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Technology adoption on farms: Using Normalisation Process Theory to understand sheep farmers' attitudes and behaviours in relation to using precision technology in flock management

Jasmeet Kaler[a,*], Annmarie Ruston[b]

[a] School of Veterinary Medicine and Science, University of Nottingham, Sutton Bonington Campus, Leicestershire LE12 5RD, UK
[b] College of Health and Social Care, University of Derby, Kedleston Road, Derby, DE22 1GB, UK

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ABSTRACT

Evidence suggests that UK sheep farmers experience lower productivity and profit margins than other livestock sectors and that they do not necessarily know where they gain or lose income from their flocks. More efficient use of precision technology has been identified as a potential way of addressing this problem. The mandatory requirement for Electronic Identification (EID) tags to be placed on all sheep offers an opportunity for sheep farmers to adopt precision technologies to manage herd health and maximise production and profit. Although the charactistics of farmers that are associated with adoption or non adoption of technology have been identified little is known about the social processes, meanings and experiences that influence uptake. This paper is novel as it draws on data from 36 sheep farmers in the UK and applies Normalization Process Theory (NPT) to gain an understanding of the reasons they do or do not use EID related precision technology on their farms. The interviews were tape recorded, transcribed verbatim and analysed using NVivo. Although respondents acknowledged the potential value of precision technology to improve their farm businesses they appeared to have alternative beliefs that were counter productive. Their beliefs that using precision technology posed a threat to their role as a good stockman, that it could not replace the need for hands-on interaction with their animals and that it was costly and difficult to use created an implementation gap. The use of NPT as an evaluation framework provided a valuable tool for increasing the understanding of contextual characteristics that undermine the routine embedding of such technology by sheep farmers. The data suggests that normalisation of the use of precision technology amongst sheep farmers could potentially be increased if manufacturers/suppliers co-design and work with farmer's to ensure that the technology enables the farmer to be in control and operates as an aid to achieving high quality stockmanship rather than a mechanism for profit maximisation.

1. Introduction

The United Kingdom is the sixth largest lamb producer worldwide and has approximately twenty five percent of the European Union's total sheep population (National Sheep Association, 2018). The UK sheep industry houses ninety different breeds and cross breeds in a 'stratified system' with farms distributed in three tiers (hill, upland and lowland). It contributes over £290 million to UK employment both on farms and in allied industries (Sheep Health and Welfare Group, 2017; National Sheep Association, 2018). Nevertheless, evidence suggests that sheep farmers in the UK experience lower productivity and profit margins than other livestock sectors, they do not necessarily know where they gain or lose income from their flocks and that this is associated with the limited use of data to support animal health management (Kaler and Green, 2013; Lima et al., 2018). The use of precision technology to support animal health management decisions has been identified as a potential way of addressing this problem (Berckmans, 2014; Walton et al., 2018). Precision farming has been defined as comprising a set of technologies that combine sensors, information systems, enhanced machinery and informed management to enhance production by accounting for variability and uncertainties within agricultural systems (Gebbers and Adamchuk, 2010). Berckmans (2014) argues that this differs from other approaches which involve monitoring of animal welfare by human experts.

Warren (2002) has suggested that a 'digital divide' exists within the farming sector between small scale cattle and sheep farms, and larger arable and dairy farms which has resulted in variation in the uptake of precision digital technologies. There has been a drive to understand this

* Corresponding author.
E-mail address: jasmeet.kaler@nottingham.ac.uk (J. Kaler).

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variation and Rose et al. (2018) reported that early research, which sought to increase the uptake of technology based decision support tools on farms, focused on identifying desirable characteristics of system design. This was founded on the premise that 'a linear relationship existed between the production of scientific knowledge, in the form of decision support tools and its uptake by the end user. Research then shifted its focus onto understanding farmer behaviour, initially using a range of economic based models of farmer decision making (Edwards-Jones, 2007). Researchers utilising a range of psychological models reported that the adoption of precision technologies in farming is positively associated with socio-economic factors, agro-ecological factors, institutional factors, informational factors, farmer perception and technological factors (Tey and Brindal, 2012; Pierpaoli et al., 2013). Pierpaoli et al. (2013) described a typical precision adopter as an educated farmer, who owns a large farm with good soil quality, and who aims to implement more productive agricultural practice. The adopter perceives precision technology in terms of profitability and is a competent computer user. Non-adopters, on the other hand, were either not considered to have sufficient skills and competencies to manage precision technology tools or lacked financial resources to purchase it.

