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# Review: Towards an integrated concept of animal welfare

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ABSTRACT

Animal welfare is an important field of study due to animal sentience, yet there is to date no consensus on the definition of animal welfare. There have been four key developments in the field of animal welfare science since its birth: the theoretical and empirical study of affective states, and hence our understanding thereof, has increased; there has been a shift from a primary focus on unpleasant experiences towards an inclusion of pleasant experiences; there has been an increasing mention and investigation of the notion of cumulation of experiences in time, and with this, the importance of the time component of both affective states and animal welfare has come forward. Following others, we define welfare as a balance or cumulation of pleasant and unpleasant experiences over time. The time period of welfare depends on when welfare considerations are necessary, and may range from the duration of single and relatively short-term experiences to the entire life of an animal. We further propose that animal welfare conceptualised in this way can be assessed at three levels: level 1 represents the assessment of the environment and 'internal factors' such as health and personality, which interact in their impact on the affective experiences of animals; level 2 represents the assessment of affective states; and level 3 represents the assessment of the balance or cumulation of these affective states in time. The advancement of research necessitates studies to be more or less comparable, and this would be facilitated by researchers mentioning which concept of animal welfare they are basing their work on, at which level of assessment they are working, which assumptions they might be drawing from to infer welfare and which time period of interest they are focusing on, even if this is not mirrored by the timing of the assessment in practice. Assessment at levels 2 and 3 still needs much study, at both the theoretical and empirical levels, including agreements on validation tools.


## Implications

There is to date no consensus on the definition of animal welfare. By describing our proposed perspective on this matter and proposing a framework of assessment, we hope to promote cohesion between studies. More specifically, we hope that future papers might include a mention of the definition of animal welfare that is used, the level at which assessment is made, which assumptions are made to infer welfare, and which time period is under scrutiny. Moreover, we hope to stimulate further the focus on certain key gaps in knowledge, specifically validation tools for affective experiences and their cumulation in time.

## Introduction

Safeguarding the welfare of animals we use for human benefit has become an important societal concern, especially in developed countries, where many would consider it our moral duty (Broom, 2016). The concept of animal welfare has fluctuated over time, following changes in values and beliefs, as well as the advancing scientific understanding of animals. There is to date no consensus on what animal welfare exactly represents. The need for a concept of animal welfare arises from animal sentience, i.e. one's ability to feel pain and pleasure, to experience pleasant and unpleasant 'affective' states.

This conceptual paper includes four aims: first to describe four key developments in the conceptualisation of animal welfare; second to give an up-to-date proposal for how we, following others before us, view animal welfare; third to present a simple framework for the assessment of animal welfare at three 'levels'; and fourth, to discuss the advantages and challenges linked to these three levels of assessment.

## Key developments in the field of animal welfare science

Rousseau (1762) and Jeremy Bentham (1823, in Duncan, 2006) were some of the first to put forward animal sentience and our ensuing ethical duty to minimise animal suffering. But it was not

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until the publication of Ruth Harrison's book *Animal Machines* in 1964 exposing the treatment of factory farm animals and the subsequent Brambell report by the Brambell Commission of the UK government in 1965 (Brambell, 1965), that animal welfare became a scientific field of research. In the Brambell report, animal welfare is defined as: "a wide term that embraces both the physical and mental well-being of the animal".

Since the Brambell report, many other definitions of animal welfare have emerged (e.g. Broom, 1986; Spruijt et al., 2001; Dawkins, 2004; Mason and Veasey, 2010a and 2010b). For example, Broom defines welfare as the ability of an animal to cope with and adapt to its environment, while Dawkins defines animal welfare as health combined with the extent to which an animal has what it wants. Fraser et al. (1997) and Fraser (2008), described three possible 'viewpoints' of how people conceptualise animal welfare, based either on 'health and biological functioning', the level of 'natural living' or the 'affective states' (defined below in detail) of an animal. Four key developments can be extracted from these evolving views of animal welfare across the past six decades: (1) an increasing study of affective states, including the defining of concepts and the development of indicators, (2) an increasing study and consideration of the positive/pleasant/rewarding 'affective experiences' (hereafter experiences), as opposed to a primary focus on the negative/unpleasant/aversive experiences of animals, (3) an increasing interest into 'balancing' or 'cumulating' these positive and negative experiences over time, and (4) an increasing mention of, or consideration for, the time element of animal welfare, and in particular whether this should be lifelong. We will briefly describe these four developments below and follow-up by providing our perspective on animal welfare. Developments 3 and 4 are difficult to disentangle and hence discussed below jointly.

