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Expert elicitation of remote meat inspection prerequisites in Sweden using best-worst scaling (case 1)

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ABSTRACT

Remote work technologies offer unprecedented flexibility to modernise official meat inspection (MI). Remote meat inspections, alongside on-site controls have a potential to make MI more sustainable when it comes to working conditions, logistic control hurdles and travel-related emissions. Nevertheless, preferences of meat control staff for features and technological set up of remote MI remain unknown.

The paper investigates preferences of official Swedish MI staff for different features of remote MI. The study utilises a quantitative method, namely best-worst scaling to compare the relative importance of six aspects of remote inspections: camera location and settings, connectivity, availability of personnel at abattoirs, communication and language, security and fraud prevention, and ability to relay olfaction and haptics. The survey, administered in September–October 2023 was answered by 54.7% of the Swedish meat control staff employed by the Swedish Food Agency. The results show that respondents rate security and fraud prevention (Security) as the most important aspect for remote MI followed by connectivity and camera placement (Camera). Communication and language (Communication) and ability to relay olfaction and haptics (Senses) are considered the least important aspects. The latter findings can be explained by the fact that Official Veterinarians, which represent the majority of respondents (49%), do not routinely communicate directly with slaughter personnel who are often seasonal workers coming from outside Sweden. Moreover, olfaction and haptics could be considered naturally impractical with remote technologies. The study also finds that respondents from different administrative units and job titles have different preferences for the features of remote MI. Respondents from the headquarter generally have higher preferences for connectivity than respondents from other units. Additionally, respondents with more hands-on experience in MI, such as Official Veterinarians, tend to rate security issues higher than respondents with leading or support roles. Overall, it seems possible to meet the control staff expectations and preferences regarding the prerequisites of remote MI by legal and technical adaptations needed for this type of control flexibility.

1. Introduction

Official meat inspections (MI) conducted at abattoirs comprise two mandatory parts: ante-mortem inspection (AMI) of live animals and the compilation of related documentation before slaughter, and post-mortem inspection (PMI) of carcasses and organs. In the European Union (EU) all MI activities are outlined in the Regulation (EU) 2017/625 (EU, 2017), and in detail in Regulations (EU) 2019/624 (EU, 2019b) and 2019/627 (EU, 2019a).

In Sweden, official veterinarians (OVs), supported by official auxiliaries (OAs) are employed by the Swedish Food Agency (SFA), the competent authority (CA) for MI. OVs oversee the carrying out of MI activities at abattoirs and game handling establishments (on-site). Moreover, OVs remain responsible for the control (EU, 2017) in all slaughter of domestic animals outside the abattoirs, at the holding of provenance to a limited extend (EU, 2021) or in case of emergency slaughter and as well as slaughter of farmed game and game handling. However, a shortage of veterinarians in all sectors of agriculture, animal

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healthcare and especially food control has been an ongoing challenge in Sweden (SOU 2022:58, 2022). The problem is exacerbated by the local conditions: Sweden is a relatively large country (5th largest in Europe) with a majority of low-capacity abattoirs (<1000 livestock units per year) which are also located at significant distances from each other and from the MI staff offices (Kautto & Comin, 2023). This combination can create unsustainable working conditions for OVs required to travel long distances to perform MIs for relatively few animals and carcasses at a time. Moreover, positive net effects of small-scale abattoirs located in proximity of farms, such as shorter travel times for animals and lower transport emissions, are reduced by the rebound effect of increased climate burden of OVs' travelling to and from official MI. Finally, long-distance travels, especially in Northern Europe's wintertime, can be affected by adverse road and weather conditions, in turn affecting animal welfare through increased waiting times between arrival at abattoir and slaughter, thus causing logistic problems and possible profit losses for the food business operators (FBOs).

Opportunities and barriers to modernisation of the traditional meat safety system have been studied for some time. Blagojevic et al. (2021) and Antunovic et al. (2021) identified challenges ahead of implementation of a risk-based meat safety assurance system (RB-MSAS) related to precautionary attitudes of key stakeholders and inadequate food chain information. With the onset of COVID-19 pandemic remote work has been introduced and streamlined in many sectors. SFA has already been working on remote meat control since 2018 with attempts to test the functionality, efficacy, and reliability of remote MI in Sweden. Remote Visual Inspection (RVI) or Remote Digital Video Inspection (RDVI), is a form of inspection where an inspector examines objects, materials, and individuals from a distance by the means of visual aids such as video technology (Mix, 2005).

Currently, remote MI in commercial slaughter and game handling is not permitted under the EU legislation, which is also binding in Sweden. However, the pilot studies conducted hitherto have shown promise particularly when carried out in conjunction with site visits (Deuss & Honey, 2023). A pilot study comparing remote and on-site AMI on 1177 inspected animals was carried out by Kautto et al. (2023). Interestingly out of a total number of non-compliance cases of 1.8%, the majority were reported by remote OVs instead of on-site OVs. Moreover, a study on remote PMI of pigs, which has utilised augmented-reality live-stream video software, has been conducted by Almqvist et al. (2021). The authors ascertained the reliability and viability of such an approach provided that the PMI method is standardised, and the inspection times are adequate. All studies show an inter-rater variability amongst OVs which is not affected by conducting MI on remote basis (Almqvist et al., 2023; Kautto et al., 2023). Furthermore, remote inspections are routinely employed in other industry sectors including agriculture (see Mahmud et al., 2023 on remote auditing), nuclear energy (see Kershaw et al., 2013 on remote inspection of nuclear facilities), maritime (see Alexandropoulou et al., 2021 on remote technologies for hull surveys and inspections) and construction (for instance, Ribeiro et al., 2020 on remote technologies for structural surveys of inaccessible structures). Moreover, there have been ongoing research on visual-only protocols for PMI, for instance in pigs. Ghidini et al. (2018), for example, tested visual-only PMI against traditional inspections in Northern Italy. They found no significant differences between the two approaches.