More recently, Lima et al. (2018) conducted a questionnaire survey of sheep farmers in the UK to examine factors associated with adoption of electronic identification technology (EID) and associated technology to record flock information. They found that farmer's beliefs were strongly associated with the use of technology to record flock information and to use it to aid decision making. In particular, feeling under pressure to adopt technology and having negative feelings about it were associated with non-adoption. However, farmers who perceived EID technology was useful were more likely to adopt it for recording flock information.

The electronic tags (EID) on all sheep in the UK was made compulsory in 2010 under the EU Council Regulation 21/2004. This regulation requires farmers to electronically record individual sheep movements and involves the use of a microchip, or electronic transponder embedded in a tag, bolus or implant to identify a farm animal. A reader (stick) sends the unique identity number to a computer. The use of EID technolgy has been promoted on the basis of having a number of benefits including: less paperwork, ease and speed of data collection, no requirement for direct animal contact and direct transfer of data on to a computer. All of these have the potential to enable the collection and use of management data to aid flock performance and animal welfare. Nevertheless, Lima et al (2018) found that whilst 99% of their respondents used EID ear tags and just over half (52%) reported having a EID reader only 21% reported using EID related technology for stock management purposes. This data suggests that the adoption or embedding of such technology is only partial.

Evidence from research into human health organisations shows that implementing and embedding new technologies, of any kind, involves complex processes of change both at individual and organisational levels (Mair et al., 2012). While, studies seeking to describe facilitators and barriers to change have added knowledge in this field they have often failed to characterise the underlying mechanisms at work that may affect successful adoption (Mair et al., 2012). Normalisation Process Theory (NPT), which is a conceptual tool used primarily to examine the implementation of complex interventions in clinical healthcare settings, aims to address this gap (Forster et al., 2011). May et al. (2007) describe it as a theory that can be used either in prospective process evaluations which aim to support complex interventions or to understand successes and failures in implementation. NPT focusses attention on the social factors and processes that may enhance or constrain implementation of a new technology and provides a framework for investigating the routine embedding of material practices in social contexts (May and Finch, 2009). The theory states that implementation is operationalised through four generative mechanisms: *coherence* - how participants make sense of the intervention/activity, *cognitive participation* - how they engage with it, *collective action* - how they enact it and *reflexive monitoring* – how they appraise its effects (May et al., 2015). May et al. (2015) suggest that the work of integration requires continuous investment by people in 'ensembles' of action that carry forward in space and time.

The aim of this paper is to build on the research conducted by Lima et al. (2018) by exploring the barriers to implementation of EID related technology on sheep farms using NPT as a framework. For the purposes of this study the intervention being studied is the use, by UK sheep farmers, of EID technology to improve flock performance and welfare (i.e that they are utilising EID for more than the basic legal requirements).

2. Materials and methods

Qualitative methods were utilised in this study in order to examine the social processes, meanings and experiences of sheep farmers in England and Wales. The study was approved by the School of Veterinary Medicine and Science Ethics Committee (Reference number: 1167 140528).

In depth, face to face, interviews were conducted with a sample of sheep farmers who had previously completed an online questionnaire about their beliefs and intentions regarding the adoption of technology on their farms and who agreed, as part of that study, to be followed up for interview (Lima et al., 2018).

2.1. Data collection

Farmers who had agreed to be approached for interview were contacted by phone by the researcher and asked if they would be willing to take part in the study. For those who agreed, interviews were set up on their farms or other locations chosen by them. The interviews lasted approximately thirty to forty minutes, were tape re-corded and transcribed verbatim.

The interview covered questions about farm characteristics, a typical day on their farm, farmers perceptions of their ability to use technology, their perceptions about the value of digital technology and EID technology, the use they have made of EID technology since the compulsory introduction of EID ear tags and whether they think it is of value. In particular, they were asked whether they used precision technology for measuring performance and health in their flocks and the utility and workability of EID related precision technology.

2.2. Data analysis

The data was entered into NVivo (NVivo qualitative data analysis Software; QSR International Pty Ltd. Version 10, 2012) and examined using the constructs of NPT. Table 1 sets out the key elements of the four NPT constructs that were considered most relevant to this study and which were used as an analytical framework. Each construct was examined until data saturation was reached. Data saturation is the point at which no new themes emerge from the data. The data was coded using the constant comparative method (Maykut and Morehouse, 1994), this involved identification of sub themes within the NPT constructs of coherence, cognitive participation, collection action and reflexive monitoring. To support analysis data was also analysed in matrices for each respondent detailing their responses within each of the NPT constructs. (Table 2)

While NPT constructs are often presented in sequence they tend to operate concurrently in practice. They are not in competition with each other and for the planning of interventions the most important constructs are Coherence and Cognitive Participation (McEvoy et al., 2014).