### *Key development no. 1 – an increasing understanding of affective states*

The earliest mention of the importance of affective states in the context of animal welfare science was the Brambell report (1965), where it is stated "Any attempt to evaluate welfare [...] must take into account the scientific evidence available concerning the feelings of animals [...]." Mason and Mendl (1993) also mentioned affective states as central to the assessment of animal welfare, and pointed to the difficulty in assessing those states. In the past decades, many papers have been published on affective states in the context of animal welfare, which has enhanced our understanding of what affective states are, and how we can assess them. Of importance to the present article is the current proposed definition of affective states and the varying views as to how these affective states exactly fit into the concept of animal welfare.

Affective states have been defined as transient subjective experiences that are not hedonically neutral (Mendl and Paul, 2020). The term 'affective state' is often used as an umbrella term for emotions and moods. While emotions are commonly described as relatively short-term states that are elicited by a specific (internal or external) event or object (Mendl et al., 2010; Paul and Mendl, 2018), moods are often described as longer lasting than emotions and generally not elicited by a specific event or object. Moods are therefore sometimes referred to as 'free-floating' states and proposed to reflect the cumulative experience (or 'running mean') of emotions over time (Mendl et al., 2010; Mendl and Paul, 2020). Affective states have been proposed to function in decision-making processes by promoting the acquisition of reward and the avoidance of punishment and thereby increase survival and reproductive success (comprehensively reviewed by Mendl et al., 2010; Mendl and Paul, 2020). Two often mentioned and key features of affective states are *valence* – i.e. whether the state is perceived as positive/pleasant/rewarding (hereafter positive) or negative/unpleasant/aversive (hereafter negative) – and *arousal* – i.e. how activated an individual is or the intensity of the state (Russell, 2003; Mendl et al., 2010; Mendl and Paul, 2020). Affective states are hence often conceptualised within a two-dimensional space along the axes of valence and arousal. Beside this *dimensional approach*, emotions in particular have been studied using the *discrete approach*. According to the discrete approach, emotions such as joy, fear and anger are generated by the activation of specific brain regions and are characterised by distinct physiology and behaviour (Mendl et al., 2010; Mendl and Paul, 2020). Mendl et al. (2010) proposed a framework combining both these approaches. Briefly, to acquire reward or avoid punishment, underlying neurobehavioural systems will be activated or inhibited resulting in one of four (i.e. a high arousal-positive, low arousal-positive, low arousal-negative and high arousal-negative) core affective states (Mendl et al., 2010; Mendl and Paul, 2020). Discrete emotions and moods can be positioned in relation to one of these four core states, indicating possible locations of these discrete affective states (Mendl et al., 2010).

Affective states involve various changes within four distinct components: a behavioural, (neuro)physiological, cognitive, and subjective component (Mendl et al., 2010). We are not able to directly assess the subjective changes in animals as animals cannot verbally share with humans what or how they are feeling. Fortunately, the other three 'indirect' components can be assessed, enabling researchers to make inferences about the subjective component of affective states in animals (see Kremer et al., 2020 for a recent review of indicators of these three components).

Turning now to how authors have described their understanding of the link between welfare and affect we have observed at least two views. Some authors equate affective states with animal welfare, suggesting that if an animal feels a negative emotion or mood, it should consequently be considered to have poor welfare in that moment, and vice versa. Some examples of this include Mason and Veasey (2010a) who stated "Welfare relates to an animal's affective (colloquially, "emotional") state: what it feels", and Bradshaw (2019) who stated "Throughout this piece I am assuming that welfare is synonymous with affect [...]". Others instead stated that affective states are an important, but not the only, part of animal welfare and its assessment. For example, Fureix and Meagher (2015) wrote "Measures related to affect have however often been raised as relevant measures for assessing animal welfare; we [...] are principally concerned about this aspect of animal welfare", and Kirkwood (2007) wrote "concern for an animal's welfare is concern, at least partly, for its feelings".

### *Key development no. 2 – a growing attention for positive experiences*

In early days, the focus in animal welfare science set out by the Brambell report mainly revolved around our moral urgency for minimising suffering in (farm) animals. This focus on the negative experiences of animals later shifted towards an increasing interest into the positive experiences of animals. In 2016, Mellor pointed out two important pitfalls of focussing predominantly on suffering in the context of animal welfare. Firstly, freedom from suffering as a cornerstone of animal welfare is not realistic as a complete freedom from negative experiences is impossible and not biologically favourable or adaptive. The experience of hunger, for example, which could be defined as a negative experience linked to some level of suffering, has evolved to incite individuals to start feeding and promote survival. Secondly, freedom from suffering is not sufficient to ensure good welfare as low levels of suffering do not necessarily translate to high levels of welfare (Boissy et al., 2007; Mellor, 2016). This shift towards positive experiences was proposed by many (e.g. Mench, 1998; Webster, 2005; Boissy et al.,

2007; Ohl and Van der Staay, 2012; Mellor, 2015). For example, Mench (1998) proposed that we move beyond suffering and towards improvements in animal welfare. Later, Boissy et al. (2007) stated that good welfare is not merely the absence of negative affective states, but also the presence of positive affective states, such as pleasure. Boissy et al. (2007) wrote "the absence of signs of pleasure or positive affect may be an indication on its own of a state of affective discomfort".

