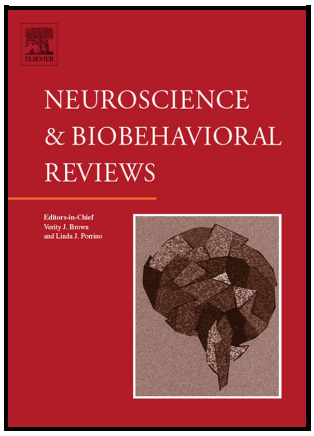

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Balancing the animal affective scales - Can the methodology of human affect balance be translated to other sentient species?

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Abstract

Assessing the welfare of non-human sentient animals is a multifaceted scientific endeavour. A human psychology approach that holds promise for application to animals is affect balance, based on the idea that how one feels most of the time is determined by the balance between the separate dimensions of positive and negative affect. Affect balance has been shown to have profound relationships with mental and physical health and well-being in humans. The aim of this conceptual article is to evaluate whether the affect balance methodology might offer a useful integrative measure of the affective/hedonic component of animal welfare and to outline key considerations for its potential application. Due to the variation in human affect balance methods, any attempt to translate them to other species requires first extracting their main underlying principles. We extracted four underlying principles, the first three relating to estimating the frequencies of positive and negative affect over time, and the fourth relating to the integration of positive and negative affect into an affect balance score or category. We then discuss how the theory behind the affect balance methodology can be translated to other species, and the theoretical and practical considerations in the development and validation of potential assessment methods. Altogether, we think that this approach holds great potential for animal welfare science and we encourage empirical studies into this topic.

Keywords: animal welfare; methodology; affective states; cumulative affect; positive affect; negative affect

1. Introduction

Assessing the welfare of non-human sentient animals (hereafter animals) is a multifaceted scientific endeavour, which compels scientists to try and open a window into the affective lives of animals. Affect is defined as any experience that is felt as valenced, i.e. pleasant or unpleasant, hence not hedonically neutral (Mendl et al., 2010). It is presently unclear which animal species experience the conscious component of affect. Nevertheless, there is a growing body of scientific evidence pointing to such experiences being present in vertebrates and possibly some invertebrates (Andrews et al., 2024; Irwin, 2024; Low et al., 2012; Perry and Baciadonna, 2017). Today, many animal welfare scientists agree that high levels of welfare necessitate both a mitigation of negative affect (**NA**) and the promotion of positive affect (**PA**) (Mellor, 2016; Rault et al., 2025; Reimert et al., 2023). Building on this, animal welfare has been defined as the accumulation and balance of PA and NA over time (Browning, 2020; Duncan, 2002;

FAWC, 2009; Green and Mellor, 2011; Mason and Mendl, 1993; Reimert et al., 2023), while positive animal welfare has been defined as flourishing through the experience of predominantly positive mental states (Rault et al., 2025). Although animal welfare concerns may go beyond the sole affective component and encompass processes such as the development of competence and resilience (Rault et al., 2025), as well as inter-connected and affect-driving constructs such as health (Düpjan and Dawkins, 2022) and naturalness (Fraser, 2023, p. 20; Gygax and Hillmann, 2018), the present article focuses only on this affective component of welfare. While welfare has been defined in terms of a balance of PA and NA, assessment methods specifically targeted at identifying this balance are currently lacking.

To identify novel, promising methodologies to assess welfare, animal welfare science may draw inspiration from psychology, a field that benefits from the ability of many human subjects to verbally report how they feel. An approach from positive psychology that holds promise for application to animals is affect balance (**AB**), proposed as reflecting the affective or hedonic component of well-being (Kolanowski et al., 2014; Matud et al., 2023; Sanjuán, 2011; Zhu, 2015). Hedonic well-being in humans can be defined as how one feels overall most of the time (Veenhoven, 2000), which is in line with the affective animal welfare definition given above. AB is based on the idea that how a person feels most of the time is determined by the two separate dimensions of PA and NA, including how PA and NA coexist, interact, and modulate one another. AB hence reflects the accumulation of positively and negatively valenced experiences of emotions and moods that contributes to a person's overall level of affective well-being, also referred to as the "affective texture of a person's life" (p.2, Fredrickson and Losada, 2005).

In psychology, PA and NA are observed as non-mutually exclusive experiences, representing distinct yet moderately correlated dimensions (Diener et al., 2010; Russell, 2003; Yoon et al., 2022; Zhang et al., 2024). Functionally, PA and NA interact dynamically: PA is proposed to broaden cognitive and behavioural repertoires (e.g. Gable and Harmon-Jones, 2011; Rader and Hughes, 2005), to help build personal resources such as competence, resilience and strong social relationships, and may buffer against, and even undo, the lingering effects of NA (Fredrickson, 2001), while NA may also be instrumental in the building of competence and resilience (Fredrickson and Losada, 2005). It is thought that the accumulation of NA over time will lead to a negative mood, which in turn will increase the propensity to experience further NA (Denollet and De Vries, 2006; Mendl et al., 2009), and vice versa for PA, pointing to positive feedback loops within each dimension of affect. Hedonic well-being hence emerges from the dynamic integration of separable affective dimensions rather than from a single continuum.

