculture, particularly for aging farmers.

Participants

All ten participants happened to be male. The mean age of participants was 52.6 years (24 to 68, SE=4.2). They averaged 40 years farming experience (SE=4.1) and each owned a mean of 4.7 pieces of large equipment with a mean equipment age of 14 years (SE=11.3). The participants reported working alone about half the time and that they felt neutral about whether getting hurt on the farm was a problem for them (*Table 1*). This was despite reporting an average of 2.4 accidents each requiring a doctor visit (SE=0.4) and 0.8 accidents requiring a hospital visit (SE=0.3). Every focus group participant reported at least one trip to a doctor due to a farming injury.

Procedure

Once the discussion began, each participant introduced himself and mentioned the types of crop and/or livestock with which he commonly worked. Then, the moderator divided the work year into seasons and asked the group to set dates for the start and end of those seasons. Starting with fall, the moderator collected the type of equipment used that season, crop and livestock worked, and the group opinions of what seasonal task was the most dangerous and why. At the conclusion of the discussion, participants filled out the demographics survey. They then received debriefing and compensation for their time.

Archival analysis

All FACE cases were originally in narrative form with a summary, introduction (demographics), investigation (detailed report of what appeared to have happened), cause of death, recommendations, and discussion (*Table 2*).

Coding scheme

Codes were developed to investigate typical human factors considerations, such as environment surrounding the accident and individual differences in the description of the victims. Four coders refined the coding scheme until 90% agreement was reached on all coded variables for five cases (165 codes) (actual agreement was 97%). Then, coders progressed through randomly selected sections of the total cases until each of the 328 cases had been coded by two coders. These cases represented all FACE reported farm fatalities from 1989 – 2006. Coded variables are presented as percent frequencies and as correlations when correlations were predicted a priori (α=0.05). The victim was aged 50+ in 178 cases.

Cluster analysis

A cluster analysis[20] was performed on the 328 cases coded from the FACE database. Some

Table 1. Focus Group demographics and survey answers; A 5-point scale is used: 1=Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree

Survey statement	Mean	SE
A tractor is dangerous	3.6	0.4
Getting hurt on the farm has been a problem for me in the past	3.0	0.2
Safety on public roads is an issue for me when I'm on my equipment	4.3	0.4
In order to complete my daily tasks, I must spend time communicating with workers	4.5	0.2
Clear communication plays a role in safety on the farm or ranch	4.6	0.2
I can think of an incident where poor communication was at the root of the problem	3.9	0.3
More safety problems occur with workers that do not speak the same language as I do	3.8	0.2
Time spent working alone	57%	6%

of these variables contained enough cases to be included in the cluster analysis. Only variables that could be coded for 80% or more cases were included in the cluster analysis. These included gender, season, farm ownership status, occupation, location on farm, farm type, ground conditions, weather-precipitation, weather-wind, debris, clothing involved, victim language, cause of death, activity during accident, proximal cause, known medical conditions, normalcy of activity, normalcy of equipment, operator error, mechanical error, design error, under influence, and tractor involvement.

Coded data were subjected to a two-step cluster analysis that allowed inclusion of nominal and scale data. The analysis was run several times on the data in a randomly entered order, as the two-step analysis can be affected by the order of variables, and produced stable results (*Table 3*)[20].

Results

The results are organized by incidents and descriptors from the focus groups that related to safety followed by the archival data in terms of frequency counts, cluster analysis, and regressions. It is noted whether the archival data differed from the focus group findings.