It is worth noting here that with the increasing inclusion and importance of positive experiences into animal welfare science, the term 'positive animal welfare' has been increasingly used (e.g. Lawrence et al., 2018; Rault et al., 2020). It has been pointed out that positive animal welfare could refer to one of three concepts: (1) high levels of animal welfare, i.e. one end of the welfare continuum, (2) positive (and transient) emotions and moods, or (3) the importance of considering positive experiences when assessing animal welfare. Due to this disparity in the use of the term positive welfare and the rapidly growing research into all three of these concepts, there is a need for bringing people together and formulating definitions, knowledge sharing and collaborations. Overall, it seems that most animal welfare scientists would agree that positive experiences are important to the concept of animal welfare.

*Key development no. 3 and 4 – an increasing reference to cumulation over time*

The growing interest into the positive experiences of animals and the importance thereof in the context of animal welfare is not independent from the long-acknowledged need to minimise negative experiences. With this combined attention for positive and negative experiences, there has been a shift in animal welfare science, mirroring a similar but older shift in human subjective well-being research, towards the concept of a balance or cumulation. Several papers have indeed defined animal welfare as a balance between positive and negative experiences (e.g. Spruijt et al., 2001; Kirkwood, 2007). For example, Spruijt et al. (2001) stated: "Welfare is defined as the balance between positive (reward, satisfaction) and negative (stress) experiences or affective states". Furthermore, the notion of a balance has often appeared together with the notion of 'quality of life' (Farm Animal Welfare Council (FAWC), 2009; Yeates, 2011). Yeates (2011), for instance, mentioned that quality of life is "a balance of all experiences within a specific period".

With this idea of a balance, the idea of cumulative experiences over some period of time also became relevant. Terms that suggest some sort of accumulation of positive and negative experiences over time include 'cumulative suffering' (Honess and Wolfensohn, 2010), 'cumulative lifelong experience' or 'cumulative affective experience' (e.g. Bateson and Poirier, 2019), and 'cumulative well-being/welfare' (Bradshaw, 2019). This idea of a cumulative experience was, as far as we know, in fact first mentioned in the Brambell report (1965) which reads "We, for our part, must pay special attention to the possible cumulative effect on the animal of the long continuance of conditions which might be tolerable or even acceptable, in the short term. Factors producing prolonged stress, discomfort or deprivation must weigh heavily with us and may, on occasion, be of much more significance for the total welfare of the animal than more acute, but transitory, suffering".

Cumulative (affective) experience has been defined as "the sum of all the events and effects, including their quantity, intensity, duration, recovery between and memory thereof, that impact, adversely, positively and by way of amelioration, on the welfare of an animal over [its] lifetime" (Pickard, 2013). The ratio of the sum, hence cumulation, of positive experiences over the sum of negative experiences represents the balance of positive and negative experiences over time.

The main concern with this concept is the objective assessment of the cumulation of positive and negative experiences (i.e. affective states) over time in non-verbal beings. Theoretical questions that require consideration include: how should we compare several mild experiences to one traumatic one (Bateson and Poirier, 2019), can negative experiences ever be compensated for by positive experiences (Yeates, 2011; Bateson and Poirier, 2019), and over which time scale should a balance be computed to reflect animal welfare? We do not have answers to these questions, but we discuss the time question below. Further consideration of the assessment of this balance over time in non-verbal beings is provided in the section 'A framework for how animal welfare can be assessed'.

Most animal welfare scientists would agree that animal welfare involves a certain time component, but what this time component truly is and how it should be included into the concept and assessment of animal welfare remains often unclear. There seems to be at least three different time scales mentioned in past literature. First, when animal welfare is equated with a particular emotion or mood, the time scale considered is then that of the emotion or mood of interest – for example, when the acute emotional response to a stressor is assessed. Second, animal welfare can be considered beyond one affective state, but not to the point of the entire life of the animal, and this – depending on the context and aim of the study – could mean studying animal welfare from hours to years. Third, animal welfare can be investigated over the entire life of the animal, but since this life may be short or long, the time scale could here also vary considerably.