Table 1
Key elements of the four NPT constructs most relevant and used in this study as an analytical framework (Adapted from Mair et al., 2012; Coupe et al., 2014).

Construct	Description	Action/work
Coherence	***Internalisation*** – do farmers understand the value, benefits and importance of new technology. ***Differentiation*** – is there a clear understanding of how use of technology differs from existing practice.	This is the sense making work that people do individually or collectively when faced with operationalising a set of practices.
Cognitive Participation	***Enrolment*** - do farmers 'buy into' the idea of technology. ***Legitimation*** – do farmers believe it is right for them to be involved. ***Activation*** – are they willing to drive implementation.	This is the relational work that people do to build and sustain a community of practice around a new technology or complex intervention.
Collective Action	***Skill set workability*** – how does or should the technology work in practice. ***Interactional workability***- does technology make their work easier? ***Relational integration*** – do farmers have confidence in technology.	This is the operational/enacting work that people do to enact a set of practices.
Reflexive Monitoring	***Reconfiguration*** –do farmers try to change the technology to suit their way of working. ***Systemisation*** - Are the benefits or problems of using a new technology identified or measured.	This is work inherent in the formal and informal appraisal of the use of new technology.

3. Results

3.1. Respondents characteristics

To ensure representation of farmers with different levels of technology skills and use, a purposive sample of forty eight respondents were selected from a database of farmers who had previously completed a questionnaire survey and agreed to take part in face to face interviews. Thirty six of these agreed to be interviewed. The study sample consisted of thirty males and six females. Seven were in the age range of 26–35, twelve within the range of 36–45, twelve were within the 46–55 age range and five were aged between 56 and 65. Four respondents had rated themselves as having a high level of IT skills, twenty three self-rated themselves as having medium level IT skills and nine said their skills were low.

Of the thirty six respondents only five reported having purchased additional hardware and software to enable them to read, record and monitor their stock and then utilising it to influence their decision making. A further eight respondents reported having purchased some equipment to enable them to collect data to inform their flock management but that they were only using it partially. They reported collecting very limited data and not necessarily using it for flock management. The remaining twenty three respondents reported not using the technology beyond the legal requirement to put EID ear tags on their sheep.

3.2. Analysis using NPT

Each NPT construct uncovered distinct barriers and facilitating factors affecting the uptake of EID precision technology and those which showed the potential to be most amenable to change. It also provided insights into how change may be achieved.

3.2.1. Coherence (construct One)

The first NPT construct 'coherence' is important because if farmers do not perceive the use of EID for performance management as relevant to them and their farms they may not engage with it beyond compliance levels.

3.2.1.1. Internalisation/Differentiation – (sub themes). In order to make sense of the work that they need to do to implement change or embed new technology on their farms, farmers will need to understand the value and benefit of the change and have a clear understanding of how any new ways of working differs from their current practice.

Table 2
Key findings from this study under each NPT construct.

Construct	Description	Key Findings
Coherence	***Internalisation*** – do farmers understand the value, benefits and importance of new technology	Respondents were able to articulate the potential value of EID related precision technology to identify problems within their flock to identify sheep that have reoccurring lameness problems.
	Differentiation – is there a clear understanding of how use of technology differs from existing practice.	Respondents currently make stock management decisions based on visual or memory cues but they recognised that precision technology would be more evidence based.
Cognitive Participation	***Enrolment*** - do farmers 'buy into' the idea of technology.	Limited buy-in by respondents who argued that good sheep farming depended on the skill of the farmer and hands on contact with the animals.
	Legitimation – do farmers believe it is right for them to be involved.	Legimacy - adoption would dependent on the technology enabling farmer to stay in control.
	Activation – are they willing to drive implementation.	The majority (23) of respondents used EID to meet legal requirements only. Limited attempt to drive implementation.
Collective Action	***Skill set workability*** – how does or should the technology work in practice.	Respondents felt that precision technology reduced direct contact between animals and farmer.
	Interactional workability- does technology make their work easier	Technology difficult to use in rural areas – poor utility of precision technology acted as a barrier to use.
	Relational integration – do farmers have confidence in technology.	Confidence in technology limited by geographical and workplace constraints.
Reflexive Monitoring	***Reconfiguration*** –do farmers try to change the technology to suit their way of working.	The majority had not adopted EID technology beyond compulsory ear tagging.
	Systemisation - Are the benefits or problems of using a new technology identified or measured.	Of those who had purchased EID readers (13) problems related to ease of use and suitablily were reported.