The greater the surplus of PA over NA, the higher the overall well-being (Moriwaki, 1974; Yoon et al., 2022): although some NA will be present in all lives, and may even have some benefits in the long-term, well-being is maximised when that negative component is dominated by a stronger, more frequent, or more enduring positive component (Van Cappellen et al., 2018). Such a 'positive' AB may mitigate the negative physiological effects of stress (as proposed in the debated 'undoing hypothesis') and stimulate future success-oriented behaviours, including health-promoting behaviours (Sirois, 2015; Sirois and Hirsch, 2015). Some authors argue that simply considering PA is enough to assess well-being (McManus et al., 2019; Tsun-Wai Chu et al., 2019) while others state that NA is also important to consider for a complete picture of well-being (Yoon et al., 2022). Others yet, such as Dogan et al. (2013) describe AB as a competence, i.e., "the skill for balancing affects arising due to negative and positive experiences" (p. 33). The latter definition is not considered further in this article.

AB is hence conceptualised as a state of the individual, which can be assessed using various AB scales and methods. The AB methodology has led to many different methods, techniques and indicators, most of which show correlations to other mental health and well-being indices, e.g. satisfaction with life (the cognitive/evaluative component of subjective well-being) and depression (Kim and Mueller, 2001; Liu et al., 2013) (see section 3.1). To date, the AB methodology has received limited attention in the animal welfare literature and, to our knowledge, no empirical study has yet been conducted to develop and validate this methodology in animals. The aim of this conceptual article is to evaluate whether the AB methodology might offer a useful, integrative measure of animal affective welfare and to outline key considerations for its potential application in animals. We first dive into the human AB literature to review the different methods used to assess AB and to extract underlying key principles that reflect the essence of the AB methodology in humans. Second, we reflect upon the translation of the AB methodology to animals, structuring this discussion along our extracted principles. We include in this reflection existing methodologies applied in animals that adhere to or deviate from these key principles.

2. Approach to the narrative review

This article is based on a narrative review approach conducted by all authors, with the aim of identifying a broad enough sample of articles to: 1) exemplify correlates of AB in humans (section 3.1) and 2) scrutinise common methods used to measure AB in humans (section 3.2). In practice, we started the process by each author sourcing five relevant papers on AB in humans using academic databases and search engines (primarily Web of Science and Scopus), with the sole criterion that the study should involve assessing AB. Search terms included combinations of "affect balance", "positive affect", and "negative affect". No restrictions were placed on publication date. Through forward and backward snowballing, additional relevant papers were added to a database (Supplementary Material 1), particularly those focusing on alternative methods to measure AB that had not been identified in the initial searches. Throughout this process, the authors met online on several occasions to review the literature identified and discuss potential gaps in the representation of AB assessment methodologies. Where gaps were identified, additional targeted searches and citation tracking were conducted to ensure that a broad range of methodological approaches was represented in the final database. From each paper, we extracted details of the AB method used and the direction of significant relationships identified between AB and tested correlates. These data can be found in Supplementary Material 1. We elected to include both correlates that can directly be translated to animals (e.g. subjective well-being, stress) as well as those with no or few immediate animal counterpart (e.g., alcohol consumption), as the latter may still have parallels in the animal world (e.g. alcohol consumption can be considered similar to stereotypical behaviour in that both can function as stress-related coping behaviours that may become habitual and maladaptive over time). Once this database of AB papers was compiled, we described the variety in methods (see section 3.2) and brainstormed possible key underlying principles of these methods, which we describe in Table 1. Our criteria for these key principles were that they should be common to all AB methods and demonstrate which steps were taken to capture hedonic well-being, as defined as the accumulation and balance between PA and NA, since this is what we, as animal researchers, aim to capture in our species.

3. Affect balance in humans

Affect balance is proposed as an inherent part of hedonic well-being in humans, showing correlations to other well-being constructs, as well as with external and internal factors known to be linked to well-being. Moreover, commonalities between the various methods to assess AB in humans can shed light onto the underlying key principles linked to the assessment of AB, which are valuable when attempting to translate this assessment methodology to other sentient species.

3.1 Correlates of affect balance

Below we highlight identified correlates of AB without addressing the direction of causality because these results are based on correlational, observational studies or meta-analyses. The full table of literature and extracted correlates is provided in Supplementary Materials 1.