With the first time scale, the issue of time in animal welfare is shifted to the same issue in the context of affective states: how long do emotions and moods last? Past authors have suggested that emotions range from seconds to hours (e.g. Sonnemans and Frijda, 1994; Anderson and Adolphs, 2014; Zych and Gogolla, 2021). For the duration of mood, authors are generally more hesitant to give a clear time frame and instead use words such as "long-lasting", "prolonged" (Anderson and Adolphs, 2014), "considerable duration" (Trimmer et al., 2013) and "more enduring" (Luomala and Laaksonen, 2000), although some authors do state a narrower duration (e.g. days, Handayani et al., 2014).

For the second time scale, animal welfare can be assessed over various time frames beyond that of a single experience and up until, but not including, the entire life of the animal. For example, a study could consider one particular transport event of 12 h or an entire rearing stage of 6 months. Here, it is important that researchers clearly state which time period they are investigating.

Related to the third time scale, the Brambell report includes "We are concerned with the welfare of the animal throughout what may be the duration of its life", while the FAWC report (2009) includes "the balance of an animal's experiences must be positive over its lifetime". The term 'lifetime experience' (Wolfensohn et al., 2015; Bateson, 2016) or 'life-focused concepts' (Robbins et al., 2018) have also been used.

When discussing the concept of time, one may also wonder how animals perceive time. In the Brambell report, Thorpe wrote "There is no doubt that many types of animals live in the present to an extent which it is hard for a human being to conceive. But, even so, many animals not only remember the past but fear the future, at least to some degree; and the extent to which they do so is of vital moment to our task". More recently, Zentall (2005) reviewed the literature on this subject and concluded that many vertebrates can retrieve information about past experiences as well as plan ahead. It is not within the scope of this article to address how different species perceive time, but it is an interesting discussion point when it comes to assessing animal welfare.

Another important challenge when considering time within the concept of animal welfare relates to what 'lifelong' truly refers to

(Bateson, 2016): does lifelong mean up to the time of assessment, or should the animal be dead before its welfare can be assessed? Furthermore, how can we deal with the issue of short and long-term effects on welfare sometimes being of opposite valence, with shorter-term suffering (e.g. removal of an infected tooth) being required for longer-term positive experiences (e.g. the ability to feed without pain) (Bradshaw, 2019; Veasey, 2017)? These important questions cannot be answered here, and will require further study. In the meanwhile, we advocate a clear statement in papers on which time scale is considered in the study of animal welfare. Note that the time scale of interest may not be the same as the time scale of what is being assessed. For example, one may be interested in the welfare of sows during the farrowing phase, but assesses welfare in snapshots at the start and end of the farrowing phase for practical reasons. These time aspects should be clearly stated and taken into consideration when inferences are made about welfare.

## Our proposed view of animal welfare

Whether they use the term welfare (e.g. Spruijt et al., 2001), quality of life (e.g. Yeates, 2011) or happiness (e.g. Webb et al., 2019), more and more researchers have pointed to the idea that animal welfare has to do with an animal's enjoyment of its life, which is reflected in the balance of its positive and negative experiences over time; with a 'good life' (i.e. high level of welfare) being defined as a life where the frequency/sum/cumulation of positive experiences outweighs the frequency/sum/cumulation of negative experiences (e.g. FAWC, 2009; Green and Mellor, 2011). This idea of an affective balance is in line with human happiness literature, where happiness (also referred to as 'satisfaction with life', 'subjective well-being' or 'apparent quality of life') is defined as one's enjoyment of life as a whole (e.g. Veenhoven, 2017).

We stand by this concept of animal welfare as the balance of positive and negative affective states over the period of time of interest, which can span from hours to years to lifelong. This means that multiple individual affective states as experienced by the animal over time form the elements of this balance representing welfare. One exception is when only one affective state is assessed or occurs – for example, the mood of an animal in the few hours following surgery is assessed to make inferences about the welfare of that animal in that specific time period. In this case, animal welfare can be conceptualised as that single affective state in that period, because the balance is based on one element only. In the given example, the element would likely be a negative mood, whereby a negative balance and hence poor welfare in the postsurgery period can be inferred. Note however that past experiences and future expectations are still very likely to affect this 'one' affective state.

We acknowledge that others may define animal welfare differently, for example as primarily reflecting health or adaptive mechanisms, or as a combination of health, natural living and affective states, but we will not further discuss these alternative views. In the next section, we propose how animal welfare defined as a balance can be assessed at various, yet equally valuable 'levels' (Fig. 1).

## A framework for how animal welfare, defined as an affective balance, can be assessed

Following the concept of animal welfare as a balance of affective states, it follows that aspects that have to do with the environment of the animal, such as a comfortable shelter or feed provision, representing *external factors* – also referred to as 'liveability of the environment' in human literature – have an impact on animal welfare only insofar as they impact the affective states of that animal. The extent to which they will impact the affective states of the animal depends on the *internal factors* of the animal. Internal factors are health, adaptability, personality, resilience, and robustness – also referred to as 'life-ability' in human literature (e.g. Veenhoven, 2006; Fig. 1). Personality is defined as individual differences that are consistent over time and context (e.g. Kaiser & Müller, 2021). Resilience is defined as the capacity to recover back to normal functioning following a perturbation (e.g. Scheffer et al. 2018). Robustness is defined as the capacity to maintain a given state in the face of perturbation (e.g. Colditz and Hine, 2016).

