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Animal Welfare Cannot Be Reduced to the Absence of Disease: A Multidomain Veterinary Architecture Linking Physical Health, Affective State, Behavioral Agency, Environmental Opportunity, Human Interaction, and Recoverability

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ABSTRACT

Animal welfare assessment is weakened when the absence of diagnosable disease, preserved production, or apparently normal behavior is treated as evidence of an acceptable welfare state. These observations remain important, but they do not by themselves resolve pain, affective experience, behavioral agency, access to valued opportunities, social conditions, human–animal interactions, temporal burden, or the animal's capacity to recover after adversity. This original non-empirical article develops a multidomain veterinary architecture for interpreting welfare evidence without assuming that one domain can substitute for the others. The synthesis separates physical health and bodily function from pain and discomfort, distinguishes positive and negative affect from observable behavior, differentiates environmental opportunity from actual use, and treats social and human interaction as context-dependent welfare domains. Time is incorporated through duration, recurrence, adaptation, compensation, and recoverability. The architecture further proposes that discordant indicators should be adjudicated according to construct fit, measurement validity, context, plausible alternative explanations, and temporal trajectory rather than averaged automatically. The intended contribution is therefore an evidence-bounded reasoning structure rather than a new welfare score. Its central implication is that clinically stable or productive animals may still experience important welfare constraints, while favorable behavioral or environmental indicators cannot automatically override severe health or pain states. The architecture requires species- and setting-specific validation, repeated-measure testing, and explicit separation of reliability, construct validity, technical performance, transferability, and prospective decision usefulness before applied use.

Keywords: Animal welfare, Affective state, Behavioral agency, Environmental opportunity, Human–animal interaction, Recoverability

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Introduction

Animal welfare is often assessed through indicators that are clinically convenient, observable, or already embedded in husbandry records. Yet welfare is not reducible to disease detection, productivity, or a short list of visible abnormalities. The Five Domains Model formalized a broader logic in which physical and functional states, environmental circumstances, behavior, and human–animal interactions inform cautious inference about welfare-relevant mental experiences [1]. This establishes an important veterinary premise: health is indispensable, but it is one component of welfare interpretation rather than a sufficient endpoint.

Positive welfare scholarship extends that premise further. Avoiding severe negative states does not establish that an animal experiences positive engagement, rewarding activity, or a life containing opportunities that are valuable to it [2]. Affective science also cautions against treating behavior as a transparent window into subjective state; affect influences decisions, but observed actions additionally reflect learning, motivation, uncertainty, constraints, and context [3]. Environmental resources likewise matter through the opportunities they create, not merely through their physical presence [4].

This article therefore develops a proposed multidomain welfare architecture in which physical health, pain, affective state, behavioral agency, environmental opportunity, social environment, human interaction, temporal burden, adaptation, and recoverability remain analytically distinguishable while still interacting. The purpose is not to assign universal weights or create an additive welfare score. Instead, the architecture is designed to prevent domain substitution: good performance should not erase pain, disease absence should not imply positive affect, environmental provision should not be equated with usable opportunity, and a single apparently favorable behavior should not overrule contradictory evidence without contextual adjudication.

Why absence of disease is an incomplete welfare endpoint

Disease status is a clinically necessary welfare input because illness, injury, impaired function, and associated discomfort can directly constrain what an animal can do and experience. However, a disease-focused endpoint becomes incomplete when "no diagnosable disease" is interpreted as "good welfare." Multidomain reasoning explicitly separates physical and functional circumstances from the mental experiences they may generate and from external conditions that can shape those experiences [1]. An animal may therefore be clinically stable while remaining unable to obtain valued social contact, exercise meaningful control, avoid aversive handling, or engage with a sufficiently complex environment.

The converse problem is also important. Positive welfare is not merely the absence of overt suffering. Concepts such as positive emotion, rewarding engagement, and quality of life add information that cannot be recovered by reversing a disease or distress scale [2]. This does not mean that all domains deserve equal weight in every situation. Severe pain, acute respiratory compromise, or major functional failure may legitimately dominate immediate welfare priorities. The proposed architecture instead rejects a substitution rule in which acceptable clinical findings automatically close the welfare assessment. Physical health should be interpreted as one domain whose importance can be decisive without becoming a universal proxy for the animal's total welfare state.