Mental and physical health and well-being. AB research has focused predominantly on mental health and well-being, consistently demonstrating positive associations between AB and other well-being indicators, such as the cognitive component of well-being (also referred to as 'life satisfaction') (Kong et al., 2015; Shrira et al., 2016; Tsurumi et al., 2018; Zhu, 2015), overall subjective well-being (Meeks et al., 2012; Radloff, 1977), flourishing (Fredrickson and Losada, 2005; Yildirim, 2019) and having a purpose in life (Sanjuán, 2011; Shrira et al., 2016). In line with this, depression and anxiety are consistently identified as negative correlates of AB, with lower AB being associated with more depressive symptoms (Kim and Mueller, 2001; Lehrer et al., 2017; Moroń, 2020; Toussaint et al., 2014) and higher anxiety (Hassett et al., 2016; Toussaint et al., 2014). Some studies found that higher AB was linked to reduced stress (Leavy et al., 2023; Lehrer et al., 2017), though others found no correlation (Pierce et al., 2018; Ruthig et al., 2014). Although the link between mental health and AB is rather unambiguous, which would make sense since AB is often conceptualised as the hedonic component of wellbeing in humans, a clear link between AB and physical health is a little less clear-cut. AB has been found to be positively correlated to daily physical health (Kim and Mueller, 2001; Sibille et al., 2012; Yoon et al., 2022), physical functioning (Quinn et al., 2021), and some forms of pain tolerance (Sibille et al., 2012), and negatively correlated to reported pain severity (Hassett et al., 2016; Toussaint et al., 2014). Moreover, high AB in older adults seems associated with improved memory performance, balance, and strength (Quinn et al., 2021). To complement this, a British cohort study found that smoking was associated with lower AB, and daily consumption of fruits and vegetables (yes instead of no) and exercise (≥1.5h/wk) were associated with higher AB (Nabi et al., 2008). Nevertheless, Leavy et al. (2023) reported no significant association between AB and cardiovascular health, whereas Nabi et al. (2008) found that only individuals with the highest AB scores had a numerically lower risk of coronary heart disease (but this was not statistically significant). Finally, blood cholesterol, diabetes, alcohol consumption, and hypertension were not found to be significantly related to AB (Nabi et al., 2008).

External factors. In the strive towards happier societies, external, or environmental, factors are often studied for their possible links to well-being constructs such as AB. Although some links have been identified, many non-significant effects were also found, illustrating the complexity of the (dynamic) interaction between external and internal (e.g. personality) factors on human wellbeing. Past studies for instance, showed that although family routine and maternal depression were not correlated with child AB, household chaos was negatively correlated with AB in children (Lo et al., 2021). The working environment matters to adult AB: high job strain decreases AB (Nabi et al., 2008) and job characteristics like task variety, autonomy, and significance seem to indirectly relate to increased AB via

their impact on the affective state of flow (Daniels, 2000; Fullagar and Kelloway, 2009). Access to green spaces within 100-1000 meters range has been linked to higher AB, especially in urban environments (Tsurumi et al., 2018). Cultural factors sometimes also correlate with AB, for example individualistic cultures seem to have higher levels of AB compared with collectivistic cultures (Basabe et al., 2002). In the domain of social relationships, social support was sometimes positively correlated to AB (Daniels, 2000; Matud et al., 2023; Zhu, 2015), and positive social relationships were consistently positively correlated to AB (Ryff, 1989; Sanjuán, 2011; Shrira et al., 2016).

Intrinsic factors. In contrast to external factors, the link between AB and internal, intrinsic constituents is somewhat less ambiguous, with relatively consistent findings in the realms of personality. Relationships between AB and three of the big 5 personality traits, namely positive correlation with agreeableness and conscientiousness and negative correlation with neuroticism, have been reported (Shrira et al., 2016; Sirois and Hirsch, 2015). In addition, higher emotional intelligence (Kong et al., 2015; Liu et al., 2013; Moroń, 2020; Veilleux et al., 2020), resilience (Lehrer et al., 2017; Liu et al., 2013; Yildirim, 2019), self-esteem (Matud et al., 2023; Shrira et al., 2016), optimism (Diener et al., 2010; Rego et al., 2012; Shrira et al., 2016), and forgiveness (Zhu, 2015) also seem positively correlated with AB, while links to coping strategy are more ambiguous (Sibille et al., 2012). Conversely, the link between AB and age is unclear, with some studies supporting higher AB at certain ages (e.g. 55-64 years: Nabi et al., 2008) and others reporting no relationship (Moroń, 2020; Prasetio et al., 2023; Rego et al., 2012), which may be linked to the different life factors that are being corrected for in these studies (Kratz and Brüderl, 2025). Finally, a British cohort study found that men (versus women) reported higher AB (Nabi et al., 2008).