However, the successful introduction of any new technological solution requires a thorough understanding of the needs, preferences and prerequisites of its prospective users. Given that remote MI is currently not permitted under the relevant regulations, large-scale user tests are not feasible; thus, studies in this area remain scarce. This paper aims to contribute to understanding preferences for specific features of remote MI and quantify these preferences using a choice experiment. Our target group is the Swedish MI staff, namely OVs, OAs and SFA's control headquarter (HQ) employees (in managerial and supporting roles). We were specifically interested in how these groups of MI experts evaluate different features of remote MI relative to each other.

2. Methods

This paper reports the findings of the second, standalone study of a two-part mixed-method project. The study utilises a quantitative method, namely best-worst scaling (BWS) (Finn & Louviere, 1992), and employs the data collected in the first study (Hunka et al., 2024), which comprised an in-depth, qualitative analysis based on semi-structured interviews, to elicit survey items.

2.1. Best-worst scaling

BWS is a widely applied method developed by Finn and Louviere (1992) for measuring relative ratings of a set of items (or objects). The method involves asking respondents to make a series of "best" and "worst" (or "most important" and "least important") pairs of items from a subset of more than two items.

BWS has the following two main advantages compared to rating-based methods, such as rating-based conjoint, in which respondents are asked to rate alternatives on a common scale, and choice-based methods such as discrete choice experiment where respondents often select their most preferred option (Louviere et al., 2013). First, a rating-based method allows ties which implies limited data to discriminate between items/alternatives. Second, unlike the paired comparison method which is a choice-based approach, where the respondent rate two items against each other, and where the number of comparisons required increases geometrically with the number of items, BWS enables ranking of a large number of items by asking subjects to choose best-worst pairs from a subset of at least three choice items in each choice task, which allows for obtaining a full ranking of choice items (in case of three items) or a partial ranking in case of more than three items in each choice task. Third, BWS provides more information about preferences of respondents by collecting information on their "worst" choices instead of asking just their most preferred choice item as opposed to discrete choice experiments (DCEs)/choice-based conjoint approaches (Louviere & Woodworth, 1983).

Due to these unique benefits, BWS is popular for measuring preferences, mainly in healthcare (see Mühlbacher et al. (2016) and Hollin et al. (2022) for a review). Application of the method in other subject areas is also growing, with notable applications for rating perceptions of responsibility in food supply chains (Erdem et al., 2012), ranking forest management policy alternatives (Loureiro & Dominguez Arcos, 2012) and understanding consumers' wine selection behaviour across multiple countries (Lockshin & Cohen, 2015). Our BWS application relates to the prioritisation of prerequisites for conducting AMI and PMI remotely.

2.2. BWS design

The items used in the present study were elicited from the results of a qualitative study (Hunka et al., 2024) conducted with a sample of 19 OVs and FBOs in Sweden in 2022 and 2023. In the qualitative study, semi-structured interviews were conducted to investigate attitudes, perceived risks, and prerequisites for remote MI. The analysis of interviews helped us identify important aspects the practitioners of MI consider as prerequisites of feasible remote AMI and PMI. More specifically, we identified the following 6 items that were further used to construct the BWS survey.

1. **Video camera location and settings (Camera)**: encompasses all the issues of image, video, and audio quality as well as lighting.
2. **Connectivity**: pertains to the quality of data transfer, functioning software, potential interruptions.
3. **Availability of personnel at abattoir (Assistance)**: relates to the availability and cooperation with personnel on site.
4. **Communication and language (Communication)**: concerns with the interpretation and understanding of instructions.

5. **Security and fraud prevention (Security)**: includes issues regarding trust, transparency and system security.
6. **Ability to relay olfaction and haptics (Senses)**: relaying non-visual cues routinely used in on-site MI.

It should be noted that the study did not ask respondents for preferred solutions for secure health marking of the carcasses and organs that passed the MI successfully.

For our BWS study with these 6 items, we used a balanced incomplete block design (BIBD) with 10 choice tasks (or blocks) each consisting of 3 items. In a BIBD experimental design, each item and item combinations appear equally often, ensuring items are equally available and leaving respondents with no signal that may (unintentionally) suggest that most frequently occurring choice items are more important (Louviere et al., 2013). The chosen BIBD design means that each of the 6 items appears exactly 5 times and each item co-appears with another item exactly 2 times. In each of the 10 choice tasks, respondents received 3 items among which they were expected to indicate the items they considered most and least important for remote MI to succeed. Appendix A presents the introduction to the choice tasks, as seen by respondents, and an example choice task translated from Swedish.

