



Original Research Paper

WelfareSense A Behavioral Assessment Framework for Improving Domestic Animal Management Practices

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Key Words	Abstract
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Increasingly, human observation of the welfare state of domestic animals is subjective and occurs infrequently, and this makes the detection of early signs of poor welfare state for animals more difficult for caretakers and institutions. This paper introduces WelfareSense, a behavioural assessment system that can be used to systematically evaluate domestic animal welfare status using indicators in companion animal, farm animal and shelter settings. It consists of six observable domains of behaviour - locomotion and activity level, feeding and drinking, resting and posture patterns, social/ interaction behaviour, vocalization patterns and stereotypic/ abnormal behaviour - and integrates them into a composite welfare indicator score which can be used for management decision-making. WelfareSense is designed as a modular system where behavioral data are captured, indicators are derived from this data, scores are weighted, and thresholds are used to classify them, with a recommendation layer that converts the scores into meaningful management recommendations. The framework is derived from existing welfare science, such as the Five Domains model and behavioural welfare indicators, and highlights the need to promote the practical application by the caretaker, who may not be specialised in ethological science. This paper outlines the conceptual design and scoring logic of WelfareSense, explores illustrative indicator weighting applied in its behavioural scoring module and provides a path forward towards empirical implementation and validation. Additionally, the discussion covers implementation issues such as data collection burden, inter-observer reliability and species-specific calibration requirements. WelfareSense is designed to be a stepping stone to light touch, low cost, welfare monitoring which can be easily adapted to a variety of different contexts of domestic animal management, used in addition to, not instead of, veterinary and ethological knowledge, and to foster more consistent and evidence-based animal care practices at the point of daily animal management.

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Introduction

The well-being of domestic animals, including house and livestock, requires timely identification of the onset of changes in their behavior. Welfare monitoring is typically episodic, with pain, distress or environmental lacks only becoming apparent when they are severe and an opportunity for the veterinarian to check welfare occurs or when the informal caretaker has an impression of it. In the field of welfare science, behavioral indicators are known for being sensitive, non-invasive markers of the affective and physiological state of an animal as change in activity, feeding, resting, social engagement, vocalization, and the occurrence of stereotypic behavior often precede overt clinical signs.

Even though behaviour-based welfare theory is robust, there are many current assessment protocols which have been developed for research or regulatory auditing purposes and need specific ethological training to apply. This leaves a disconnect between welfare science and the practical, day-to-day science of domestic animal management, especially for the hands-on people involved: the welfare caretaker, the farm worker, the shelter animal handlers. WelfareSense is intended to bridge this gap by using a structured, weighted scoring method to translate known welfare domains into a species- and environment-independent tool that can be readily trained in the required animal and in the desired environment.

The following key contributions. First, it categorises the behaviours of domestic animals relevant to welfare into six domains which are

easily observable and identifies a composite scoring method for combining these domains into a meaningful welfare score. Second, it suggests a threshold-based classification system which assigns behavioral scores into categories relevant to the care taker's management, and a recommendation layer that provides guidance on care taker actions. Third, it outlines a validation strategy and implementation issues such as burden of data collection, inter-observer reliability and the requirement for species-specific calibration, providing WelfareSense as a stepping stone to future empirical implementation instead of a complete clinical instrument.

This paper is organized as follows: Section 2 reviews the related research on behavior-based welfare frameworks and technology-assisted welfare monitoring. Section 3 introduces the WelfareSense framework, its behavioral domains, scoring logic and classification scheme. The considerations for implementation and a suggested validation strategy are discussed in section 4. An example of the indicator weighting in the framework is discussed in Section 5, followed by a discussion of some of the implications for practice. The paper ends in Section 6, where directions for future empirical work are suggested.

Related Work

Mental state was included as a new dimension in welfare frameworks, thereby offering a structured approach to the interpretation of observable animal states to produce a welfare assessment (Mellor & Beausoleil, 2015). Broom's seminal research showed the feasibility

of measuring welfare in terms of measurable indicators such as behavioural, physiological and health based indicators and the need for common and scientifically valid assessment practices for all species and production systems (Broom, 2011).

Quantitative analysis of activity patterns, time budgets, and behavioural diversity have been emphasised as good indicators of welfare as a result of a methodology review of behavioural organisation (Asher et al., 2009); if observation protocols can be standardised and interpreted consistently by all observers, then quantitative measures can be used as a useful indicator of welfare. Lying, resting, and sleep behaviour in calves has been investigated by systematic review of precision livestock farming technologies to capture aspects of these behaviours automatically, showing both the potential and current challenges, such as validation gaps and challenges for field deployment, for continuous behavioural monitoring in calves (Pesenti Rossi et al., 2024).