Overall, these correlates across a range of domains give us confidence that AB is a relevant state to translate to other species in the context of animal welfare understanding and assessment.

3.2 Affect balance methods used in humans and their key principles

A table of methods extracted from the studies identified for the present article is available as Supplementary Material 1. In humans, AB is typically assessed by scoring PA and NA separately and then integrating these scores, yet the methods used to measure PA and NA and to combine them vary between studies. Variation occurs across several parameters: the technique used to score affect (questionnaire, sampling, proxy or behavioural observation), which has to do with whether affect is scored in real time or based on recall and whether participants are capable of self-report; the discrete types (e.g. sadness, contentment, guilt) and number of affects scored; the scales used for scoring each of these affects; the time period under consideration (e.g. one day, one month, one year); and how the PA and NA scores are integrated (e.g. subtraction or ratio).

Techniques for scoring PA and NA. Affect is most often scored via self-reports, typically via questionnaires, which estimate the frequency (or proportion of time) spent experiencing specific, discrete positive and negative states. It is often assessed retrospectively, asking participants to recall affective experiences over a past period, commonly by answering questions along the lines of: 'how often have you experienced state X in the past week'. Retrospective assessment of affect is susceptible to memory and current-mood biases (Csikszentmihalyi and Larson, 2014; Robinson and Clore, 2002; Veilleux et al., 2020). For example, people asked how often they felt disappointed in the past two weeks may not remember each instance of minor disappointment, especially when in a good mood while being asked. These biases can be minimised by real-time reporting techniques using (signal contingent)

experience sampling (**ESM**) (also referred to as ecological momentary assessment), which prompt participants via mobile devices to report their current affect, typically daily or several times per day (e.g. seven times per day: Fullagar and Kelloway, 2009). However, this advantage of real-time reporting is counterbalanced by the time-consuming and intrusive nature of ESM, requiring more effort and time from participants. Participants may refuse to report their state at inconvenient moments, though typically only a limited number of refusals per day is permitted. Consequently, the experimental design will need to balance the number of data points per day and the total study duration with participant willingness, possibilities of missing data points or fallouts, as well as the need for (monetary) compensation. Although self-reports are most common, some studies use proxy reports by individuals who know the focus person well. This is typically the case where children, elderly people, or patients with dementia are involved, or when interactions between people are of interest (e.g. newlyweds: Gottman, 1998). For instance, in a study by Lawton et al. (1996), trained research assistants were asked to estimate the proportion of time they observed the same six affects over the preceding 4 weeks in Alzheimer patients. An alternative method to assess AB in individuals less capable of self-reports is the use of behavioural observations. For instance, Lo et al. (2021) classified successive time intervals as PA or NA based on facial expressions, vocal tone, and verbal content to assess AB in 5-year-old children.

Number and types of affect and scales. The specific types of affect included for PA and NA vary, likely reflecting the different contexts in which the methods are applied. For example, studies on depression often focus on affect types relevant to depressive symptoms (e.g. Garamoni et al., 1991), such as sadness or despair, studies on dementia select affect types that reflect typical symptoms of the disease, such as confusion or anger (e.g. Lawton et al., 1996), while studies on subjective well-being include PA types such as contented, joyful and happy (e.g. Yildirim, 2019). Studies on AB of employees, in turn, use different affect types relevant in a workplace context, such as comfortable, at ease, tense and worried (Rego et al., 2012).

Methods to assess AB have been subject to critique regarding the definition, interpretation and choice of affect types (e.g. Diener et al., 2010). In many cases, affect types are not explicitly defined, leaving participants to interpret terms, which may increase individual variation. Questions included in self-reports have, moreover, sometimes been criticised for their wording (Kim and Mueller, 2001). For instance, the question "During the past few weeks, did you ever feel on top of the world?" in the Affect Balance Scale (ABS; Bradburn, 1969) may be interpreted as extreme or indicative of a mental disorder, e.g. feeling euphoric, rather than as a reflection of PA by some of the participants (Perkinson et al., 1994). Interestingly, some of the terms classified as PA could arguably be considered neutral, rather than positive, for example 'alert' which appears in the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988) and some ESM studies (Fullagar and Kelloway, 2009). Another potential problem is that arousal, an inherent dimension of affect, may not always be evenly represented across NA and PA. For example, PANAS seems slightly more focused on high arousal affect (Shrira et al., 2016), while other methods cover both high and low arousal affect (e.g. Fredrickson and Losada., 2005; Rego et al., 2012).