Physical health and bodily function

Physical health and bodily function remain central because disease, injury, impaired locomotion, nutritional disturbance, and loss of physiological function can directly limit welfare-relevant capacities. The challenge is not whether health belongs in welfare assessment, but how health evidence is selected and interpreted. A systematic review of animal-based welfare indicators in dairy cows found substantial variation in the validity and practicality of available measures, showing that even familiar health-related indicators differ in what they can support and how feasibly they can be applied [5]. A clinically intuitive measure is therefore not automatically a valid representation of a broader welfare construct.

Routine records illustrate the same boundary. In Norwegian dairy herds, an algorithmically generated Animal Welfare Indicator based on routinely available health, production, and management data showed value for selected outcomes but was not suitable as a stand-alone replacement for on-farm welfare assessment [6]. The relevant lesson is not that automated or record-based monitoring is inherently inadequate. Rather, data availability determines which welfare dimensions are represented. In the proposed architecture, physical-health evidence should be clinically specific, linked to the function it actually measures, and interpreted alongside domains that may be absent from routine records. Preserved production or normality on selected health metrics should therefore narrow uncertainty only within their validated scope.

Pain and discomfort

Pain and discomfort warrant analytical separation from general disease status because the presence, severity, and duration of aversive bodily experience cannot always be read directly from diagnosis. Methodological work on mammalian pain facial-expression scales shows that apparently intuitive pain indicators require explicit evidence of validity, reliability, and practical feasibility, and that measurement must remain species specific [7]. A recognized disease or procedure may increase the probability of pain, but it does not remove the need to assess the animal's actual response.

Temporal persistence also matters. Following hot-iron disbudding, dairy calves given local anesthesia and meloxicam still displayed changes in inactivity, rumination, and sucking behavior across portions of a three-week observation period, with different measures showing different patterns over time [8]. These findings do not establish that every behavioral change represented continuous pain, because healing, development, feeding motivation, and measurement method can also contribute. They do show why an immediate post-procedural snapshot is insufficient for some adverse exposures. Within the proposed architecture, pain assessment should combine species-appropriate indicators, clinical context, and repeated observation where warranted. Recovery of one behavior should not automatically be interpreted as resolution of discomfort if other relevant indicators remain abnormal or uncertain.

Positive and negative affective states

Affective state is central to welfare because welfare ultimately concerns the quality of the animal's experienced condition, yet affect is inferred rather than directly observed. Decision-making research provides a useful safeguard: affective states can alter expectations, valuation, and behavior, but the same outward action may also arise from learning history, uncertainty, competing motivations, or environmental restriction [3]. Behavioral evidence is therefore informative without being self-interpreting.

The architecture proposed here treats positive and negative affect as partially independent dimensions rather than opposite ends of a single simple scale. Multidomain welfare reasoning, positive-welfare scholarship, and affective decision theory collectively support a distinction between the circumstances surrounding the animal, the valence of its experiences, and the behavioral processes through which those experiences may be expressed [1-3]. Thus, low evidence of negative affect should not automatically be recoded as positive affect, and a positive behavior should not cancel credible evidence of pain or fear. Confidence should increase when affective interpretations converge across validated behavioral, physiological, clinical, and contextual evidence. Where indicators diverge, the appropriate response is not forced averaging but explicit uncertainty and investigation of alternative explanations, including limited opportunity to express the behavior being measured.

Behavioral agency and choice

Behavioral agency concerns more than whether an animal is active or offered multiple environmental features. Choice and control are distinct constructs: choice involves selecting among alternatives, whereas control concerns the capacity to influence outcomes predictably [9]. Both may be welfare relevant because they shape what the animal can obtain, avoid, or regulate. However, neither construct implies that every additional option is beneficial. A choice can be trivial, constrained, costly, or composed entirely of undesirable alternatives.

The empirical evidence accordingly supports caution. A scoping review of choice-based animal-welfare studies found that many experimental comparisons reported favorable welfare-related effects, but the evidence base was small, concentrated largely in mammals and captive or zoo settings, and included neutral or unclear findings [10]. The proposed architecture therefore treats agency as a domain requiring evidence about meaningful access, actual use, and the consequences of control rather than counting options. Agency should also be distinguished from affective outcome: an animal may possess control without using it at a particular moment, while failure to exercise a choice can reflect preference, illness, fear, social competition, or limited understanding. Species, prior experience, and husbandry context must therefore constrain interpretation.