Respondents were able to articulate ways in which the use of precision technology and EID data could be of value:

> "It will certainly (help to identify) which ones are the best or worst ones in terms of feet. I would know the worst ones in terms of lambing percentage, I'll know the worst ones in terms of lambing difficulties, let's say. You'll always pick them out really, you'll always identify the really worst ones, but I think where it (technology) will improve things is it will identify the sheep that you need to make a decision about. I think that's where technology will really play a role." Respondent 22
> "In my day job (outside farming) I use a computer all the time, for speed and to store a lot really and to present useful information, in a helpful way as opposed to my lambing book where it's all in there but it never comes out again (after lambing) – so yes I am fairly positive about the benefits of technology." Respondent 35
> "It would be useful for lame feet, mastitis etc. to record information so you can identify repeat offenders and they can be culled. I am thinking about recording information – I should do it really but I need to understand more about it." Respondent 17

In making sense of the potential role of technology in managing their flocks respondents were able to clearly articulate ways in which adopting the technology would differ from current practice and the improvements it could bring:

> "Well, it could benefit my flock in years to come because, as I said, I like to go through the ewes this time of the year and monitor what the actual ewe has done over the past twelve months, past two to three years and know which ewes to select. I'd like to select ewes for breeding replacements from my top 25% from the flock, set the criteria for lameness, for productivity and what sort of weaning weights the lambs have done off the ewe and everything like that. So by embracing technology like that I would improve my flock and fertility and everything in the long term, because whereas I've been selecting on visual, what you see. Oh, it looks good, it might be a waster but it looks good." Respondent 16
> "I suppose as technology improves, perhaps it will improve all those, what do you call it? Heat time collars, do them for ewes in the future, then we can monitor them what way. Ewe 123 hasn't moved for four hours, where is she then? Oh she's stuck in a fence or whatever. Perhaps, yeah Drone technology as well – rather than having to drive round on a bike, you can hover over with a drone and check the stock. Scanning data, simple things like that have done wonders where before you had to type everything off a piece of paper and it's been about ten years plus that we can scan things in, so yeah." Respondent 15

Respondents generally were able to appreciate that the use of EID and other related technology to collect and analyse data for improved performance could be of value and could potentially transform their businesses. Thus, the idea of using technology appeared to have some coherence for respondents and make sense in the context of their farms and sheep farming generally.

However, although respondents could see the potential value of using EID and related technology to monitor performance this alone was insufficient for them to truly 'buy-into' the use of the technology. The data that emerged within the remaining NPT constructs illuminated farmers perceptions and behaviours/practices which reduced the likelihood of uptake in spite of an overall positive attitude to the technology.

3.2.2. Cognitive participation (construct two)

The second NPT construct is important in understanding the context for decision making and the actions taken by sheep farmers. It involves understanding the extent that they believe it is right for they, themselves or other sheep farmers to use it and the extent to which they 'buy into technology' through their actions. This construct relates to the relational work that people do to build and sustain a community of practice around a new technology or complex intervention.

3.2.2.1. Buying into the idea (sub theme). Twenty two respondents, argued that the key to high quality sheep farming was, in fact, good stockmanship and they believed that the technology could not be a substitute for that. They expressed strong views that good sheep farming and sheep welfare depended on the skill of the farmer. The 'farmers eye' was the only reliable tool for decision making:

> "A computer won't tell you what's wrong with something and for the welfare of the animal, the computer won't know if there's a sheep lambing, the lambs coming the wrong way and you have to assist. It's just sometimes you can see a sheep, if it starts lambing, right ok. You go back ten minutes later and you think hang on, there's something up here. And you assist –it - it's only a farmers eye that can do that." Respondent 4
> "If you see a sick sheep you won't find it on the computer, well dairy farmers, would have measures they've got pedometers and things … but things like that with sheep you have to be there, so technology would aid in some places but you'd still have to be there." Respondent 31
> "Well talking IT technology, you know, …it can't lamb sheep, it can't trim feet, it can't feed animals, well it can, I suppose if individual food is on the e-type reader and all the rest of it but that's never going to happen…especially on a sheep farm, I am talking about an upland sheep farm." Respondent 7

Looking after their sheep was seen to involve having a personal touch and being hands on:

> "You've got to be able to look after them, and if a sheep's lambing you've got to be there to look after it.. you can put up cameras and watch them from a distance and things like that but you need the personal touch really, hands on. Respondent 8

Recognising when their animal was ill was attributed to being a good stockman. Respondents did not consider that a computer/precision technology would be of value in assessing the health of an individual animal and therefore it was seen as superfluous – the computer/technology could not do the job of a stockman:

> "Another thing about EID is it cannot replace good stockmanship either.- I think when the tag scheme first came out, you know, they would say 'Oh, you know, if you keep recording that animals' tag and you see its performance dropping it could be its lame". We shouldn't need a computer to tell us our animal is lame – if they are not gaining, not performing, it needs to go hand in hand with good stockmanship." Respondent 4
> "I think there is a raft of technology that can support your stockmanship skill, but if you haven't learned that stockmanship, in the first place – I don't think you can run a farm from spreadsheets and data." Respondent 19

A further eleven respondents also suggested that as many aspects of sheep farming were dependent on the skills of the farmer the value of technology was in assisting them in a way that still ensured that the farmer was in charge. Even where there was an acknowledgement of that technology could be beneficial it would still need to support the role of the farmer as the person in charge:

> "I suppose it can do so, you know, just by the way you measure a field when sowing or spreading fertilisers, GPS and all this technology could prove very beneficial, yes. We haven't got that at the moment but I am sure it could be good, yes. But I still have to be in charge … it's the human that makes the decisions." Respondent 4
> "Sometimes, for some technology you get better return on your stock, but that's not down to technology really, that's just down to you as a stockman doing the right thing for the animals.."

Respondent 9

"If a drone will fly over the top of my flock of sheep and record all the numbers, brilliant go with it all the way, 100%. … but the stockman is still going to have the basic skills of looking after livestock. However, good your drone is, it can zoom in and show you that the sheep has got maggots, but it can't turn that sheep over and trim it for you and treat it, you've still got do that." Respondent 18

"I think for livestock farming, I suppose inevitably there's going to be robot milkers, but there's never going to be, you can't, replace shepherd can you? You can't get robots lambing sheep – you are still going to need human contact to go and pare feet and sort out any problems." Respondent 20

Good stockmanship was linked by respondents to having a 'farmers eye', the farmer's skill and a human or personal touch none of which could be left to technology.

However, where the aim of using technology was to support the shepherd or stockman or where it supported activities that did not involve direct contact with the sheep respondents were more likely to see the use of technology as legitimate:

"It's all to do with managing the land, - on the paper side, getting rid of the books, (with technology), yes brilliant, but the farming it can't take away from that." Respondent 29

"Not a lot (technology taking over), paperwork yes, from grass growth to the quality of the lamb. .it's going to be an aid on the paper-side but not for the traditional farming." Respondent 22

Overall, respondents appeared to buy into the legitimacy of using technology only where it still allowed the farmer to remain in control and where it could take over tasks that would not affect the human/animal contact.

3.2.2.2. Activation (sub theme). Activation is concerned with whether farmers can sustain the use of technology long term, whether they are thinking about or planning to use technology and whether they drive adoption of the technology.

A small number of respondents (5) described having bought the software and or equipment which would enable them to capitalise on the use of the EID system. They reported that this has enabled them to read, record and monitor data:

"We record pretty much everything,… lambs are tagged at birth or within twenty four hours of birth. So we know the mother and the father going back, parentage beforehand. We weigh them as they go uphill, we weigh them, we scan them and we have all the sale and slaughter data for decades." Respondent 11

"For performance, the software we have now, it enables us, you know, it can be graphed easily and we can look at the whole flock, we can ring fence the poor performers and pull them out and we have the back up of geneticists as well – the data I record goes to her, she crunches it, it comes back to us and all the time we will be using data to make decisions. The new equipment that we have invested in has made a massive step change for, you know – it is the key to running sheep at scale." Respondent 2

"I was on the fence with the EID job but I can see a lot of benefit of it now. Its beneficial just looking at the stock, it opens up your eyes and you start asking the questions about what is making some sheep perform better than others or which breeds do better." Respondent 32

These farmers had acknowledged the value of the technology and used it to gain a better understanding of their sheep at flock level enabling them to see which animals were productive and which were poor performers. The data collected by these farmers to assist decision making was generally associated with understanding the whole flock or population health rather than focusing on individual sheep.

A further eight respondents reported still being at the early stages in their use of the EID related technology for monitoring purposes and were not necessarily using it to the full effect:

"We have a EID reader now and we have been reading it and it has been quite interesting but we only use it to segregate breeds we don't really record much from it." Respondent 21

Their use of the technology had not yet moved beyond identifying individual animals that have had problems in order to treat the individual animal – the data was not being used to assess the impact of poor performing sheep on the flock as whole.