2.3. Selection of participants and survey administration

The study was administered online. The data on BWS and selected respondent characteristics were collected from a present (small) population of experts involved in MI in Sweden. These include personnel at SFA: OVs, OAs and control supporting veterinary inspectors (VIs) as well as team and unit leaders. The first group, OVs and OAs have hands-on experience with on-site MI, while the second group consists of support and leading staff who do not perform MI routinely. The latter job title (VI) is used for staff employed at SFA headquarters in the Food Control Unit. Team and unit leaders are employed by respective control units in managerial roles. They can be experienced in MI but do not routinely perform inspections.

As of September 2023, SFA Control Department had 256 employees, considered as representative size for the whole year, who were in some way involved with MI (either as OV, OA or supporting/leading staff). We invited all respondents to participate on the September 27, 2023. The survey remained open for a month, with two reminders sent during that period. In total, 228 started the survey and just 140 respondents provided valid and complete responses. In addition to the BWS experiment which comprised 10 choice tasks, the survey gathered information about the administrative unit (geographical scope of work area) and job title of respondents. More specifically, we asked whether respondents were from North, South and Mid-Sweden, and the headquarter of the SFA as well as whether they were working as OV, OA, VI, leader or other (job title).

2.4. BWS data analysis method

BWS data were analysed using both simple and more advanced analytical approaches to determine aggregate, i.e., sample level results, as well as individual ratings and clusters of individual ratings, such as separate results for each unit presented in Table 1.

2.4.1. Normalised difference scores

The most common, simple approach to determine individual and aggregate ratings is (normalised) difference scores. The BWS difference score is computed as the difference between the total number of times each item is chosen as best and the total number of times it is chosen as the worst for both aggregate and individual ratings. When this difference is divided by the total number of times a considered item is available for choice, difference scores become normalised difference scores.

Suppose n_{ij} represents the number of times item j is available for choice to respondent i over all choice tasks, and n_{ij}^{best} and n_{ij}^{worst}, respectively represent the number of times the respondent i chose item j as best, and then as worst item. The normalised difference score of i for, here represented by s_{ij} can be determined as

$$s_{ij} = \frac{n_{ij}^{best} - n_{ij}^{worst}}{n_{ij}} \tag{1}$$

Similarly, the aggregate rating of item j, S_j can be determined by aggregating individual difference scores as follows.

$$S_j = \frac{N_j^{best} - N_j^{worst}}{N_j}, \tag{2}$$

where $N_j = \sum_{i=1}^{I} n_{ij}$, $N_j^{worst} = \sum_{i=1}^{I} n_{ij}^{worst}$, $N_j^{best} = \sum_{i=1}^{I} n_{ij}^{best}$ and I denotes the total number of respondents.

2.4.2. Analytical estimation

BWS data can also be analysed using more sophisticated statistical estimation methods such as multinomial logit (MNL) regression and hierarchical Bayesian (HB) models. The advantage of using such estimation methods is that these models also yield estimates of uncertainty (i.e., standard errors) corresponding to each item's parameter estimate.

MNL is a widely used analytical model to estimate parameters (i.e., relative importance) of items at an aggregate level. Lipovetsky and Conklin (2014) demonstrated that the count of total, best and worst choices of items provide sufficient statistics to obtain MNL model parameters, denoted as β_j's (for item j) as follows.

$$p_j = \frac{N_j - N_j^{worst} + N_j^{best}}{2N_j},$$

$$\beta_j = \ln\left(\frac{p_j}{1 - p_j}\right), \tag{3}$$

where N_j, N_j^{worst} and N_j^{best}, respectively are the number of times j is available for choice (total number of times j is shown to respondents during the experiment), then chosen as worst and chosen as best across all choice tasks and respondents in the sample (see Lipovetsky and Conklin (2014), also for the calculation of standard error of β_j).

In the same fashion of computing the choice frequency of item j at sample level, p_j, j's choice frequency for respondent i, p_{ij} can be computed as follows.

$$p_{ij} = \frac{n_{ij} - n_{ij}^{worst} + n_{ij}^{best}}{2n_{ij}}$$

Table 1
Distribution of respondents by unit and job title.

Unit	Job title					Total
	Official veterinarians	Official auxiliaries	Veterinary inspectors	Leader	Other	
North	24	3	4	5	–	36
Mid-Sweden	23	26	1	4	–	54
South	22	9	2	5	1	39
Headquarter	–	–	7	1	3	11
Total	69	38	14	15	4	**140**

Lipovetsky and Conklin (2015) showed that by treating p_j and p_{ij}, respectively as empirical prior and likelihood sample probabilities, the Bayes formula can be used to obtain posterior estimates of individual probabilities. When these posterior probability estimates are used in equation (3), we obtain Bayesian individual parameter estimates for each item and respondent. It is possible that the respondent might always pick j as the best item resulting p_{ij} to be one or as the worst item which makes p_{ij} to be zero. In this case, the posterior individual probabilities can be replaced by a precision value, E when $p_{ij} = 0$ and $1 - E$ when $p_{ij} = 1$. The Bayesian individual parameters obtained in this way are highly correlated with results from computationally demanding HB-MNL models.