Apart from the specific types used, also the number of affect types used in AB research in humans varies from 1 (e.g. Basabe et al., 2002; Kolanowski et al., 2014) to 20 or more (e.g. Garamoni et al., 1991) within each of the two valence categories. The total number of affect types used may differ based on context: e.g. whether a specific set of symptomatic affect is in focus (as in depression and anxiety disorder; e.g. Lawton et al., 1996), or the life satisfaction (cognitive component of subjective well-being) of a non-clinical population is investigated, which potentially calls for a wider range of items (e.g. Kong

et al., 2015). Most studies employ equal numbers of PA and NA terms, but some also use different numbers, often with more NA than PA items. This is common when AB is applied to assess poor mental well-being, such as depression, as in the Centre for Epidemiologic Studies-Depression (CES-D) questionnaire (4 PA terms versus 7 or 16 NA terms (Radloff, 1977; Shrira et al., 2011). However, an imbalance between numbers of PA and NA types of affect is also found in some studies of well-being (7/8: Pierce et al., 2018; 3/6: Tsurumi et al., 2018; 2/4: Moroń, 2020). Finally, although a set number of types may be scored during data collection, some studies remove terms after analysis. For example, Rego et al. (2012) initially scored 9 PA and 9 NA items, but following a principal component analysis (PCA), 3 items (depressed, tense, calm) were removed on the basis of cross-loading (high loadings on multiple principal components), leaving 8 PA items and 7 NA items for the final calculation of AB.

In many methods for assessing AB, each affect type is scored on a scale. Two commonly used scales are a 5-point Likert scale ranging from 'never or very rarely' experienced to 'always or very often' experienced (e.g. Diener et al., 2010; Watson et al., 1988), and a binary scale indicating whether the affect type was experienced within the given period ('yes' or 'no') (Bradburn, 1969). The sum of the scores on all PA terms is then computed and compared to the same sum for NA terms. With the Likert scale, the categories are usually assigned the values 1 to 5, whereas in the binary case, the occurrence is equated with a value of 1 (versus 0 for no occurrence).

Time period under consideration. AB studies also differ in the timescales used, i.e., the period over which AB is computed. Certain studies investigated short timescales, asking participants to rate how they feel in the current moment on a number of affect types (e.g. Meeks et al., 2012; Sirois and Hirsch, 2015), or scoring video observations of behaviour over periods of 30 seconds (Lo et al., 2021) or 20 minutes (Kolanowski et al., 2014). At the other extreme, some studies asked participants to rate how they 'generally' or 'always' feel (e.g. Liu et al., 2013, note that PA and NA are still estimated separately), or how they have felt in the past year (e.g. Sanjuán, 2011; Watson et al., 1988). Between these two extremes, reported timescales vary from one day to 15 weeks (Fullagar and Kelloway, 2009). In some cases, participants are asked to rate their affect in anticipation of a specific recurrent event in their life (Fong and Tiedens, 2002). The time period under consideration will differ between contexts and depend on the specific research aims.

Integration of PA and NA. The way in which PA and NA scores are integrated also varies across AB studies. In the past, a common method was to subtract the NA score from the PA score, sometimes with the addition of a constant (PA-NA+c; e.g. Sirois and Hirsch, 2015). In contrast, some studies focusing on depression subtracted the PA score from the NA score (NA-PA; e.g. Bordas and Fruchart, 2023; Radloff, 1977). Alternative approaches divide PA by NA (PA/NA; e.g. Rego et al., 2012),or divide PA by the sum of PA and NA scores (PA/[PA+NA]; e.g. Garamoni et al., 1991). Other studies have moved away from solely using AB calculations, criticising them as too reductive, since participants with both high PA and NA scores would receive similar AB scores to those with low PA and NA, while these might in fact represent different AB profiles (e.g. Kim and Mueller, 2001). Instead, some of these latter studies created four categories of participants, typically: High PA + low NA (labelled "healthy"); High PA + high NA (labelled "reactive"); Low PA + low NA (labelled "low"); Low PA + high NA (labelled "depressive") (Hassett et al., 2008; Sibille et al., 2012; Toussaint et al., 2014). This categorisation requires cut-off points derived from the observed sample of participants, e.g. population means (Hassett et al., 2008).

Due to the variation in AB methods used in humans, any attempt to translate these methods to other species requires first extracting the underlying principles that characterise the methods. These

underlying principles should be covered by a majority of AB studies and together encompass the essence of the methodology, that is: why such methods are thought to assess the target, i.e. affective/hedonic well-being of an individual. We extracted four underlying principles, presented in Table 1, and include a general explanation of the principles as well as key points of interest per principle, when thinking of translating the AB methodology to non-human species. The first three principles relate to estimating the frequencies/proportion of time of PA and NA over a period, hence relate more to the assessment of affect than AB, while the fourth and final principle concerns the integration of PA and NA into an AB score or category.