Species-specific behavioural signals have also been investigated as a measure of welfare, such as vocalization patterns in young domestic animals, which have been found to be reliable indicators of need and are thus considered to be a separate behavioural domain for welfare assessments (Weary & Fraser, 1995). Motivational and preference-based approaches also support the need for multi-domain and not single indicator assessment of welfare as it takes into account the animal's own view of its welfare needs (Muns et al., 2015). Lastly, applied welfare assessment protocols for non-traditional or

under-studied species demonstrate how general behaviour-based protocols can be adapted with animal-based measures, where species-specific baselines are not available (Benn et al., 2019). WelfareSense extends this body of work by integrating several behavioural areas together to create a single, more easily applicable scoring system which could be used in everyday home management of domestic animals, but would not be used exclusively for research or audit environments.

The Welfaresense Framework

Overview and Design Principles

WelfareSense is based on three principles, interpretability, meaning that even those without ethological skills, should be able to understand why a welfare score is produced; modularity, meaning that behavioral domains and weights can be recalibrated for other species or other contexts; and, actionability, meaning that scores can be directly used as management guidance, rather than as an abstract numerical output. The framework is structured in four flow: behavioral data acquisition, extraction of indicators, weighted scoring and threshold-based classification, with a layer of recommendations.

Behavioral Domains

WelfareSense groups observable behaviour into six domains that reflect a range of the best established relationships in welfare science and are clearly observable at home: (i) locomotion and activity level, which reflects overall mobility and activity budget; (ii) feeding and drinking behaviour, reflecting appetite, intake duration and intake regularity; ((iii) resting and posture

patterns, (iv) social and interaction behavior, (v) vocalization patterns, and (vi) stereotypic or abnormal behavior.

Each domain is scored on a normalized scale from 0 to 1, based on the deviation from a baseline on a species- and context-specific scale, with 0 being the score for behaviour very much at the extreme of compromised welfare and 1 being the score for behaviour very much at the extreme of the base line or positive welfare. Baselines do not need to be assumed across all species and management situations but should be determined by the species and management situation.

Weighted Composite Scoring

A WelfareSense Index (WSI) is computed as a weighted sum of domain scores: $WSI = \sum$

over i of $(s_i \text{ multiplied by } w_i)$, where s_i is the normalized score for domain i , and w_i is the weight for domain i and the weights sum to one. The weights are shown as an example in Figure 1 that was used conceptually to validate the scoring module; these values are used as starting values for the weights to be calibrated when deployed based on expert judgment and empirical validation data and should not be considered as universal parameters. The inclusion of stereotypic and abnormal behaviours with the core time-budget domains also reflects the underpinning of welfare science which has shown that repetitive abnormal behaviour is a particularly strong indicator of chronic welfare compromise, even if it occurs at comparatively low frequency.

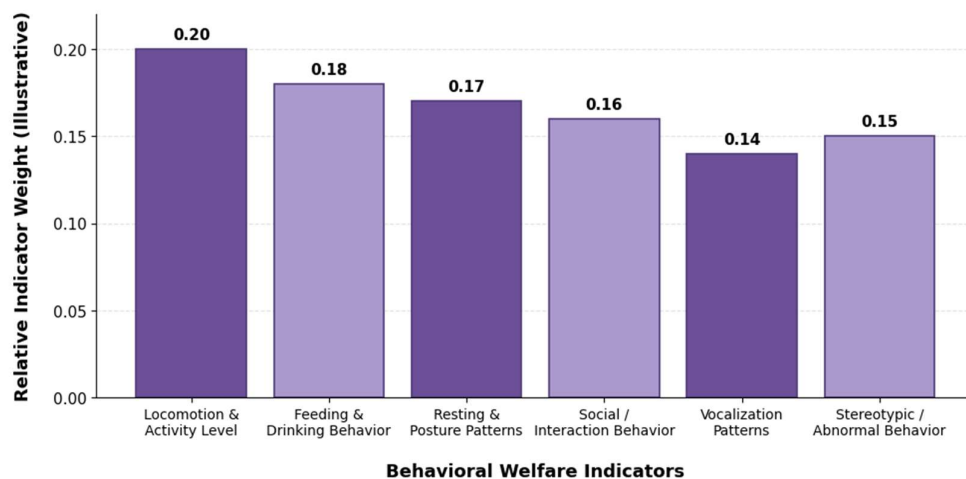


Figure 1: Illustrative Indicator Weighting Configuration for the WelfareSense Behavioral Scoring Module