Environmental opportunity

Environmental opportunity describes what the surroundings make possible for the animal, not simply what equipment, space, or resources are present. Resource-based positive-welfare frameworks are useful because they connect husbandry provision with opportunities for motivated or valued behavior rather than assuming that provision itself constitutes welfare [4]. The distinction is clinically and behaviorally important: a resource can exist but be inaccessible because of pain, fear, social exclusion, location, timing, or individual preference. Conversely, the absence of observed use does not automatically demonstrate that an opportunity lacks value.

For this reason, environmental opportunity and behavioral agency should be interpreted together when a welfare claim depends on choice or control. Evidence on resource opportunity, conceptual distinctions between choice and control, and experimental choice studies supports the narrower conclusion that meaningful welfare interpretation requires attention to whether an option is accessible and usable, not simply available [4, 9, 10]. The article therefore proposes an opportunity–agency compatibility check: before inferring benefit from environmental provision, assessment should ask whether the animal can reach the option, whether competing constraints alter access, whether meaningful alternatives exist, and whether use or non-use has a plausible interpretation. This is an adjudication aid, not a validated score.

Table 1 decomposes environmental opportunity into successive links, showing why provision, access, control, and use cannot substitute for one another.

Table 1. The opportunity chain from environmental provision to meaningful animal use

Link in the opportunity chain	Question to ask	Evidence that the link is present	What failure at this link means
Provision	Is the resource or alternative physically present at relevant times?	The option is available in the environment	No welfare opportunity can be inferred from a resource that is absent
Physical access	Can this animal reach and use it given mobility, pain, body size, and fear?	Approach and use are mechanically possible	Provision exists, but the opportunity is functionally unavailable
Social access	Can the animal use it without displacement, monopolization, or avoidance?	Use is not systematically blocked by group structure	A shared resource may not be an opportunity for every animal
Meaningful choice and control	Can the animal initiate, avoid, or terminate engagement among meaningful alternatives?	Access is voluntary and sufficiently predictable	Counting options can overstate agency when control is absent
Use or non-use across time	Is the pattern consistent across health states, contexts, and repeated observations?	Use, avoidance, or non-use has a reproducible context	Non-use remains ambiguous until barriers, familiarity, fear, and preference are examined

Social environment

Social environment influences welfare through access to conspecifics, relationship quality, competition, separation, predictability, and the animal's capacity to regulate social contact. Importantly, the welfare value of a social arrangement cannot be settled by physical-health outcomes alone. A systematic review of early cow–calf separation found that reported health effects were mixed and context dependent, making health evidence insufficient as a complete rationale for the welfare value of contact or separation [11]. This supports keeping social conditions analytically separate from disease risk even though the domains interact.

Responses to social transition are also multicausal. In a factorial dairy study, full- or part-time cow–calf contact combined with gradual or abrupt weaning and separation did not yield a simple pattern in which apparently gentler management uniformly reduced distress-related behavior [12]. Vocalization and seeking behavior may reflect social separation, but hunger, expectation, previous contact patterns, and the sequence of management changes can contribute. The proposed architecture therefore treats social indicators as context-dependent evidence rather than fixed welfare labels. Assessment should consider the social opportunity available, the animal's prior relationship history, competition or exclusion, and the timing of transitions. A change in one social behavior should trigger interpretation, not automatically determine the welfare conclusion.

Human–animal interaction

Human–animal interaction deserves a distinct welfare domain because humans are not merely part of the social background: they control handling, restraint, treatment, feeding routines, access to resources, transport, procedures, and many opportunities for choice. A review of positive human–animal relationships identifies voluntary approach, proximity, anticipation, relaxation, and other rewarding responses as potentially informative while emphasizing that learning history, human behavior, familiarity, and animal agency shape their meaning

[13]. Frequent human contact is therefore not intrinsically positive; its welfare value depends on how the animal experiences and can regulate the interaction.