"We should be recording more. .not keeping ewe lambs with lameness I suspect… .but as we are not currently doing that I think as far as we're using it at the minute it is to record lameness on the EID reader once we've treated it. Respondent 12

"I think it would be handy for lambing going down the road of recording and tagging at lambing time and possibly looking at weight gains. I have got a EID reader and laptop and am beginning to do these things." Respondent 35

However, the majority of respondents (23) indicated that they have been able to meet the basic requirements of the law by recording data manually and did not use the EID technology beyond identification purposes. Most reported that their paper-based system was adequate because they did not 'count' or use the data at population or flock level or they did not possess an EID reader to facilitate this:

"We record obviously, movements, when we dose medicine and all that, that's all down - but we don't count, we just say in the medicine book that they have been done with whatever medicine, batch number and date done.. so that's quite a simple system but it passes legislation what we do so that's all we do it for really – but I can't see us doing anything else really. Respondent 8

"I don't do any performance recording or anything, I just tend to tick to what I have treated and dosed. Most of it goes down in a diary-there's EID's in the ewes but I don't use the EID's for anything extra." Respondent 9

Respondents stated that information was held in the farmers' head', or in a diary and the actions taken using such information was often recorded using traditional methods of putting a physical mark on the sheep:

"Not a lot, when we are breeding we keep a register, we weigh lambs we are fattening and when selecting them to go to slaughter and when we treat lameness we put a mark on their head." Respondent 31

"I tend to keep a diary and then put things in a medicine book when I get back on the farm – the information is also in my head." Respondent 27

3.2.2.3. Sustaining the use of technology (sub theme). This was described by many as difficult and two main issues were identified:

Firstly, the costs incurred in acquiring the technology were considered challenging and this caused them to consider whether it would add value to their farm:

"Well the disadvantage is the cost, it's always the cost. It might end up, over time, saving you money if it can make your job easier. We're injecting those lambs for pasteurella, if there was an automatic sheep injection system which you could just inject them through and it automatically did it a lot better than we are that would be wonderful. But it would cost a lot of money … it's the upfront costs." Respondent 10

"I'd love to record more but couldn't justify the costs of all the EID stuff so I use the mobile phone – it's better anyway out on the field when it's wet because I can put it in my pocket." Respondent 19

Well a lot of farmers think there is no point in it really (EID) they

don't do anything with it, so it's just costing them money because a lot of farmers just tag them before they go to slaughter." Respondent 8

We would like to go down the road of EID and all that software but to justify the money at the moment with lamb prices as they are we can't justify it." Respondent 1

Secondly, they worried about their lack of skills in the use of information technology:

"I'd like to be the best at technology, but I find it.. some of it isn't easy to use I'd like to do more, I am willing to do more, I can see the benefit of doing more but it frustrates me when I can't use something because of this button or that button or I've forgotten how to shift that into that, it's just the complication of it really that frustrates me, because when you're busy it's just another thing that frustrates you." Respondent 23

"The problem is I'm with the generation where I'm one generation too far to be sharp enough as a whizz kid to understand it all….I'm just a bit old for it perhaps." Respondent 18

The second construct – cognitive participation – which aimed to question or examine the extent to which farmers bought into the idea of a new technology or service revealed that buy-in was limited and dependent on supporting farmers to remain in control of the care of their sheep, having a hands-on approach to care and using the 'farmers eye' to monitor their health. Uptake was linked to respondents' beliefs that good sheep farming depended on the skill of the farmer (good stockmanship) and that technology could not replace that skill.

3.2.3. Collective action (construct three)

Collective action was concerned with how the technology should work in practice, whether it made the work easier and whether farmers had confidence in it.

3.2.3.1. Skill set workability (sub theme). Respondents described challenges associated with using technology for sheep farming. These included the farmer's time being taken away from direct contact with the animal. Having direct contact with their animals was linked to their view that as good stockmen their responsibility is to the welfare of the individual animals:

"When they work it's good, but it's got to be …well in my mind it's got to be quite simple in a way, there's no point being too complicated because the farmers have got limited time as it is, you've got to have something that works, obviously you're wanting to do as much as you can in terms of recording, but you've got to have it to work on the farm as well, you don't want to be all day spending time with the computer/reader things like that, you want to do as much work as you can in a day." Respondent 31

"The disadvantage is that it can take your attention away from the animal - you have got to come off from the screen and look after the animal's welfare." Respondent 6

Challenges associated with the remote or rural location of their farms were also identified. The geographical location of farms meant that access to Wi-Fi/internet and other connective technology was limited:

"With sheep it's a job, isn't it? Because look at where we are (uphill) but if every field was flat, then it's much easier you know, you can use SATNAV tractors but we don't have SATNAV tractors." Respondent 7

"You've always got these remote locations, wi-fi isn't sort of rural- so you've got a big downside to that. The only way to get wi-fi at home is through the satellite we can't get it any other way." Respondent 13

The need for technology to have basic utility and to link with other technology was considered to be important:

"It would need to be cost effective and link to an App on the phone or something like that then I could take that data with me anywhere and download it onto the laptop at home or sync it – I think it would work pretty well. It would need to be reliable – if not I'd probably bin it, get frustrated with it and not use it again. First and foremost it has got to be reliable, waterproof and robust. It will get dropped and it will get dropped in poo and sheep will stand on it and so probably it needs to be robust. Good battery on it, as well – very simple practical things. And big enough so a mucky finger can operate it." Respondent 35

"Technology is good but I find it very fundamental. It's all based on spread sheets and the package we have is really based on a spreadsheet and they expect you to have a hell of a lot of knowledge but where everybody's knowledge level is iPhone and so the interface should just be like the iPhone – it should be tap and simple – it shouldn't require you to have knowledge of the inner workings." Respondent 13

"It needs to work, it needs to be pretty robust, one thing that annoys me is if something works for a bit and then just doesn't somehow – then I wish I hadn't touched it." Respondent 34

3.2.3.2. Interactional workability (sub theme). Interactional workability is concerned with whether the technology would make work easier to undertake. Some respondents considered technology could potentially reduce their workload:

"Well I suppose it's like the CCTV, we just look at a screen rather than going out to check the sheep but you see everything on the screen then that's fine isn't really.." Respondent 20

"There's less contact (with the animals), like with the stick reader now you are at arm's length aren't you rather than having to actually catch hold of the head and read the tag… it's less strenuous isn't it? Just grab hold of something and read it rather than having to wrestle with it. So definitely less strain, just make life easier." Respondent 21

Whilst other respondents, suggested that there was a danger that farmers could 'get sucked into' the technology and as a consequence lose valuable time. This in turn would undermine the value of the technology:

"You can get too sucked into the technology and you want to record everything and then you get smothered in information and you waste your time." Respondent 13

"The advantages are, its hopefully time-saving and making you money really, if possible at the end of the day. The disadvantages are, if it becomes a constraint on time so you spend more time actually recording the data and …actually you are recording things that don't need to be recorded. That's when actually it's not being helpful…it can be time saving but it can be a bind as well." Respondent 3

The use of technology was not necessarily felt, by some respondent, to save them time due to difficulties in setting it up in the first place:

"Well the advantages, I suppose all the recording would be an advantage for some people… but just get on with it rather than having to set things up, like with the EID tags, it just took such a long time to get it all up and running. Time that you could spend doing other things." Respondent 4

3.2.3.3. Relational integration (sub theme). Relational integration is concerned with whether farmers have confidence in the technology. Respondents suggested that not all technology on the farm was fit for purpose and they did not have confidence that it would make their business more efficient:

"If they don't work right, you're losing a lot of time, when they work, they work well, but when they don't it's a bit of a headache." Respondent 31

"The advantages (of technology) are it can make your life a lot easier, you can do lots of things quicker.. the disadvantages are, it's not always reliable enough, it's not always strong enough, it doesn't always work well enough, the batteries aren't good enough sometimes." Respondent 11

They were also concerned about their computers crashing or someone hacking their data:

"I guess perhaps your relying on one thing (technology) if the whole system crashed. .movements and things like that, it could be a disadvantage I suppose, someone hacking your account." Respondent 22

"It can aid you in a lot of organisational type things and in showing your performance and monitoring and benchmarking, all that kind of thing. Disadvantage is when it crashes, when the internet won't work". Respondent 30

3.2.4. Reflexive monitoring (construct four)

3.2.4.1. Reconfiguration and systemisation (sub themes). Reconfiguration and systemisation are concerned with whether farmers try to change the technology to suit their way of working and whether the benefits or problems of using new technology are identified or measured.

As only thirteen of respondents reported having purchased an EID reader most respondents were not able to use the system to its full potential or be able to identify the problems that they experienced using the technology. Those who had not obtained a reader generally wrote the identification number of the animal on paperwork for the purposes of selling or culling their sheep or they relied on the purchaser or abattoir to have a reader. Of those who had purchased readers there were a number of problems reported including ease of use and suitability for withstanding the weather.

4. Discussion

Most studies examining the adoption of technology on farms have identified the characteristics of farmers that are associated with adoption or non-adoption of technology. Many of these characteristics, such as educational attainment, size of farm are not easily amenable to change by manufacturers or suppliers of technology. This study is novel in that it has applied NPT, a sociological theory utilised within human health, which deals with the adoption of technologies and organisational innovations to identify processes and beliefs which influence the likelihood of uptake or implementation. May et al. (2018) suggest that implementation theories are useful in providing explanations for relevant phenomena and can frame the collection and analysis of data. They can identify, characterise and explain mechanisms that have been empirically demonstrated to motivate and shape implementation processes and affect their outcomes (May et al., 2018). NPT, in particular, aims to elicit information about what individuals and groups do rather than what they believe and intend.