In this paper, we use normalised difference scores as well as the MNL model to analyse aggregate ratings and the empirical HB procedure suggested in Lipovetsky and Conklin (2015) to estimate individual parameters. Individual parameters were estimated to better understand the variations in preferences of respondents from different units and in different job titles. Finally, we also grouped respondents primarily responsible for MI (such as OV) or as an auxiliary (such as OA) and respondents with support or leading roles (i.e., Leaders, VI and other support staff), plotting the distribution of individual estimates for these two broad groups. Given that the groups within our target population are small, we presented the results as distributions of individual estimates. The rationale behind this is the sensitivity of single summary measures such as means of estimated parameters to outliers, particularly in our case where the number of respondents per unit and/or job title is small. The analysis was performed in R (R Core Team, 2010) with the "bwsTools" R package by White (2021).

3. Results

This section presents aggregate results for all participants (ratings and a MNL regression model), followed by distributions of individual estimates. Participants were divided into groups relative to their unit (department), job title, and practical involvement with on-site MI.

3.1. Aggregate rating results

To determine the respondents' aggregate rating of items, we computed normalised difference scores for all items and subsequently estimated MNL regression model parameters which indicate the importance of each item. The results from these two approaches are presented in Table 2. The columns "Total", "Most important" and "Least important" in Table 2, indicate respectively the number of times corresponding items were available, chosen as most important and chosen as least important across all choice tasks, and respondents in the sample. For each item, the normalised difference scores, S_j are computed using equation (2) and reported in Table 2 under the column "Normalised differences".

According to the normalised difference scores, Table 2 shows that respondents by far consider security and fraud prevention (Security) as the most important aspect for remote MI. It is also evident from the normalised difference scores that the quality of internet and data transfer (Connectivity) and placement as well as setting of video cameras (Camera) are the next most important considerations for remote MI to succeed. Very close normalised difference scores for Camera and Connectivity reveal that aggregate ratings may not be sufficient to discriminate between these two items.

In contrast, the normalised differences column in Table 2 shows that respondents consider communication and language issues (Communication) as the least important concern to conduct remote MI. Although, a background qualitative study revealed concerns about the possibility to relay haptic and olfactory information in remote MI, respondents to our BWS study consider this aspect (Senses) as less of a concern.

We report the MNL regression model estimates corresponding to each item, β_j under the "Parameters" column in Table 2. The standard error associated with each parameter estimate and the respective lower and upper bounds of the 95% confidence interval are also given in Table 2. In general, we find MNL model results provide consistent ratings of items as obtained based on normalised difference scores. Respondents rate Security as the most important aspect of remote MI followed by Connectivity and Camera which, as in the normalised difference scores, have very close parameter estimates. We find Communication followed by Senses as items respondents attach lower importance to move to a remote MI. The 95% confidence intervals show, almost all estimated parameters except for Assistance, which reflect the importance of items, are statistically significant. The only item with a statistically insignificant parameter estimate is Assistance, which implies that respondents' preferences vary greatly (or are polarised) in ranking the importance of availability of on-site FBO assistants during remote MI.

The final column in Table 2, Choice probability, indicates the average likelihood of the respective items to be chosen as the most important aspect for remote MI if all six items were presented at once.

3.2. Rating of items by unit and by job title

SFA MI is conducted by different units divided by their geographical location and coverage into: North, Mid-Sweden, South and the leadership/support unit at the SFA headquarters. Furthermore, people with different job titles participated in the survey. In this section, we present individual rating results by unit, by job title, and by practical involvement in on-site MI.

3.2.1. Rating of items by unit

The majority, namely 54 (38.6%) respondents were from Mid-Sweden while only 11 (7.9%) were from the SFA headquarters. We estimate empirical HB parameters for each individual based on the procedure suggested in Lipovetsky and Conklin (2015). Fig. 1 shows the distribution of estimated HB parameters for each choice item in each unit.

We note from Fig. 1 that the estimated parameters of the impracticability of palpate and olfaction in remote MI (i.e., Senses) as well as issues related to language and communication with on-site support staff (i.e., Communication) are negative for most of the respondents. This is evident from the box plots where the interquartile range falls below zero for these items for all units, except Senses in Mid-Sweden and Communication in South. However, the relative rating of these two items differs between units. For instance, while the parameter estimates

Table 2
Normalised difference scores and MNL model results, N = 140. Parameter values marked in bold are significantly different from 0 (used in MNL as a relative reference level) at $p = 0.05$, two-tailed t-ratio.

Items	Total	Most important	Least important	Normalised differences	Parameters	Standard error	95% confidence interval	Choice probability
Assistance	699	205	192	0.0186	0.0372	0.0535	[-0.0677–0.1421]	0.1704
Camera	699	257	218	0.0558	**0.1117**	0.0536	[0.0067–0.2167]	0.1836
Communication	702	191	285	−0.1339	**−0.2694**	0.0539	[-0.3750–0.1639]	0.1254
Connectivity	700	249	208	0.0586	**0.1173**	0.0535	[0.0123–0.2222]	0.1846
Security	697	273	202	0.1019	**0.2044**	0.0538	[0.0989–0.3000]	0.2014
Senses	703	225	295	−0.0996	**−0.1998**	0.0536	[-0.3049–0.0947]	0.1344