Focus groups

The farmers in the focus groups owned numerous pieces of equipment ranging from several tractors with multiple attachments for those tractors, to combines, mowers and four-wheelers. Farmers reported using generally older equipment with some tractors

Table 2. Sample of codes with possible values for archival data analysis of fatal accidents

Code type	Code	Values
Demographics	Age	In years
	Gender	Male / Female
	Occupation	Agricultural farmer / Livestock farmer / Mechanic / Handyman or worker
Time	Year	Calendar year
	Season	Spring / Summer / Fall / Winter
	Time of the Day	Morning / Afternoon / Evening / Night
Location	State	USA state
	Accident area	Pasture / Barnyard / Barn / Field / Road / Orchard / Machine shed / Feed lot
Equipment	Tractor involvement	Yes / No
	Type of tractor	Crawler / Tricycle / Wide-front utility / Skid steer loader / Forklift / Narrow front end
	Equipment age	<10 / 11-20 / 21-30 / 31-40 / 41-50 / >50 years
	Seatbelt present / used	Yes / No / Not applicable
Cause of death	Proximal cause	Tractor roll-over / Tractor run-over / Struck by falling object / Slip or fall
	Medical cause	Bleeding / Crushed or blunt-force trauma / Asphyxia / Electrocution / No autopsy
Contributory factors	If / how did clothing contribute?	Did not contribute / Entangled machine / Distraction / Slip
	Under the influence	Yes / No
	Known medical condition	Yes / No

dating back to the 1950's. Open and obvious hazards were discussed, followed by hidden hazards and attitudes expressed by the farmers.

Tractor roll-overs

Roll-overs were considered one of the most common reasons for injury and death on the farm. The farmers in our groups mentioned mowers as a particular hazard for roll-overs. A frequent task was to mow the banks of ditches that surround fields. Edging the mower along the side of the bank could easily result in a roll-over into the ditch, as could an item or hole on the bank. This task was complicated by the design of the machinery: farmers looked behind them as they drove to keep the mowing equipment close to the edge of the ditch. This limited their forward attention and vision so that obstacles and direction change went unnoticed. Also, during mowing, debris often flew from the mower into the face of the driver. This type of distraction reduced the attention the farmer devoted to driving, steering, and avoiding obstacles that could roll the mower into a ditch. One farmer noted: "Hell, you should wear a football helmet (laugh) to cut the ditch banks". These dangers are likely increased for older farmers, due to age-related declines in attention and in the ability to inhibit distractors[21].

Power take-off

A power take-off (PTO) shaft connects a tractor to attachments, such as an auger wagon or equipment that does not have an engine. The PTO is a rapidly spinning shaft that spans the distance between tractor and attachment. Farmers listed guards (plastic and metal) that shielded the body and clothes from contact with the PTO shaft, but also mentioned having to drill through or remove the guards when the PTO needed maintenance. The cost of replacing a PTO guard was estimated at 80-100 USA dollars and farmers were not interested in replacing one that had been drilled through or altered for maintenance. One problem with PTO shields was a tendency toward complacency. As one farmer said: "Don't cross it. We have a bad tendency to want to get to the other side to work on the other side and you

Table 3. Number of cases and their percentages in influential categories from the cluster analysis; Bold indicates high importance for that category in that cluster; Non-bolded companion data from the other cluster is provided for comparison; Cluster 1 concerns containers; Cluster 2 concerns tractors

Variable	**Categories**	**Cluster 1: n=106**		**Cluster 2: n=103**	
		n	**% of n=209**	**n**	**% of n=209**
Season	Spring	13	27	**35**	**73**
	Summer	33	45	**40**	**55**
	Fall	**35**	**70**	15	30
Location	Road	1	3	**37**	**97**
	Container	**26**	**100**	0	0
Gradient	Flat	**100**	**85**	18	15
	Inclined	5	7	**63**	**93**
Clothing	Entangled	**22**	**100**	0	0
	Not involved	**80**	**44**	**101**	**56**
Activity	Transporting	7	18	**33**	**83**
	Repairing	**25**	**93**	2	7
Proximal cause	Crushed	17	17	**81**	**83**
	Entangled	**24**	**96**	1	4
	Other	**28**	**82**	6	18
Tractor	Yes	51	35	**96**	**65**
	No	**55**	**89**	7	11

have a chance to straddle it". However, one farmer indicated that having a safety shield on the PTO shaft made it more enticing to step over, "It can fool you that way. It can".