Measurement itself can be context sensitive. In dairy cows, avoidance distance at pasture showed acceptable inter-observer reliability and moderate test–retest reliability, but individual scores were not stable across the season and did not correspond closely with avoidance distance measured at the feeding rack [14]. Contextual change may therefore reflect either a real alteration in the relationship or a change in what the test elicits. Individual preference further constrains interpretation: gilts choosing between scratching and stroking showed no general group-level preference for either tactile interaction [15]. The proposed architecture consequently treats human interaction as preference-sensitive and context-dependent, requiring attention to voluntariness, predictability, prior experience, withdrawal opportunity, and repeated response.

Temporal duration of welfare states

Welfare judgments are vulnerable to snapshot bias. A single observation can miss delayed adverse consequences or brief but recurrent negative states, whereas a transient abnormality may be overinterpreted when its duration is unknown. Post-disbudding calf evidence illustrates this problem: behavioral changes occurred across different portions of a 21-day period rather than collapsing into one immediate post-procedural response [8]. Duration therefore modifies the interpretation of an indicator even when its direction is already known.

Affective science likewise distinguishes short-lived emotion-like states from longer mood-like tendencies capable of influencing subsequent decisions [3]. This does not justify diagnosing mood from persistent behavior alone. Instead, it supports adding a temporal layer to welfare assessment. The architecture proposed here records onset, duration, recurrence, and direction of change where data permit. A severe but brief event, a mild recurrent restriction, and a persistent unresolved state should not be treated as equivalent because they produce superficially similar observations at one moment. Appropriate observation windows must remain construct-, species-, and exposure-specific. No universal temporal threshold is proposed.

Adaptation, compensation, and hidden welfare costs

Animals may maintain outward function while altering physiology or behavior to compensate for challenge. This creates a risk of interpreting stability as evidence that a welfare problem has resolved. The literature on allostasis and allostatic load is instructive but cautionary: a broad scoping review identified inconsistent operationalization, frequent reliance on single biomarkers, and comparatively limited use of multisystem indices intended to represent cumulative dysregulation [16]. Stable production or an apparently normal short-term biomarker may therefore be compatible with successful adaptation, unresolved cost, or neither.

Longitudinal resilience research offers a second clue. In dairy cows around parturition, sensor-derived behavioral patterns contained information about later resilience-related health classification, although performance was imperfect and the construct concerned health resilience rather than whole-animal welfare [17]. Automated milk-feeder data from Holstein calves have similarly been used to quantify variability and deviations in intake trajectories as resilience-related traits [18]. These approaches support trajectory analysis, not equivalence between production stability and welfare.

Table 2 places adaptation patterns on a timeline, separating immediate functional stability from cross-domain recovery and longer-term recurrence or reorganization.

Table 2. Welfare-recovery trajectories distinguished by what happens during, after, and beyond an adverse challenge

Trajectory pattern	During the challenge	After the challenge	Longer trajectory	Welfare interpretation
Convergent return	Relevant domains deviate in a manner compatible with the exposure	Several measures move toward the prior state	No persistent compensatory signal is detected across an appropriate interval	Recovery becomes more plausible but still requires multidomain confirmation
Stable output with discordant secondary measures	Production or function is maintained	Other behavioral, physiological, affective, or social indicators remain altered	The discordance persists or resolves on a different timescale	Stable output may reflect compensation and cannot certify complete welfare recovery

Recurrent deviation and return	The adverse pattern reappears under repeated or cyclical exposure	Apparent recovery occurs between episodes	Repeated regulation creates a cumulative trajectory	Recurrence may itself carry welfare burden even when each episode resolves
Persistent new baseline	Several measures move away from the prior state	They stabilize without returning	A reorganized or impaired state becomes established	Stability is non-diagnostic; a new multidomain reference is required

Recoverability after adverse exposure

Recoverability is proposed here as the capacity for welfare-relevant states to return toward, or reorganize into, an acceptable post-adversity condition across time. It is intentionally broader than health resilience, production resilience, or return of one behavioral measure. Longitudinal dairy evidence shows that behavioral trajectories around parturition can contain information about resilience-related health outcomes [17]. This supports repeated trajectory measurement but does not validate multidomain welfare recoverability.