Most human studies on AB rely on established psychological instruments rather than explicitly testing the validity of AB as an independent construct. In these studies, AB is typically derived from validated measures of PA and NA, most commonly the PANAS (Watson et al. (1988) or Scale of Positive and Negative Experience (SPANE; Diener et al., 2010), while earlier instruments such as the ABS (Bradburn, 1969) are primarily referenced for their theoretical or historical relevance. Consequently, the validity of AB is generally assumed on the basis of prior validation of the underlying scales or inferred indirectly through correlations with related constructs, including life satisfaction, subjective well-being, depression, and stress. Some studies have investigated the link between these AB questionnaire methods and daily emotional experience (using ESM), demonstrating a clear correlation between the two (e.g. Veilleux et al., 2020).

Table 1. Key underlying principles derived from (the majority of) human affect balance methods identified during the literature search. PA=positive affect; NA = negative affect; ESM = experience sampling method.

Name given to the Principle	Core Idea/Explanation	Key Points for translation to non-human species
Direct access principle	Focus directly on the discrete type (e.g. joy) and valence of affect rather than indirect indicators of affect (e.g. facial expressions)	- Humans can generally self-report how they feel, giving more or less direct access to the specific type of affect, without having to use indirect indicators from the realms of behaviour, cognition or physiology.
Equal valence principle	Estimate frequencies of PA and NA separately but (in general) symmetrically	- Commonly, an equal number of types and similar scales are used for both PA and NA, which does not imply that they both impact human hedonic well-being equally but may imply that the intensities of these two valences can be assessed using similar scales and are hence comparable.
Frequency dominance principle	Assessment of PA and NA focuses on estimating the 'frequency' of PA and NA in a given period	- Participants are typically asked about 'how often' they experienced a specific affect, or affective events are counted (ESM), meaning that assessment focuses on affect 'frequency' in a given period of interest. - Duration and (valence) intensity of affect may be indirectly recorded if these are correlated with frequency, i.e. a longer or more intense affect may lead to it being reported as 'more often' experienced or recorded more often using ESM. More intense affects may also bias memory leading to participants recalling a particular affect type as experienced more often.

Proportion of occurrences principle	Integration of PA and NA into an affect balance estimates the proportion of occurrences one experiences PA versus NA in a given period	- The integration of PA and NA into an affect balance score or category seems to reflect the proportion of occurrences experiencing PA across a given period. - Proportion of occurrences of PA versus NA may integrate frequency, duration and intensity of PA versus NA. - Some studies also consider the separate frequencies of PA and NA, by creating categories of AB: People with a similar PA/NA ratio but different (low versus high) PA and NA frequencies will, in this way, be studied separately.

4. Reflection on the application of the key underlying principles of the human affect balance methodology to other species

We propose the following definition of AB for use by animal scientists (based on the human literature): "*Affect balance is an individual's presumed/inferred overall affective experience, construed as the integration of the frequency of positively and negatively valenced states over a period of interest".* This definition allows the investigation of AB in animals across various time frames, from a few hours to an entire lifetime. While this does not specify how AB relates to animal welfare, as discussed in the Introduction, some definitions of animal welfare align closely with this AB definition, particularly those that define animal welfare in terms of an animal's affective experience and as the balance and accumulation of PA and NA over time. The four underlying principles of methods used to assess AB in humans, as described in Table 1, provide a framework for considering how the AB methodology might be translated to other sentient species. This section outlines whether and how these four principles can be applied to animals, whether assessment methods following these principles already exist, and which theoretical questions need to be considered to develop and eventually validate a method to assess AB for animals.

4.1 Direct access principle

The direct access principle implies that the specific types of affect that feed into the AB can be directly assessed, given that human participants are often capable of self-reporting how they feel. In non-human animals, however, direct self-report of affect is currently not possible with existing methods, and we must rely on indirect behavioural, cognitive or physiological indicators.

Proxy-report methods based on qualitative assessment of affect have been put forward in animal welfare science. A widely used example is the Qualitative Behavioural Assessment (QBA), developed to assess an animal's current affective state, based on the assumption that trained human observers can interpret an animal's affective state by intuitively integrating perceived signs and signals (Wemelsfelder et al., 2001). This approach uses qualitative descriptors of affects, e.g. positively occupied, anxious, calm, which may be either predetermined or generated by observers through 'Free Choice Profiling', to characterise both PA and NA (Wemelsfelder et al., 2001). Each descriptor is scored on a scale from 'minimum' to 'maximum', and multivariate methods integrate the different descriptors to produce an overall QBA score. Although QBA is mostly used to assess momentary affect, some other qualitative

methods consider longer periods. For instance, King and Landau's (2003) four-item questionnaire developed for primates asks raters to estimate how often each animal is happy, how satisfying each animal finds its social experiences, how successful the animal is at achieving its goals, and to imagine how happy they would be if they were that animal for a week. Qualitative methods have been criticised for their subjectivity, with risks of observer bias and potential influences and biases resulting from the visible environment in which animals are kept, on the observer's perception of affect (Tuyttens et al., 2014), but in the AB context similar biases may be expected in studies on humans.