As with the other machinery, farmers mentioned the PTO often needs to be in operation to diagnose problems with it. This violated their own rule of turning off the PTO before approaching. This kind of paradox was common: a task needed to be done but it could not be completed using appropriate safety rules. Numerous farmers described working without a PTO shield, and the resulting accidents. Specifically, a relative of one farmer lost an arm to a PTO from leaning across it and having his clothing catch and another mentioned the death of a friend when the PTO touched and caught the man's chest. In summary, everyone knew the danger of an unshielded PTO and reported extreme care around this hazard. However, they also reported accidents involving the PTO.

Repairs to machinery

Repairs occur year round, though focus groups reported most repairs occurred in the winter. When repairs occurred during high-workload seasons, they often occurred in the field or wherever the equipment broke down. One complaint about safety systems was that automatic cutoffs interfered with their diagnosis for repair. Farmers use creative methods to get around these cutoffs, such as putting a heavy tool case on the seat when they leave the machinery or trying to perform the task before the cutoff occurs (for instance, less than eight seconds).

While repairing machinery, farmers mentioned they relied on the hydraulics to keep the machinery lifted rather than using external jacks. A pinhole in a hydraulic line can cause a fatal penetration of human tissue from the escaping high pressure liquid. Even knowing this hazard, farmers in the focus groups reported the desire to cover such pinholes with their fingers because it looked like liquid escaping from a hose. Though most hydraulic lines have shields, these must often be removed for repair to the lines.

Fumes during repairs or work

While the aforementioned hazards that involved PTOs and tractors were open and obvious because farmers were aware of the consequences of unsafe action, other hazards were less obvious and people might attend to them less, especially when more obvious hazards are present. Consider the relatively mundane task of conducting repairs and maintaining equipment during the winter months. Due to the weather, repairs often occurred in an enclosed space where running equipment produced carbon monoxide. Other fumes, such as methane and hydrogen sulfide, collect in enclosed spaces, such as silos, wells, and tanks.

Distraction could also play a role: if someone were working on a PTO, they might be careful to avoid the PTO while the presence of carbon monoxide went undetected. Fumes were specifically listed as a danger by farmers, but their only method of detection was to be 'careful' not to run the machinery 'too long' in an enclosed area. Alarms for carbon monoxide detection were not mentioned by the farmers. These issues may be especially problematic for older male farmers who display age-related and gender-specific declines in olfaction[22]. Methane fumes from manure pits were detectable by farmers, however, the danger they posed was difficult to comprehend. One farmer mentioned an incident where a single person was overcome by such fumes and seven others died trying to save each other as they were all overcome. Fumes that cause injury or death can also be present in upright silos, but farmers reported these fumes were undetectable.

The hazard of suffocation inside a container was also mentioned. Though farmers discouraged entering a grain bin or auger wagon and related stories about accidents happening from entering them, they still mentioned playing in containers as children. The obvious hazard in these areas was the sharp equipment located in these containers, such as augers, but the hazard leading to many accidents was more subtle. Farmers explained that moisture can cause the grain in these containers to form a 'bridge', or a false surface hollowed underneath by grain passing out the bottom of the bin. Stepping on this surface (despite the rule of not entering the bin) caused the farmer to fall through and the bridged grain to collapse.

"It looks solid, until you do step on it, and it caves in and then it's just like a …quicksand, but quicker. I mean you can't climb out, you can't uh, breathe, you sit there and smother, you'd like to be able to use your hands but that wouldn't be enough".

The farmers knew not to enter the containers, and yet these accidents still occurred. It was not enough to provide a warning or explanation inside: they understood there was a hazard present. More research in this area is needed to understand how to avoid this hazard. For example, sensors or some other way to detect when bridging occurs may provide enough information to remove the hidden portion of the hazard and allow farmers to deal with the known hazard.

Power lines

Focus groups mentioned power lines multiple times and understood that danger comes from the infrequency of this hazard: dozens of turns may be made with equipment and only one of them would be in proximity to a power line. Exacerbating this hazard was the need to work past nightfall when visibility is reduced and that attending to the obvious hazard of power lines consumed the attentional resources needed for avoidance of other hazards.

Human reaction-time.