In using NPT as an analytical framework for this study it was possible to generate a greater understanding of why adoption of precision technology (in this case EID), to inform health and production decisions, may be illusive on UK sheep farms and what would need to change to facilitate adoption.

Data generated within the first NPT construct of 'coherence' indicated although using precision technology would represent a different way of working from their current practice, respondents believed that such technology could benefit their businesses overall. This suggests that sheep farmers held positive views about the value of precision technology – that it held some coherence for them. However, whilst this supports the idea that with the provision of appropriate and credible educational or information transfer, provided by suppliers/veterinarian advisors might be able to influence farmer behaviour and intent to adopt (Toma et al., 2018) data collected within the remaining NPT constructs suggested that this, in itself, was unlikely to ensure effective adoption.

The second NPT construct – cognitive participation – aimed to examine the extent to which the respondents actually bought into the idea of the technology. This included whether they believed it was legitimate for them to devote time to it and whether they adopted or used it. Buy-in was limited the majority of respondents held fairly strong views that such technology could not do the job of a stockman. They believed that there was a need for farmers to remain in control of the care of their sheep, to have a hands-on approach and to using the 'farmers eye' to monitor flock health. Limited uptake was linked to respondents' beliefs that good sheep farming depended on the skill of the farmer (good stockmanship) and that technology could not replace that skill – thus this set of beliefs or frame of reference appeared to negatively influence adoption.

The third NPT construct - collective action - also provided data that demonstrated that adoption of the technology was likely to be limited. Data within this construct revealed that the technology did not necessarily work well on their farms being costly and having limited workability on their farms meant that for respondents it did not represent a good investment. Hostiou et al. (2017) also found that if the tools are not adapted to the farmers' needs and skills it can have a negative effect on farmers and their animals.

The fourth NPT construct examined whether farmers attempted to change technology to suit their farms and whether they measured the benefits of the technology to ensure its continued utility. However, as most of the respondents reported only using EID to meet legal requirements there was little evidence to support that this stage of technology implementation had been reached. Normalisation of the use of EID technology beyond a basic identification tool requires ongoing investment of meaning, commitment, effort and appraisal by farmers. This was potentially thwarted by farmers having two conflicting frames of reference relating to precision technology. Firstly, that it could potentially be of value to their overall farming business and secondly, that it posed a risk to their animals and their role/identify as a good stockman by creating a physical distance between the two. Frames of reference are complex sets of assumptions and attitudes which are used to filter perceptions and create meaning including beliefs, schemas, preferences, values and culture and other ways in which we bias or undermine our judgement. Respondents common and shared beliefs about the importance of human intervention in the care of their sheep outweighed the value they placed on using precision technology for stock health management. They linked the adoption of the technology with a risk to the wellbeing of their flocks. For farmers to fully engage they would need to be convinced that the technology would not detract from the quality of care they believed they provided but rather would need to support them to engage with their animals more effectively.

Both frames of reference would need to be understood and acted on would need to be acted on by key stakeholders (manufacturers, farmers, vets, suppliers) to stand a greater chance of getting farmers to take action and use the technology to its full.

5. Conclusion

To the authors knowledge this is the first study, within the farming context and veterinary epidemiology as whole, that has sought to understand farmer beliefs and behaviours using the NPT theory. The results suggest that the theory may be of value to understanding the barriers to the adoption/embedding of EID related technology but also precision technology in general on farms more generally and to identify which factors are most amenable to change. In utilising NPT to provide an in-depth understanding of factors influencing the uptake of digital technology (EID) by sheep farmers this study has characterised the

underlying mechanisms at work that may have affected the low uptake of technology by sheep farmers in the UK. It has added to knowledge in this field by illustrating ways in which competing frames of reference and workplace constraints operate to prevent adoption of a technology.

It has shown that farmers having conflicting beliefs or frames of reference adversely affected adoption, resulting in farmers not buying into the idea of the technology and not necessarily seeing it as 'legitimate' within the context of sheep farm The study also confirmed findings of other studies about the need for technology to work effectively 'in place' i.e. in the context of sheep farming needs to have skill-set and interactional workability.

Thus, it is important for those promoting the use of precision technology to be aware of how these factors affect farmers behaviour and to work with farmers to embed situated knowledge in the design and implementation of technology.

Manufacturers/suppliers would benefit from understanding how farmers interpret the value of technology in the context of their farm and work to co-design technology with the farmers.

Future studies would benefit from using NPT theory as a prospective data collection tool before implementation in order to provide guidance for knowledge transfer agents, manufacturers to ensure the best possible level of implementation..

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