Threshold-Based Classification and Recommendations

The composite WSI is broken down into three categories of welfare: Satisfactory ($WSI \geq 0.70$), Requires Attention (WSI between 0.40 and 0.69),

and Critical ($WSI < 0.40$). There are three action levels: Satisfactory (routine monitoring to continue); Requires Attention (more frequent observations, review of changes in the environment or management); and Critical (escalate to the caretaker or veterinarian

immediately). These thresholds are recommended as a starting point for calibration studies, not as absolute clinical thresholds, and are likely to need to be adjusted for each species and age class, and for each management context.

Implementation Considerations and Validation Strategy

There are a number of considerations when implementing WelfareSense. The data collection burden must be low enough for it to be used routinely, so the framework is set-up to allow for manual periodic observation checklists, and semi-automated behavioural logging when available, but not sensor instrumentation of the whole system. A calibration phase is also strongly recommended prior to scaling up, particularly if a behaviour-based tool is being used by non-specialist carers; this should include structured training for observers alongside tests of agreement on domain scores, and may also involve calculating inter-rater reliability statistics on domain scores. Additionally, there is a need for species and context specific calibration as there are significant differences in baseline behavioral norms among species, breeds, life stages, and housing systems. The proposed staged validation strategy is: an initial expert-review stage to assess domain weights and thresholds based on veterinary and ethological expert opinion; a pilot stage for comparing WSI outputs with agreed reference protocols and clinical welfare assessments for a defined animal population; and an iterative recalibration stage to adjust domain weights and thresholds based on pilot agreement statistics. This staged approach is designed to ensure any future reported

performance of WelfareSense is based upon empirical calibration data specific to the deployment context, not assumed based upon the conceptual framework alone.

Discussion

In Figure 1, the illustrative weighting considers the six domains to be given relatively equal levels of weighting, although slightly more than this goes to locomotion and activity level and to feeding and drinking behavior, reflecting the importance of these as early and easily observed signs of welfare in the existing literature. This is a starting point to be modified and used as a transparent setup, not an optimized one. One of the most important practical benefits of the WelfareSense design is that, in addition to recognising that welfare may be compromised, the composite scoring enables caregivers to indicate which behavioural domain is jeopardising the welfare, thereby allowing more effective management responses to be made than would be possible had they only been given an undifferentiated welfare score. Having a good baseline is also critical for the usefulness of the framework because the use of a normalized deviation from baseline to make the classification becomes problematic if the baseline is poorly established. Therefore, large-scale deployments should be preceded by empirical baseline development in representative domestic animal populations in the future. Some of the current conceptual limitations are no empirical validation data, the condensation of a large number of different behavioural repertoires into six domains, and the future necessity for further automation of the extraction of indicators in

environments where manual observation cannot be done.

Conclusion

In this paper, WelfareSense, a framework for the behavioural assessment of welfare that aims to increase the accessibility and usefulness of welfare-relevant behavioural monitoring in normal domestic animal management, was introduced. WelfareSense's structure of six domains of behavior observed in pigs (locomotion, activity level, feeding and drinking behavior, resting and posture patterns, social and interaction behavior, vocalization patterns, and stereotypic or abnormal behavior) and the combination of these domains in a transparent weighted scoring allows for a translation of established welfare science into a tool that is practically usable and interpretable. A persistent lack of ethological expertise in everyday management practices is filled by the framework's threshold-based classification and recommendation layer, which are geared towards providing timely caretaker response to the fish. This paper has concentrated on the conceptual design, scoring logic and illustrative indicator weighting of the framework, along with a staged approach to validation that incorporates expert review, comparison with reference protocols in a pilot, and iterative recalibration. WelfareSense is not meant to be a replacement for veterinary diagnosis or existing audit-rated welfare protocols, but is instead offered as a complementary, lightweight behavioral monitoring tool for companion animal, farm and shelter environments. Empirical calibration of domain weights and thresholds should be

emphasized for representative animal populations in the future, along with formal testing of inter-observer reliability and investigation of semi-automated data collection to decrease caretaker workload. This empirical basis is crucial before it can be recommended overall to be implemented on a larger scale and will guide the implementation of the conceptual design in the framework to measurable improvements in domestic animal welfare outcomes in diverse management conditions.

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