Alternatively, PA and NA in animals may be inferred indirectly from behavioural, cognitive or physiological indicators of short-term, event-based affect (e.g. Boissy et al., 2007; Kremer et al., 2020). While some indicators may be thought to reflect discrete affect trypes, they are more often mapped on a two-dimensional scale of valence and arousal (e.g. Mendl et al., 2010). Assessment of affect valence without specification of affect type seems, however, sufficient for AB, given that in human AB research different discrete types of PA and NA are simply summed. Yet even this seemingly simpler task of assessing affect valence alone requires rigorous validation (Neville et al., 2020; Nielsen et al., In press), and to date we still lack an exhaustive (and potentially utopic) list of validated indicators for PA and NA that unambiguously reflect affect valence in any species. This is further limited by a discrepancy in the level of research between species, where for example species with higher levels of brain organization (e.g. mammals) have been studied more extensively than other species (Kremer et al., 2020). Indirect indicators of affect valence, moreover, come with several practical limitations. First, some animals, particularly prey species, may conceal how they feel, making behavioural signals difficult to detect (Banchi et al., 2020; Carbone, 2020; Orth et al., 2020; Steagall et al., 2021; Turner et al., 2019). Second, indicators of PA have been less well studied in the past than indicators of NA (Babington et al., 2024; Lawrence et al., 2019; Turner, 2019; Yeates and Main, 2008). Third, indicators of low arousal affective states are scarce; because low arousal is often associated with inactivity, distinguishing between positive and negative valence based on behavioural observations is challenging (Fureix and Meagher, 2015). Moreover, low and high arousal states may differ in terms of their impact on the long-term cumulation of affect, with low arousal states potentially reflecting outcomes of behaviour and having more impact on this cumulation (Scheven and Gygax, 2025). Fourth, some indicators are invasive or intrusive, and repeated sampling may itself alter the animal's affective state. Fifth, both behavioural and physiological indicators may be affected by natural fluctuations such as circadian rhythms or hormonal cycles, making the timing of sampling critical (Aragona et al., 2024; Bosa et al., 2025; Mârza et al., 2024). These limitations highlight the importance of carefully selecting indicators of affect. For a method to validly assess AB in animals, indicators should ideally be easy to identify, non-intrusive, repeatedly or continuously monitored, reflecting short–term affect, while also capturing the full range of both PA and NA across high- and low-arousal states. In the absence of validated indicators, mainly for PA and particularly low arousal PA, it has been advocated to collect a smart combination of credible indicators with emerging validation or integrative indicators (Kremer et al., 2020). Practical examples of this are provided in Fig.1.

4.2 Equal valence principle

The equal valence principle of AB highlights the need to assess PA and NA in an equivalent manner, meaning that there is no bias towards recording one affect valence more than the other. In human studies, this principle is typically met by estimating PA and NA frequencies separately but symmetrically. This symmetry is achieved by using an equal (or similar) number of affect types for PA and NA, and

applying comparable scales to both. Proxy-report (qualitative) methods like QBA or alike could, in principle, list a similar number of PA and NA types. Current welfare assessment tools focus predominantly on NA. For example, assessment protocols for primates, which assess PA and NA separately, tend to include more NA types than PA ones (Prescott et al., 2023; Robinson et al., 2016; Whitham and Wielebnowski, 2009). The same holds for other welfare assessment protocols, such as Welfare Quality®, AWIN (Animal Welfare Indicators) or AssureWel projects, which also include substantially more NA-related indicators than PA-related ones. This principle is important in captive species also, despite these species theoretically experiencing a broader range of NA types, because it is important that we are able to determine whether and how much NA outweighs PA.