The architecture therefore treats recovery as a pattern characterized, where evidence permits, by magnitude of deviation, duration, direction of return, recurrence, and concordance among affected domains. Automated calf-feeding work demonstrates that deviations from an expected trajectory can be quantified at high temporal resolution [18], but intake stability cannot establish good welfare. Similarly, recovery of production, locomotion, or one behavior may coexist with unresolved pain, diminished agency, altered social interaction, or physiological burden.

Recoverability should consequently be interpreted against the adverse exposure and the welfare domains plausibly affected. Return to the exact pre-exposure state is neither always possible nor necessarily the correct reference because animals may establish a new baseline. The construct remains explicitly proposed until cross-domain recovery trajectories are validated against independent welfare-relevant outcomes.

A proposed multidomain welfare architecture

Recent consensus work defines positive animal welfare in terms extending beyond physical health and prevention of suffering to predominantly positive mental states, competence or resilience, and opportunities to pursue desired outcomes [19]. That breadth supports, but does not validate, the architecture proposed here. The architecture organizes evidence into interacting domains of physical health and bodily function, pain and discomfort, affective state, behavioral agency, environmental opportunity, social environment, and human–animal interaction. Temporal duration, adaptation, possible hidden cost, and recoverability modify interpretation across those domains.

The structure is deliberately non-additive. Operational accounts of the Five Domains Model emphasize structured inference rather than automatic numerical equivalence among domains [20]. Accordingly, no favorable domain is permitted automatically to cancel severe adverse evidence elsewhere, and no universal weights are assigned. Each domain retains its own evidential strength, uncertainty, alternative explanations, and transfer boundaries before cross-domain reconciliation.

Operational accessibility must also remain separate from validity. A simplified Animal Welfare Assessment Grid used across zoo species demonstrated high inter-rater reliability in its studied setting, but reliability does not establish comprehensive construct validity or external transferability [21]. The proposed architecture therefore distinguishes whether an indicator can be scored consistently, whether it measures its intended welfare construct, and whether that interpretation generalizes.

Because the contribution is relational rather than numerical, the architecture is most efficiently represented as interacting evidence states separated from the welfare inference they support.