In the context of the framework we propose here, internal factors of the animal (e.g. its health) are not components of its welfare, but instead are factors, like the external factors, that may impact the affective states of that animal, which in turn influence the affective balance and hence welfare. As Mason and Mendl (1993) stated "an animal with a tumour it cannot feel does not have a welfare problem, even if it does have a health problem". Hence, when external and internal factors are assessed, e.g. size of the enclosure or disease, it is 'assumed' welfare that is being assessed (Webb et al., 2019). That is, assumptions must be made as to how these factors influence the affective states, and further the welfare, of this particular individual. When one infers the affective response of animals, and further the accumulation and balance thereof, one is assessing 'apparent' welfare. Apparent welfare is the balance of the experiences of the animal in response to the interplay between its external and internal factors (Webb et al., 2019).

We summarise these different aspects into three levels of assessment of animal welfare (Fig. 1): Level 1 = assessment of external and internal factors that (putatively) influence transient affective states; Level 2 = assessment of transient affective states; Level 3 = assessment of the balance of positive and negative experiences over the period of time of interest. We address below each of these levels of assessment.

### *Level 1 – assessing external and internal factors*

Assessment at level 1 is the assessment of factors that (putatively) influence an animal's affective states and consequently its welfare. These factors can be divided into two interacting categories: external/environmental and internal/animal factors.

External factors are characteristics of the environment in which the animal lives. Indicators of external factors can, for instance, be resource-based (e.g. size of enclosure) where they relate to the facilities or resources that the animal has access to, or management-based (e.g. feeding frequency). For example, to make inferences about an animal's affective state, one can investigate the feed provided and assess whether this is enough to meet the animal's nutritional requirements, or whether it promotes the animal's natural feeding behaviour. Where nutritional requirements are not met and natural feeding behaviours thwarted, one can infer that the animal will consequently experience a negative affective state. Examples of other external factors likely to exert an influence on an animal's affective state are for example climate, noise, the social group, components of the environment allowing for the expression of natural behaviours and so on.

Internal factors, as mentioned above, include health, personality, adaptability, resilience, and robustness. These internal factors interact with external factors in terms of the impact on an animal's affect. A painful health issue for example is likely to cause negative affect, but will also likely affect the experience of the environment (and vice versa), whereby a long walking distance to a feeder, for example, which prior to the health issue was not responsible for negative affect, may now lead to negative affect.