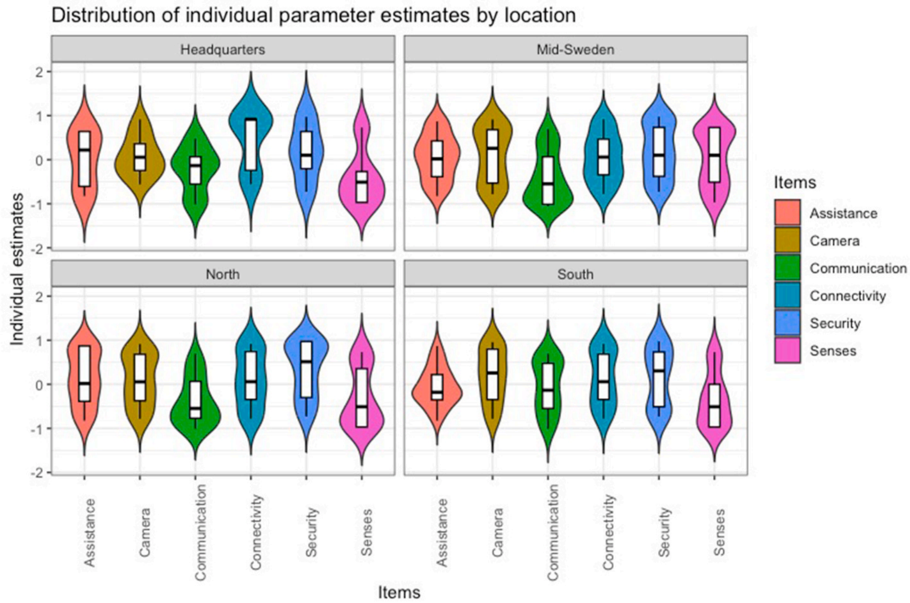

Fig. 1. Distribution of individual parameter estimates by unit.

for Sense are concentrated below zero for respondents from HQ and South, this is true for the parameter estimates of Communication for many of the respondents from Mid-Sweden and the North. The result suggests while Sense is the least important item for headquarters and unit South, Communication is the least important among respondents in Mid-Sweden and the North. In addition, we notice that the most important item suggested by the distribution of parameter estimates in Fig. 1 varies across units. For example, looking at the number of respondents with a positive parameter estimate, Connectivity in Headquarters, Camera in Mid-Sweden, Security in the North and both Camera and Security in the South appear to be the most important items.

The disaggregated result summarised by Fig. 1 reveals also that the estimates for Connectivity and Camera, which have remarkably close normalised difference scores and estimated parameters in Table 2, are distributed differently in various units.

3.2.2. *Rating of items by job title and by role in MI*

Similarly, we plotted the distribution of individual parameter estimates for each item by job title in Fig. 2. As indicated in Table 1, most of the respondents are official veterinarians (49.3%) and official auxiliaries (27.1%).

Security remains the most important aspect of remote MI for most of the respondents (See OA and OV on Fig. 2). Also, we observe that respondents from all job titles except OA rate issues related to the ability to

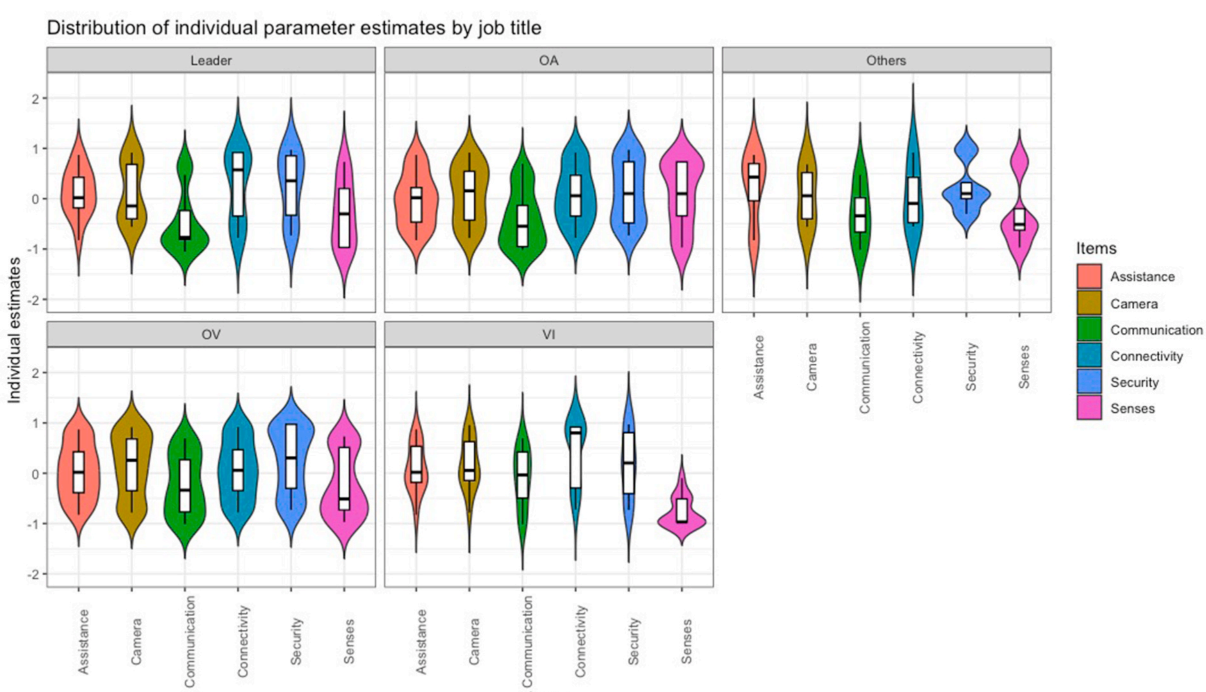

Fig. 2. Distribution of individual parameter estimates by job title.