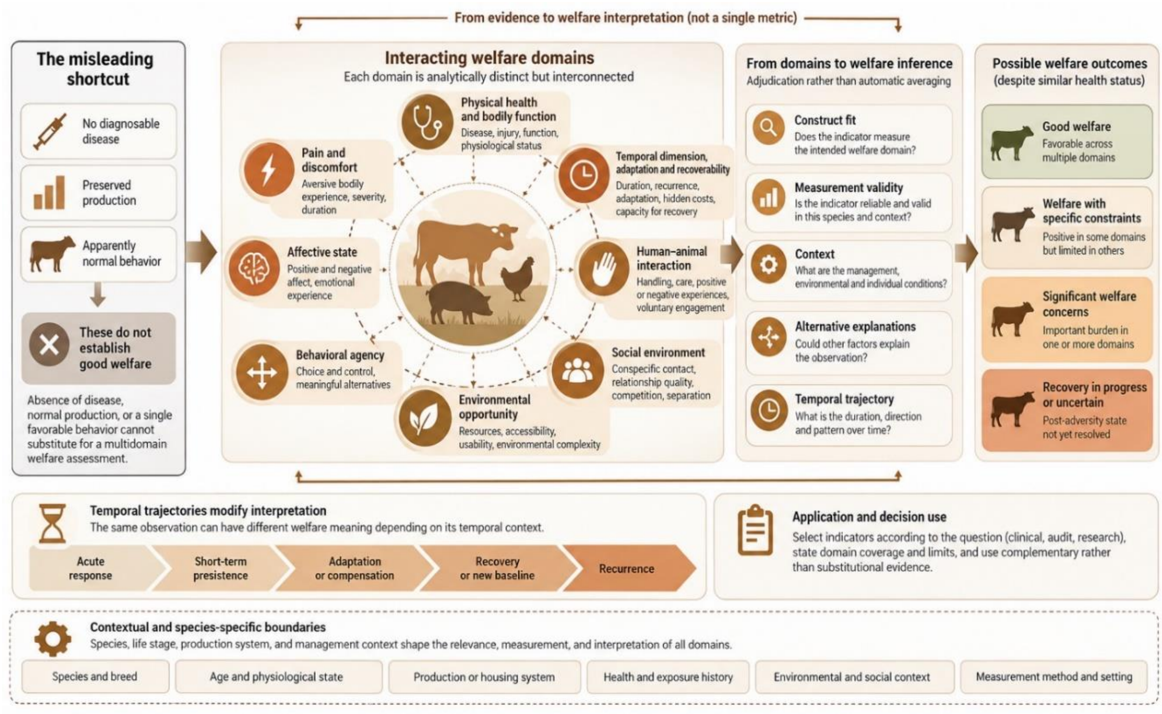

Figure 1. Welfare states diverge when preserved function masks constrained experience, agency, or recovery

Reconciling discordant welfare indicators

Discordance is expected when indicators measure different constructs, operate at different timescales, or are differently constrained by context. In horse husbandry, candidate affiliative behaviors differed in validity, reliability, and feasibility; voluntary social proximity appeared more promising than social play or grooming for standardized positive-welfare assessment, while contextual interpretation remained necessary [22]. An apparently positive behavior is therefore not automatically interchangeable with another positive indicator.

Technical measurement creates another layer of discordance. Automated detection of calf play achieved high classification accuracy yet still overestimated a low-prevalence behavior, while play itself varied with age, sickness, weaning, and temperature [23]. Technical accuracy and welfare validity are therefore separate questions. Cross-species contextual effects are equally relevant: in zoo-housed carnivores, enrichment and age predicted several candidate positive-welfare behaviors, indicating that opportunity and life stage can alter indicator expression [24].

The architecture consequently proposes adjudication rather than automatic averaging. Greater interpretive priority should be given to construct fit, measurement validity, directness, temporal relevance, and plausible alternative explanations. A conflicting indicator may represent a genuinely different welfare dimension rather than error. When available evidence cannot resolve the discordance, uncertainty should remain visible and prompt additional observation or reassessment rather than being mathematically concealed.

Welfare assessment applications

Applied welfare assessment should begin with the decision being made. Clinical triage, a routine farm audit, longitudinal research, and automated surveillance need not use identical indicators, but each should state which welfare domains it measures and which remain unresolved. Dairy-cow indicator research demonstrates that validity and practicality differ across measures, making an unquestioned universal instrument difficult to justify [5].

Streamlined or digital assessment can still add substantial value when its evidential limits are explicit. Simplified multidomain tools may improve accessibility and scoring consistency, while sensor systems can collect high-frequency observations that direct human assessment cannot continuously reproduce. However, measurement validity, operational reliability, and external model performance are distinct requirements [5, 21, 25]. The proposed application rule is therefore complementary rather than substitutional: reduced or automated panels should be used only within constructs, populations, and contexts for which their interpretation is supported, with routes to direct observation or veterinary reassessment when domain coverage is incomplete.

Applications should additionally distinguish screening from diagnosis and monitoring from welfare adjudication. A signal can be useful for detecting possible deterioration without identifying affective state or total welfare. Making that distinction explicit is preferable to forcing every measurement system to provide a comprehensive welfare verdict.

Validation requirements

Validation must occur at the indicator level, domain level, cross-domain interpretation level, and—where relevant—the decision derived from the architecture. External validation is particularly important. In dairy cows, a real-time welfare-classification model performed differently when applied to unseen herds than under herd-specific evaluation [25]. Performance established internally therefore cannot be presumed to transfer across management systems, populations, seasons, or data distributions.

Reliability is similarly necessary but insufficient. A livestock welfare risk-assessment tool showed preliminary agreement with officer ratings and useful observer-reliability results, yet longitudinal testing against later welfare incidents or repeated poor-welfare outcomes remained necessary [26]. Criterion agreement should not be mistaken for prospective prediction.

Indicator-level research in preweaning dairy calves further demonstrates that measures considered useful can differ in inter- and intra-rater reliability and may require clearer categories or additional assessor training [27]. The proposed architecture therefore requires separate evaluation of practical utility, repeatability, construct validity, sensitivity to meaningful change, temporal stability where appropriate, and external transferability. Where prediction or decision support is claimed, prospective calibration and decision usefulness require additional testing.