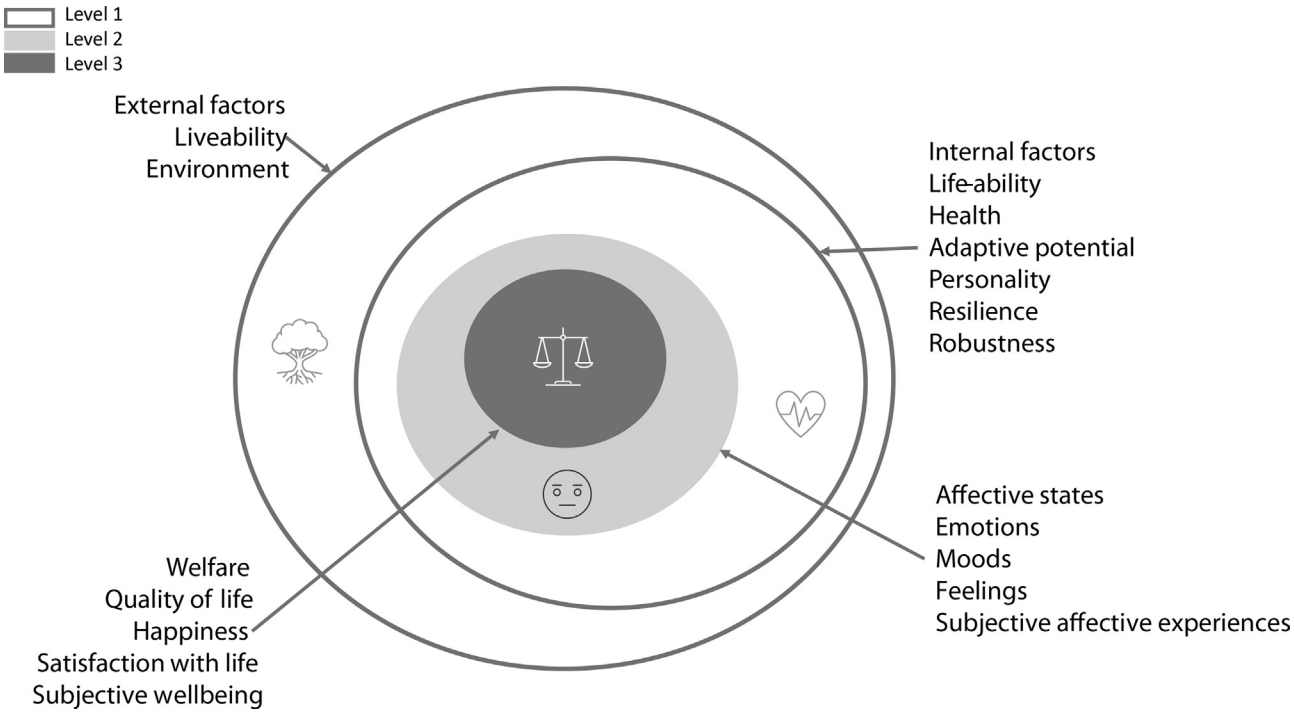


**Fig. 1.** Framework of the three levels of animal welfare assessment.

*Advantages*

Many indicators related to assessing internal and external factors in the context of animal welfare have been commonly applied, and several of these, especially in the case of external factors, are more or less objective and often feasible to assess, even at a large scale. Though the assessment of factors at level 1 is an assessment of 'assumed' animal welfare, as opposed to 'apparent' welfare, it is nonetheless valuable, as has been demonstrated by the vast body of influential research which has been generated based on these factors. To make studies more comparable across levels and factors, it would in our view be valuable to specifically and explicitly state which assumptions are made to infer animal welfare based on level 1 factors/indicators.

*Challenges*

The use of level 1 indicators to infer welfare involves several challenges. First, the expected impact of these factors on an animal's affective state may have been inferred from previous research (e.g. a lack of rooting materials and space makes pigs more pessimistic, Douglas et al., 2012), or may be inferred from logical and well-supported assumptions (e.g. wounds are painful to a pig). It is, however, generally unknown how large the impact of ex/internal factors is on an individual animal's affective state. We may for example demonstrate through experimental work that small pens lead to social stress in a certain group of cows and generalise this further to be true for all cows. However, particular circumstances and types of cows may be affected differently by the same amount of space. For instance, depending on personality, resilience or dominance status, one individual may be minimally affected by limited space, while another may experience frequent and long-lasting negative affective states under the same conditions (e.g. Kremer et al., 2021).

Second, although there is no lack of indicators related to in/external factors to choose from, it can be tricky to select which can or should be used to make inferences about animal welfare (see Dawkins, 2021). One solution to this problem, which has been repeatedly mentioned and applied, is to combine as many indicators on internal and external factors as possible and integrate all of these into a 'balanced consensus' (as done in welfare assessment protocols by e.g. Blokhuis et al., 2010; Caroprese et al., 2016; Mellor, 2016; Mellor et al., 2020). The integration of different types of indicators related to internal and external factors, and the weighing of these against one another into a final score is not straightforward (e.g. Czycholl et al., 2018; Dawkins, 2021; Forkman, 2021) (and may not be necessary), although based on expert judgement. As the consequences of the factors on affective states of individual animals are often not assessed (for practical reasons or because we lack the tools), possible weights given by humans to each indicator may not reflect the experience of the animals under study.

Third, assessments at level 1 are sometimes conducted at group or herd level, rather than individual level, leading to inferences about animal welfare being based on the average animal.

Fourth, it is unclear how often welfare assessments need to be performed (Czycholl et al., 2018) for a more or less accurate assessment of 'assumed' welfare. This is a problem common to all levels of welfare assessment described in this paper. Specific to level 1 indicators, while some reflect relatively short-term conditions (e.g. skin lesions due to a recent fight which heal within a few days), others, particularly resource-based indicators, can hold for an animal's lifetime (e.g. feeder space). Selecting multiple indicators as well as conducting multiple assessments in time may provide a more complete picture of the assumed welfare state of an individual. Another strategy is to record certain level 1 factors over long periods of time, sometimes including the entire life of the animal, which leads to an assessment of cumulative effects. For example, some efforts are currently being made to study the entire lifetime of farm animals, from birth to death, by integrating the different phases of a production system (e.g. calf rearing and dairy cow) using sensor technology that detects health issues (e.g. https://www.clearfarm.eu/). Another example of cumulative assessment of level 1 factors is welfare assessment protocols that aim to integrate level 1 indicators over the life of (laboratory) animals (up to the time of assessment), by combining indicators

describing the environment, health and functioning, experimental/clinical events and behaviour – including their frequency, intensity and duration (e.g. Honess and Wolfensohn, 2010; Wolfensohn et al., 2015). Note that some behaviours here may be indicators of affective states and hence level 2 indicators, which are addressed below.