relay palpation and olfaction in remote MI (i.e., Senses) as well as language and communication with on-site personnel (i.e., Communication) as the least two important aspects. Furthermore, Fig. 2 shows that the median individual estimate for these two items (except Senses by OA) falls below zero, which is not the case for any of the other items.

Interestingly, there is a difference between the distribution of individual estimates of Senses for OA and OV. In addition, veterinary inspectors (VI) consider Connectivity as the most important aspect for remote MI: the median individual estimate of this item is exceptionally high among VI respondents.

Finally, Fig. 3 shows the preferences of respondents who were divided into two groups depending on their responsibilities related to MI. The first group, OVs and OAs have hands-on experience with on-site MI, while the second group consists of support and leading staff who do not perform MI routinely. These two groups differ in terms of what is considered as the most important item for remote MI. More specifically, while most of respondents with supporting/leading role consider Connectivity as the most important item, Security is considered by most OVs or OAs as the most important. In addition, we observe that most OV or OA respondents consider Camera as the second most relevant item while respondents with supporting/leading role consider this item as less important than Connectivity and Security.

4. Discussion

Our study postulates that remote MI has the potential to improve the efficiency and effectiveness of meat inspection in Sweden, but this first requires addressing security concerns, improving internet connectivity, selecting and positioning cameras carefully for successful implementation. Both Almqvist et al. (2023) and Kautto et al. (2023) rated handhold mobile phone cameras as user-friendly alternative in their studies. Probably the most interesting to explore are group differences between participants responsible for various tasks, which demonstrates the advantage of analysing individual ratings of items in terms of providing additional insights.

. Such differences can be explained by the type of tasks performed by respective groups of participants. For instance, on the one hand the role of OAs is to perform PMI tasks, where olfactory information and in some cases, palpation, are used alongside visual assessment of carcasses and internal organs. On the other hand, VIs at the SFA headquarters are employed in supporting and leadership roles, and do not routinely perform MI on sites as a part of their daily tasks. "Connectivity" results can suggest that VI respondents could have probably come across internet connectivity issues in remote MI pilots and their choices reflect this fact. This is also corroborated by our earlier, qualitative study of the same population, where participants explicitly mentioned connectivity challenges (Hunka et al., 2024). It is also possible that the VIs and HQs emphasised connectivity the most presumably because they are often involved in remote work in other areas, such as remote meetings, and their work contribution would essentially rely on the quality of data transfer, functioning software and potential interruptions. However, the importance of connectivity could be also considered in the light that the VIs group constitute only the 10% (=14 out of 140) of the respondents and that they mainly based at the HQs.

A second difference can be observed in relation to Assistance which varies by unit and job title. It is worth remarking that while the individual estimates of Assistance for about half of the respondents from the North are positive, the estimates corresponding to this item for most respondents from the South are negative. This is not surprising given that long travel distances to and from abattoirs and game handling establishments, coupled with shortages of staff are present to the greatest extent in the Northern part of Sweden, where remote MI might be needed the most. It is, however, important to note that at the aggregate level this parameter was not significantly different from zero, which indicates that, on average, respondents are indifferent about this aspect of remote MI, hence this possible explanation should be taken with caution. A study conducted by Deuss and Honey (2023) suggests that the lack of interpersonal engagement is one of the major drawbacks of remote food audits. Another interesting result relates to Communication which does not stand out as an issue neither at the unit nor job title level. Arguably, this could be due to the fact that in many cases the MI findings need not to be communicated, and the communication between OVs and slaughter personnel in practice remains limited, also due to often noisy environment. Both OVs and OAs are used to inspect without communication and language is not perceived as a significant barrier in remote MI (or not more of a barrier compared with on-site MI).

The issue about Security has emerged as critical especially in the North, while other groups are either more divided (South) or more indifferent about this aspect of remote MI (HQ and Mid-Sweden). This seems to corroborate the results of the qualitative study, where several respondents raised concern that the security issues could be manipulated (Hunka et al., 2024). It can be inferred that there exist several ways