Some farmers identified equipment that operated so quickly it defied expectations. For example, a corn "snapper" pulls corn into itself automatically from the stalk. If a person tried to remove a jammed stalk of corn from the feeder, it could pull the corn in so quickly that the human could not release the stalk before the hand made contact with the moving parts of the machine.

"… a lot of old folks going around with one, two and three fingers because it took what they called snappers….that snapper would just pull your hand….while you were holding that ear of corn, or that stalk, it would snatch it right off there and tear your fingers".

Farmers acknowledged that the danger of this machine was in the violation of expectation: people believed they could let go quickly enough that their hand would not go into the machine. Although such violation of expectation is hazardous at all ages, the slowing of reaction time that can accompany aging puts older farmers at even higher risk[23].

Approaching

Farmers noted approaching someone working in a field was surprisingly dangerous. Again, they explained this hazard in terms of expectation violation.

"You're … in a wide open area running that machine thinking you ain't got a problem to worry about. You ain't going to strike anything. All you got to do is keep your eyes up front. Then all of a sudden you'll stop, you got a problem so you start backing up that machine, next thing you know, you're backing up over somebody because they didn't think to get out of the way because they thought you were going to keep going forward".

Increased communication in the agricultural environment, particularly proximity based communication, is a potential solution. Second, proximity based warning systems could be added to equipment. As this method has been successful in the context of automobile warnings and in other industrial settings[24], this approach might transfer well to the development of technology-based farm warnings.

Inevitability

Farmers in the focus groups mentioned accidents as part of the job. This is different from regulated jobs where accidents are considered rare rather than common. Farmers also mentioned a high level of independence in their work. However, this translated to a tendency to blame themselves for accidents rather than faulty or poorly designed equipment. Farmers almost always mentioned an accident as a result of not paying attention or being careful enough. Comments included "We try to pay attention to everything" and "It's common sense". An excerpt from one group is provided as illustration:

"We all here have been through it and know it…Well we know to go around to the front of the header, stay out of the, if you got a bean table, you stay out of the way of the wheel. And, but if you got uh, lets say corn head. And you look up there and you see the problem is that it's jammed up. For some reason or another…we'll play stupid for that second. And we'll look up and snatch that stalk out, cause the header is running a whole lot slower than we'll…we'll have a lapse, thought, and you just go up there and put your hand on it, and it will burn it. Or you'll have a near miss, [and get] that stalk out. And I don't know what you call that. Stupidity I suppose, but we all have…"

"It happens to everybody".

Farmers almost never mentioned difficulty with the equipment or poor design as a cause of an accident. Completing tasks was paramount, despite poor or failing equipment, weather, or time of day. Study of these attitudes can explore what safety methods are most acceptable and how to phrase and design safety systems that are effective and utilized by users with these attitudes. Models exist for the effect of attitudes on warning compliance[25], but these may require adaptation for an agricultural context.

Archival data

General analysis

Quantitative data from fatal accidents were generally consistent with the focus group reports. In the FACE data, the older the farmer, the more likely a tractor was involved in the fatal accident, ($r(328)=-0.13$, $p=0.011$). Victim age correlated positively and significantly with the age of the tractor: older farmers were more likely to be using older equipment when they died, ($r(160)=0.15$, $p=0.034$). The most common age range of tractors involved in accidents was 21 to 30 years old (18.8% fell into this range). The fewest tractors were less than 10 years old (9.6%) or over 50 years old (3.4%).

A roll-over or run-over was defined as the body of the tractor falling on or passing over the body of the victim. Fatal accidents due to run-over or roll-over were comparatively few (5.8%). Most fatal accidents were due to the victim being crushed (45.6%), though often they were "crushed" by an attachment on the front of the tractor or by the weight of the tractor itself. Thus, operation of the tractor was connected to most of these fatalities, either by pressing the victim against a surface or rolling over the victim. The second most frequent cause of death was PTO entanglement (9.3%) which coincided with the concerns expressed by the farmers in the focus groups.