*Level 2 – inferring affective states*

Inferring transient affective states is needed to feed the 'affect balance' that is required to depict an individual's welfare over the selected period of time (Fig. 1). Affective states can be inferred from their behavioural (e.g. escape behaviour, tail postures), (neuro)physiological (e.g. heart rate variability) and cognitive components (e.g. cognitive bias and appraisal). These components have already been extensively reviewed, including their advantages and limitations (e.g. Kremer et al., 2020; Mendl and Paul, 2020; Alexander et al., 2021; Laurijs et al., 2021; Murphy et al., 2021). We summarise here the advantages and challenges of these types of indicators which are relevant to the discussion in the present paper.

*Advantages*

An advantage of assessments at level 2 versus level 1 is that apparent affective consequences of a particular combination of external and internal factors are being assessed, and consequently, where valid indicators exist, less assumptions need to be drawn. Another advantage is that level 2 indicators are typically done at the level of the individual animal, while external and internal factors are sometimes studied at the group level.

*Challenges*

Making inferences about affective states from their potential indicators comes with a number of important challenges. We describe five key challenges below. First and foremost, we lack clear validation tools, as the 'gold standard' of verbal self-reports found in human studies is not available in animal studies. This means that even with level 2 indicators, many assumptions must be drawn, often heavily based on human research (Mendl et al., 2022). How can we be certain that what we are assessing is in fact the subjective experience of an animal when this animal is unable to confirm this to be true? For this, we need clear validation tools and precise research protocols, devised by animal welfare scientists. Inferring affective states in animals, particularly mammals, who share physiological systems with humans, could be supported by research into the physiological correlates of various affective states translated from human research using verbal self-reports of affect as validation.

Second, inferring affective states can be problematic due to certain indicators not being unequivocally linked to a particular valence (reviewed in Kremer et al., 2020). For example, physiological changes linked to affect often reflect arousal rather than valence, limiting conclusions as to the pleasantness of an experience (Paul et al., 2005). Similarly to level 1 factors, it has hence often been advised to use multiple indicators of affective states, preferably from all three components (i.e. behaviour, cognition and physiology) as this is likely to lead to a more complete and clear interpretation of the affective state under study (e.g. Kremer et al., 2020).

Third, indicators of affective states can be time-consuming or laborious to assess, and can influence the animal's affective state due to handling, sampling procedures or temporary removal of animals from their home environment. For example, training animals for a judgement bias test (a cognitive test to assess an animal's mood, Mendl et al., 2009) can take time and may provide cognitive enrichment and be rewarding in itself (Roelofs et al., 2016). Furthermore, obtaining physiological indicators is often invasive, for instance when blood sampling is required, and may necessitate fixation of the animals, thereby possibly inducing a negative affective state.

Fourth, certain categories of affective state have not been much studied, for example longer-lasting moods, positive states and states of low arousal, which are more subtle and hence more difficult to detect. The past focus on negative states is gradually changing, with more and more positive states receiving research attention, as mentioned above.

Finally, an important consideration relates to the timing of affective states. Aside from the division of states between emotions and moods, little work to our knowledge has been done to assess how long specific affective states might last in animals. It would be valuable to put more effort into this, especially when it comes to level 3 indicators where a balance of positive and negative experiences (possibly based on time) may need to be computed. We conclude here that inferring affective states is extremely valuable in the context of animal welfare but that this is still an emerging field that requires much theoretical underpinning and empirical support.

*Level 3 – assessing the balance of positive and negative experiences*

Level 3 indicators reflect what we, and others before us, define as animal welfare. They represent the balance of (cumulative, aggregated, summed) positive and negative experiences over the period of interest. Research into level 3 indicators of animal welfare is rather recent and hence not well established yet. This means that much of what we discuss below is mainly theoretical and based on human research. That being said, there are to our knowledge two approaches concerning an assessment at level 3: the repeated assessment of affective states over time and subsequent computation of a ratio referred to as '*affect balance*', or a one time (or two times as a baseline is likely required) assessment of the cumulation of positive and negative experiences over time, referred to here as '*cumulative affect*' (Webb et al., 2019).

In humans, affect balance can be assessed through a method called '(affective) experience sampling' (Csikszentmihalyi et al., 2014). For example, using a mobile device, people are asked to report their affective state at random moments around seven times per day over the course of a week or two, and the ratio of the number of positive over the number of negative affective experiences is computed. Affect balance in humans correlates with self-reports of human 'happiness', 'satisfaction with life' or 'subjective well-being', under stable contexts (e.g. the Affect Balance Scale based on recollection of past affect: Bradburn, 2015). Note that where the context is unstable and big life changes occur, for example, the loss of a loved one, the level of happiness and hence the affect balance will change (Moor and de Graaf, 2016). We are not aware of any published affect balance studies in animals. Challenges of assessing affect balance are described below, after we first explain cumulative affect.