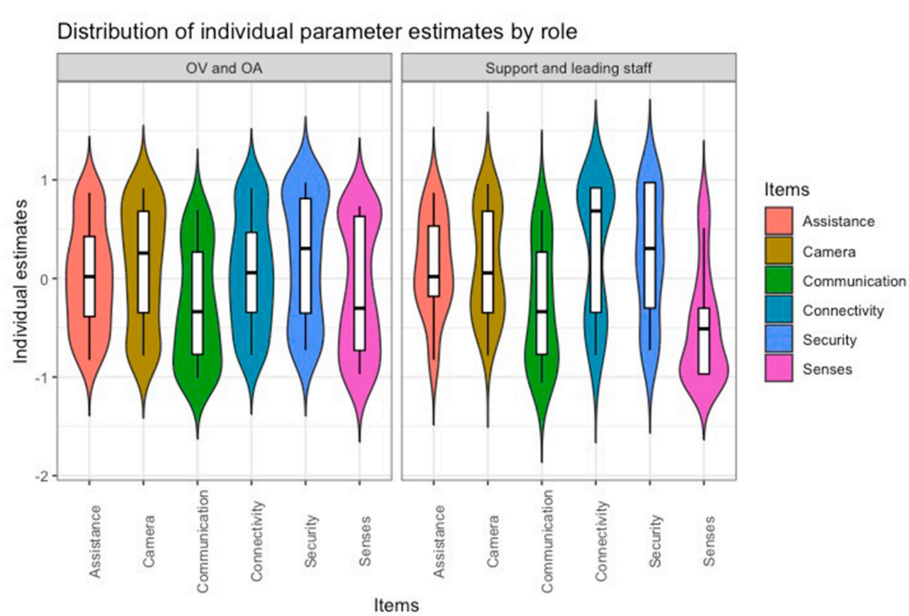

Fig. 3. Distribution of individual parameter estimates for OVs and OAs compared to support/leading staff.

to address such an issue for instance by digital time stamps on the streamed video and closed-circuit tv (CCTV) at the abattoir premises as proposed by the OVs in the first qualitative part of the study. It is worth noting that CCTV as a tool for monitoring animal welfare in abattoirs has already been implemented in several countries, notably Spain, England and Scotland (Fernandez, 2023). The emergence of Security as a critical factor can be also interpreted through the fact that the respondents, lacking the IT or cybersecurity background, were not aware of already existing fraud prevention methods.

The importance assigned to cameras by OVs is perhaps not surprising as they provide a key tool for remote MI. However, it should be further investigated and tested what is a viable option to adopt. The solution could consist of a combination of fixed cameras, hand-held cameras with a specific protocol describing the steps of remote MI, and how its minimum duration could address both issues with staff availability and motion sickness simultaneously (Hunka et al., 2024).

4.1. Study limitations

Best-Worst Scaling (BWS) quantifies individuals' priorities in a clear and accessible way. It is easily comprehensible by respondents and relatively simple to implement. However, the limitations of BWS might impose some constraints on the study results. Firstly, BWS only provides rankings among the items included in the task and does not consider any omitted factors. Therefore, the results are limited to, and relative to, those items. Secondly, even though the BWS attributes were derived from the qualitative part of the study, these attributes are subject to different interpretations by respondents across various groups (job title and unit). This could explain some discrepancies between this study and the previous qualitative study. The third limitation is that BWS assumes that preferences among individuals in the sample are similar enough for the mean to represent the group. As it can be seen from the results, this assumption does not hold for all subgroups.

Finally, there is the common challenge of obtaining a representative sample size, as complete population samples are seldom available for research. In this study, surveys were distributed to the entire population with a response rate of 54.7%. Therefore, the sample is representative at the aggregate level. However, the response rate differed at the sub-group level. In OV and OA groups the response rate was 48%, while all other groups jointly had a response rate of 94% (33 responses from 35 employees).

4.2. Implications for remote MI and avenues for further research

Our study quantified experts' preferences for remote MI prerequisites uncovered in an earlier qualitative study with a similar sample of respondents (Hunka et al., 2024). Together with the first pilot studies currently conducted in Sweden (Almqvist et al., 2021; Kautto et al., 2023) and around the world (Deuss & Honey, 2023), our study offers additional evidence for potential establishment of remote MI as a control option alongside MI on-site. Remote MI could, in certain circumstances, make the current setup of on-site MI more robust and resilient against adverse external conditions such as extreme weather events or lack of staff in case of sick leaves.

The items in our study can be roughly divided across several dimensions. Whereas the concerns and preferences our respondents indicated can be considered as a whole, such rough categorisations help to systematically discuss implications of our results for prospective implementation of remote MI.

The first categorisation we propose is across the line of remote technology necessities and features that can be considered in subsequent steps of the technology implementation. For the remote MI to take place three items fall under the category of necessities, whereas the other item can be considered at a later stage. A stable and fast internet connection inside and outside the premises is the first prerequisite. At present, this could present a problem in some remote areas even if the Internet and mobile 4G and 5G networks in Sweden are well developed. The second prerequisite is the availability of up-to-date digital equipment that would allow for accurate, high-quality video streaming. The third and equally significant prerequisite is the FBO staff on-site the abattoir and game handling establishment who is trained in using the provided equipment and in conducting MI in collaboration with a remote OV. These three conditions must be met before other aspects of remote MI are to be considered. While currently it is not clear who is to bear the costs of such a modernisation, deciding a common, agreed standard for connectivity, digital equipment and staff training could be the first step towards remote MI.