Containers (such as grain bins, silos, manure pits, or other enclosed spaces specifically for storing products or waste) ranked third in terms of the location of an accident (11.7%). Overwhelmingly, container deaths were due to asphyxia (66.7%). The other major cause of container deaths was blunt force trauma (19.4%). Bleeding, crushing, and electrocution composed the last 13.9% of cases. Interestingly, not all asphyxia cases were due to gases; many occurred because the victim was covered in a solid material, such as grain, and suffocated.

Electrocution composed only 3.4% of coded fatalities and few were due to power lines. Most occurred as the victim was repairing equipment, often in a barn or machine shed. Out of the 11 fatalities due to electrocution, 7 occurred during repair activities. The mismatch between the fear of electrocution outdoors from the focus group (and perhaps the increased attention on a task when near power lines) and the fact that most fatalities occurred during indoor repair work is notable. Farmers in the focus groups were apparently attending to outdoor sources of electricity rather than attending to the potentially more dangerous indoor sources.

Cluster analysis

The variables in Table 3 were found to contribute significantly to the clusters, as determined by a chi-square analysis. Two accident types were revealed by the cluster analysis. The most influential categories of each variable are listed, followed by the percent of that attribute present in a cluster. For example, the variable 'Season' may be read as 'Most accidents from Cluster 1 occurred in the fall, while most accidents in Cluster 2 occurred in the summer. More than two-thirds of all fall accidents are listed under Cluster 1'.

In general, Cluster 1 accidents were characterized by occurring in containers where the victims had clothing entangled by moving machinery or a variety of other causes, often during repair work. Cluster 2 accidents were characterized by tractor involvement. This type of accident tended to occur while transporting (on a road), clothing was rarely a factor, and the victim was crushed by the moving machinery.

Table 4. Summary of stepwise regression analysis for variables relating to age; R2 (Step 1)=0.057; ΔR2 (Step 2)=0.058; ΔR2 (Step 3)=0.055; ΔR2 (Step 4) =0.025; B=regression coefficient; SE B= standard error; β=standardized regression coefficient; p<0.05

Step	Variable	B	SE B	β
1	Farm ownership	12.7	4.3	0.24
2	Farm ownership	13.8	4.1	0.26
	Tractor involvement	-9.7	3.1	-0.24
3	Farm ownership	11.7	4.1	0.22
	Tractor involvement	-11.0	3.1	-0.28
	Normalcy of activity	11.4	3.7	0.24
4	Farm ownership	11.6	4.0	0.22
	Tractor involvement	-9.8	3.1	-0.24
	Normalcy of activity	10.5	3.7	0.22
	Medical conditions	9.0	4.2	0.16

Regression

A stepwise regression analysis was run using the variables likely to be linked to age as predictors: farm ownership, tractor involvement, normalcy of activity, and medical conditions that may have contributed to the accident (*Table 4*). Farm ownership accounted for the most variance, where the older farmers were more likely to own the farms where they were killed. Surprisingly, the older the farmer the less likely a tractor was involved in the accident although tractors accounted for more fatalities in general than any other farm technology. Older farmers were more likely to be killed during normal activities. It is unknown whether this was because older farmers only engaged in normal activities or whether long-term exposure to an activity invited complacency. Last, older farmers were more likely to have a medical condition that could have contributed to the accident.

Limitations

It is important to recognize the limitations of this work. For instance, the archival data and focus group participants solely reflect information regarding farmers in the United States. While it is unknown whether the behavioral trends uncovered in these data will generalize to farmers living and working in other countries, it is likely due to the demographic and equipment/task similarities within this particular occupation and the heightened accident rates for older farmers in other countries[14,15]. Whether specific cultural differences in hazard recognition and safety attitudes exist is still an empirical question. Moreover, it is also unknown whether sampling issues might have influenced the results. Because research participation in the focus groups was voluntary it is possible that participants may have differed in some way from those who declined to participate. However, the consistency between the trends discovered in the focus groups and the archival data analysis suggest that selection bias is not likely. Given these potential limitations, these data appear to provide useful information that can inform human factors researchers and practitioners in a number of farming-related areas.