Because "validated" cannot responsibly function as a single undifferentiated state, the final figure separates measurement quality, interpretation, generalization, and application boundaries.

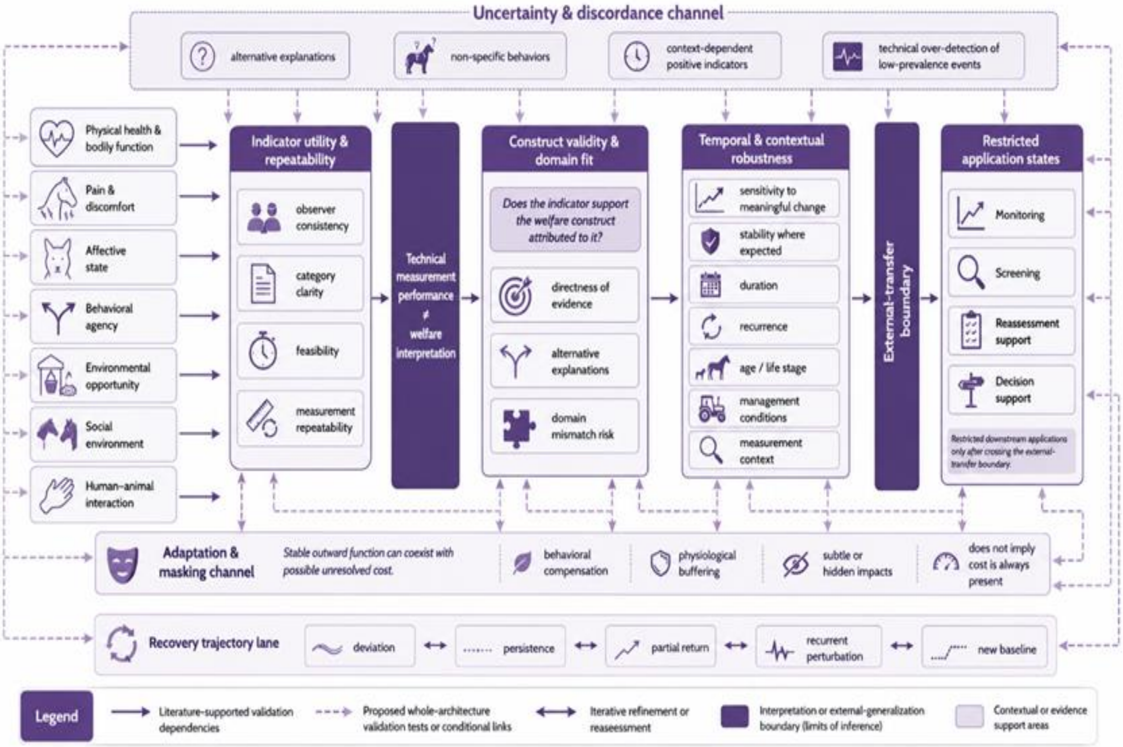

Figure 2. Validation fails when reliable measurements outrun construct fit, temporal robustness, or external transfer

Validation proceeds through distinct indicator, construct, temporal/context, transferability, and application boundaries. Solid connectors indicate established validation dependencies; dashed pathways identify proposed whole-architecture tests. Discordance, compensation, and incomplete recovery redirect interpretation toward reassessment.

Conclusion

Animal welfare assessment becomes conceptually unsafe when absence of disease, preserved production, normality on selected measures, or one favorable behavior is allowed to stand for the animal's whole experienced state. The architecture developed here preserves physical health as a core domain while separating pain, affect, agency, environmental opportunity, social conditions, and human interaction, with duration, adaptation, possible hidden cost, and recoverability modifying their interpretation.

Its principal contribution is a proposed reasoning structure for preventing domain substitution and adjudicating discordant evidence without forcing it into an unvalidated total score. Favorable evidence in one domain may coexist with important burden in another, while apparent functional recovery may not establish multidomain welfare recovery. The architecture therefore remains deliberately evidence-bounded. Its usefulness depends on future species- and setting-specific validation of indicators, temporal trajectories, reconciliation rules, transferability, and decision usefulness. Until such testing is completed, it should be treated as a structured, testable welfare architecture rather than a validated assessment instrument.

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