The second categorisation we propose divides the items in our study into three aspects: physical, technical and digi-physical prerequisites for remote MI. Whereas purely technical aspects, namely connectivity and digital equipment need to take centre stage before remote MI is implemented, physical aspects such as communication between remote and on-site FBO staff and availability of on-site FBO staff to assist in remote MIs are equally important. The last category, digi-physical interaction is defined as either a combination of digital and physical events or a digital component that requires or triggers subsequent physical events. The term is increasingly used in healthcare and digital marketing (Entezarjou et al., 2022). We propose that two items, Security and Senses fall under that category, as they materialise at the interaction between technological solutions and users' preferences, familiarity with and trust in the technology. In the first qualitative part of this study, several ways of ensuring security of the remote MI have been proposed by the OVs, such as digital time stamps on the streamed video and CCTV at the abattoir premises which would provide additional and tamper-proof records of each remote MI (Hunka et al., 2024). It is of utmost importance that the users on both sites of the remote MI setup trust that whatever technological solution is chosen, it fully protects the transferred data. This implies a significant effort in choosing, testing, and implementing any proposed security measures. Similarly, relaying of olfaction and palpation via digital means relies on two assumptions: 1) that the user is able to interpret the incoming data correctly, and 2) that the user trusts that the incoming data are accurate and reliable. These imply not only significant effort in developing and choosing the technology, such as developing an electronic nose, but also require that users are trained in interpreting the data and that a common, agreed standard for interpreting such data exists in the first place. Moreover, strong food safety culture and mutual understanding of the roles of FBO and CA are key issues in this context (Vågsholm et al., 2023).

Further research is needed in several areas. First, pilot studies could establish better understanding not only of the performance of remote *versus* on-site MI, but also of the specifics, additional conditions and requirements remote MI staff faces in comparison to on-site MI. Moreover, empirical user studies could provide additional in-depth understanding of preferences of various groups of potential remote MI users such as OVs, OAs and FBO personnel, facilitate the creation of common standards for remote controls, and finally help chart the most optimal ways for each group to learn the new related skills. Moreover, more comparative studies between remote and on-site MI in different countries would help establish the quality and efficiency criteria and remote MI standards across the whole EU.

The remote MI can become a viable option offering more flexibility in MI in the future. However, conditions for MI on remote basis, such as all necessary equipment, minimum internet network capacity, animal health conditions in the uptake area of the establishment or staff training, are to be defined in connection to the flexibility option offered in the EU regulations, always considering a high level of food safety, and animal health and welfare.

CRediT authorship contribution statement

Aemiro Melkamu Daniel: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Agnieszka**

D. Hunka: Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Emanuela Vanacore:** Writing – review & editing, Writing – original draft, Project administration, Conceptualization. **Shiva Habibi:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Ingrid Medin:** Writing – review & editing, Conceptualization. **Arja H. Kautto:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A

How this survey works

The tasks in this survey are choices between alternatives. These alternatives represent important areas to consider in implementation of REMOTE meat inspections.
The alternatives are:

Video camera location and settings: encompasses all the issues of image, video and audio quality, as well lighting.
Connectivity: e.g., quality of data transfer, functioning software, potential interruptions.
Availability of personnel at abattoir: availability and cooperation with personnel on site.
Communication and language: interpretation and understanding of instructions.
Security and fraud prevention: trust and transparency issues, system security.
Ability to relay smells and haptics: relaying non-visual cues used routinely in on-site meat inspections.

You will be asked to rate 3 alternatives against each other and pick the most important and the least important option on each screen.
The tasks might be perceived as a bit repetitive, but these repetitions are necessary, it is how this survey method, called Best-Worst Scaling, works. This will allow us to build a model showing how meat inspection practitioners evaluate various aspects of remote meat inspections.

There are 10 screens in total and the selection of alternatives on each screen is different. Please make all 10 choices. There is no need to be consistent in your selections or to remember previous screens. There are no right and wrong choices, your spontaneous answer is important and valuable to us!

Fig. A1. Introduction of the method and choice tasks.

Imagine that you are about to conduct an official meat inspection as usual, starting with AMI and then proceeding to PMI.
The only difference is that this time the inspection will be done remotely. Instead of traveling to a small-scale abattoir, you connect via internet to assigned on-site technical support staff. You will be able to see the video transmission, communicate with the support, request repeated checks if something is out of place, and direct the person assisting you. The abattoir makes sure that the internet is stable and fast both outside and inside the buildings, and that the support staff is ready and waiting for you.
Assume that you are testing remote inspection, so certain features will still be tweaked to meet your expectations and needs.

On the following screens, you will be asked to repeatedly evaluate different aspects of remote meat inspections.

Tillbaka Nästa

Fig. A2. Introduction to the experiment.

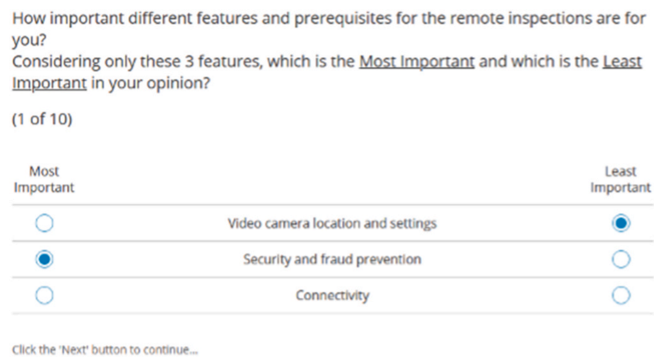

Fig. A3. Example choice task (first out of ten). Example shows best and worst choices already made.

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