Discussion

In conclusion, these results identified multiple areas that could benefit from further research and design or redesign of farm equipment for aging farmers. The first of these areas is the hidden hazard. A brief list of hidden hazards includes: fumes from machinery being repaired in an enclosed area, fumes from animal feces, the deceptively solid appearance of grain in containers, the speed of some machinery, and approaching a worker in an open field. Government safety regulations have shown remarkable results in reducing farming accidents[26] and the USA requires training for high stakes farm practices, such as pesticide use[27]. Such programs could be extended to the most problematic areas found in the current study. Although it is impossible to know how many of the fatal coded accidents were due to hidden hazards, comments from the focus groups suggested that even experienced older farmers were susceptible to counter-intuitive equipment behavior.

The second area ripe for research and redesign contained well known hazards, such as the PTO. Future work should investigate how to reduce the hazard, what causes interaction with that hazard, and under what circumstances accidents occurred (for instance, multi-tasking, unusual situations, complacency). An example of promising work in this area was a study of which tasks required interaction or close proximity to a PTO shaft.[28] Farmers were in closest proximity to the PTO to observe operation and adjust settings. Our first recommendation is to engineer ways for these activities to occur remotely. Our second recommendation for reducing this type of hazard is to eliminate the barriers to maintaining PTO guards -- simplify their replacement, reduce their cost, and promote their use.

The last area of research concerned technology acceptance and adoption of safe practices. Farmers were concerned with safety but accepted that their tasks often resulted in injury. An investigation of how to design interventions to work with these attitudes would be highly beneficial. Previous work suggests that working alone on the farm is linked to injury of older farmers[29] and the current work supports that most fatalities occurred while working alone. Other prior work found that older farmers did not value technological safety systems, such as a rollover protection system (ROPS) for tractors and were less likely than younger farmers to install these systems[30]. Last, farmers indicated a strong need to finish tasks despite environmental stressors, sometimes hurrying and skipping or circumventing safety measures. The current work gave insight into this tendency by current farmers interviewed in the focus groups to accept risk as an occupational hazard.

There are several potential psychological explanations for these attitudes regarding risk. The first is optimism bias[31, 32] where people believe that they are more capable than others. A second explanation is the third person effect[33], where some people believe that they are less susceptible to hazards than others[34]. While there was some support for these explanations, it was not always strong. Alternately, an economic explanation might be more feasible such that safety-related choices are strongly linked to economic motives as well as the independent attitudes of the farmers. A typical family farm owner over 55 averages less than 10K/year from farming activities[35]. While an injury would affect how much work could be completed, the potential injury may not be as salient as the consequences of unfinished work. Research in how to change the cost-benefit analysis older farmers likely perform on safety versus task completion could help alter attitudes in favor of safety.

Finally, the question of learning applies to all of these areas: how much are older farmers expected to learn about new technology and new techniques as they continue to work? Our data on the age of their equipment suggests that they continue to use familiar tools, yet this does not protect them from injury. Older farmers can learn to use new technology, provided the benefit is high enough to them[36], but what would cause them to invest both time and other resources into such a change? Some countries, such as Sweden, have eliminated the cost-benefit analysis by farmers by mandating tractor safety features on small farms[37]. Such laws have significantly reduced accident rates and cost to the government from accident related healthcare costs[38]. It is unknown how different cultures, such as the independent attitudes of the farmers in our focus groups, would tolerate such mandates. In general, applied research can address many questions critical to keeping older farmers safe. We have provided recommendations in each area of research based on our data. Finally, the solutions uncovered by human factors researchers and professionals need to be disseminated to the farming populations in formats that are acceptable, understandable, and lead to adoption of equipment and techniques[39]. Through these efforts we hope to improve the quality of work-life for older farmers, reduce accidents, and understand more about human-machine interaction.

Acknowledgements
This research was supported in part by a grant from the North Carolina Agromedicine Institute at East Carolina University. Portions of the data from the archival analysis were presented at the 53rd Annual Meeting of the Human Factors and Ergonomics Society[40].

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