In humans, cumulative affect without the need for verbal communication may be inferred from physiology. Biomarkers that have been proposed are numerous, including single markers (e.g. telomere attrition: Epel et al., 2004) or composite markers (e.g. allostatic load index: Schenk et al., 2018) (for a review of some of these biomarkers see Steptoe, 2019). Even in humans, the research into these biomarkers is novel and requires further empirical work. Telomere attrition has also been applied to animals, and we hence discuss it here as an example of a potential indicator of cumulative affect. Telomere attrition is the shortening process of the extremities of chromosomes which occurs naturally with ageing (Epel et al., 2004). In humans, accelerated telomere attrition has been

linked to cumulative stress (Epel et al., 2004), while deceleration of telomere attrition has been linked to repeated and frequent positive experiences (Archer, 2017). Studies in vertebrate animals suggest that telomere attrition shows potential as an indicator of cumulative affect (Bateson, 2016; Bateson and Poirier, 2019), but more work is required with regard to replicability and (species-specific) validation, and it remains to be seen to what extent physical stress or other factors unrelated to cumulative affect impact telomere attrition (Bateson, 2016; Bateson and Poirier, 2019; Bradshaw, 2019; Browning, 2022).

*Advantages*

The main advantage of level 3 indicators, if valid indicators can be developed, is that they assess apparent welfare and reflect the enjoyment of an animal's life over time, and as a consequence require in theory less assumptions to be made than level 1 and level 2 indicators when it comes to inferring welfare.

*Challenges*

Since level 3 indicators are in their infancy, there are many challenges linked to this type of assessment. Where affect balance is being assessed, the same challenges as for level 2 (affective states) indicators are of relevance, including the lack of validation tools and the difficulty in finding valid and unequivocal indicators that are practical to collect and reflect all states, including more subtle affective states.

An additional challenge here includes a possible weighing consideration: should more intense or longer-lasting states weigh more in the balance? In human research where the frequency of positive and negative affective states is recorded at random moments in time, intensity of affect is not included while duration is to some extent taken into account due to the repeated assessments over time (as mentioned above, note that the validity of such assessments are likely dependent on a stable context). It has been suggested in humans that the intensity of affect is less relevant than the frequency of affect to happiness levels (Diener et al., 2009). This seems reflected in questionnaire studies where the intensity of affect is not used to compute cumulative affective experience (Ferreira et al., 2021; Lazić et al., 2019). It remains to be seen whether the same applies to animals, and it is important to consider that intensity may play a larger role in the face of traumatic events.

Challenges linked to assessing cumulative affect via physiology include a need for further validation in animals (and humans). For example, telomere attrition seems to be difficult to apply in young animals or over short time spans, and may need a baseline measure due to inter-individual variability in telomere length (Bateson, 2016). Depending on the period of interest, in particular with very short periods, the use of cumulative affect indicators may not be suitable.

## Conclusions

Following others, we have proposed that animal welfare can be conceptualised as the balance of positive and negative experiences over time. This means that welfare can be assessed at different periods in time as well as in the short and long-term, from the assessment of a single affective state to the entire life of an animal. In the past, lifelong animal welfare has been given various names, including 'quality of life' or 'happiness'.

Following this proposed conceptualisation of animal welfare, which is based solely on the affective states of animals, external and internal aspects such as natural features of the environment or health, are not a part or component of welfare but rather feed into welfare in an interacting manner. It is important to note here that some of these internal factors can in turn be affected by welfare. For example, in humans, higher levels of happiness are proposed to lead to better health and longevity (e.g. reviewed in Steptoe 2019). In addition, we proposed a conceptual framework whereby animal welfare may be inferred at three different levels: level 1 represents the assessment of external/environmental and internal/adaptive factors that may impact the affective states of animals; level 2 represents the assessment of these affective states; and level 3 represents the assessment of the balance or cumulation of these affective states over a period of time.

All three of these levels of assessment involve advantages and challenges. The main challenge linked to level 1 assessments in our view is the need for assumptions to be made about how these factors impact affective states. The main challenge for level 2 and 3 assessments has to do with a lack of validation tools. Next to these particular challenges, there exists key gaps in our knowledge of level 2 and 3 indicators requiring further theoretical underpinning and empirical study before we can come closer to assessing the balance or cumulation of affective experiences over time in animals.

## Ethics approval

Not applicable.

## Data and model availability statement

Data or models were not deposited in an official repository. No new datasets were created.

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## Declaration of interest

None.

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