When using behavioural, cognitive or physiological indicators of affect as potential inputs for AB assessment, we face not only the inherent limitations of these indicators (listed under the 'direct access principle'), but also the challenge that validated indicators of PA are still lacking, likely due to these being harder to detect than NA indicators, but also due to the comparatively smaller number of studies on PA than NA to date. Another methodological issue concerns the heterogeneity of affective indicators, ranging from vocalisations and facial expressions to oxytocin and heart rate variability (Babington et al., 2024; Kremer et al., 2020). These differ substantially in the temporal window of experiences they represent, i.e., how they relate to affective experiences over time. While some indicators might reflect the animal's current and momentary affective state, others may reflect a past state, as is the case with stereotypies (e.g. Mason and Latham, 2004) or some physiological variables that show delayed responses (e.g. oxytocin, Rault et al., 2017), or an integration of states over longer periods of time. Moreover, affective indicators vary in whether they are always present (e.g. facial expressions are continuously observable, whereas vocalisations are intermittent). This raises methodological challenges regarding how such heterogeneous indicators can be combined as inputs to AB, as they do not have the same scales. Here we imagine two approaches will support the integration of different indicators. First, we might need to force the selected indicators into similar scales, with e.g. 1 reflecting the bottom of the distribution and 5 reflecting the top end of the distribution, with equidistant steps across the full range. This would make indicators with different ranges and units more comparable. Even when using a single category of indicators, e.g. only vocalisations, there is an implicit assumption that indicators within that category reflect PA and NA to the same degree or rate, an assumption that may not hold (e.g. PA may lead to fewer vocalisations than NA). Moreover, some indicators may only reflect NA or only PA, without an equivalent for the opposite valence, which further complicates symmetrical assessment. Second, we could consider using specific and short time windows for which we decide which of PA or NA is dominant and combine time windows instead of indicator ratings. This helps when indicators overlap in terms of which affect they reflect, and to avoid over-counting a specific valence. These two approaches are illustrated in Fig.1.

4.3 Frequency dominance principle

The frequency dominance principle emphasises that, in human AB methods, generally the frequency of affective events is estimated without considering other affect characteristics such as duration or valence intensity. Our assumption is that frequency partially reflects duration, because longer-lasting affect is more likely to be recorded as more often experienced. The link between frequency and intensity of affect is less clear. However, as mentioned above, AB questionnaire methods correlate with daily emotional experience as estimated using ESM. This may also hold for retrospective assessments, where individuals

reporting how often they experienced a certain affect type in a past period may give more weight to events that were longer or more intense, possibly via memory biases including the peak-end process, i.e. people judge an experience based on how they felt during the peak and end of the experience (Varey and Kahneman, 1992). In animals, we may need to take into account duration and intensity because we rely on indirect indicators of affect.

Another concern is that of sampling frequency. While certain indicators may, in theory, be measured continuously, e.g. those recorded using technology such as accelerometers, cameras, or microphones, others may need to be sampled manually and less frequently. But how frequent is frequent enough to accurately reflect an estimation of the overall frequency of PA and NA? Other behavioural tests may also be sensitive to measurement bias. If we select the sampling moments poorly, we may again bias our sampling towards either PA (e.g. facial expressions at the always-rewarded feeder) or NA (e.g. facial expressions following painful procedures). The validity of various sampling frequencies would need to be determined for each indicator of affect, species, and context, which would be laborious work. And although in humans the ESM is typically sampled approximately seven times per day, people can always report how they currently feel. In contrast, there may be many sampling moments when we are unable to conclude which valence an animal feels, meaning we may need a much larger number of sampling moments in animals to account for these missing data (Cartoni Mancinelli et al., 2023).

In Fig.1, we present two possible methods for illustrative purposes, which differ in how they capture PA and NA frequency in animals. Method A makes use of continuous recording technology (e.g. microphones), to monitor and count a single indicator of affect that ranges across PA and NA, i.e., vocalisations in pigs (Briefer et al., 2022). This method makes the assumption that pig vocalisations equally reflect all PA and NA events, which may not be the case, e.g. low arousal PA may be under-represented by vocalisations. Method B instead samples random time windows within a period of time (5 min per hour of diurnal period) which are in turn classified as dominated by PA or NA based on multiple behavioural indicators of affect, e.g. vocalisations (PA and NA), tail posture (PA and NA), and play (PA only). This second method circumvents issues with single indicators being biased towards a certain valence and the problem of ensuring that every affective event is recorded. However, for every 5-min time window, PA and NA may have to be weighed against each other when indicators are pointing to multiple valences. With both methods, indicators that provide continuous estimates of affect (here we mean indicators that can always be recorded as they are always 'present', not continuous recording via technology), such as heart rate variability, will require pre-determined (potential individual) thresholds to distinguish between PA and NA.

4.4 Proportion of occurrences principle

The proportion of occurrences principle reflects the target state that the AB score is thought to assess, namely: how often an individual experienced PA versus NA over a given period of time, hence how the frequency of PA compares to the frequency of NA. For this integration of PA and NA, as in humans, simple ratios (PA/NA or PA/[PA+NA]) or subtractions (PA-NA) could be calculated, or categories could be created (Yoon et al. (2022). Hence AB could theoretically relatively easily be computed in animals if we have reliable indicators of the valence (and potentially intensity and duration) of affect.

As with some of the more recent human studies, the integration of PA and NA via calculation could be avoided, and instead, these two dimensions could also be considered separately. This is what is done in

the Welfare Footprint Framework (WFF; Schuck-Paim et al., 2025). WFF aims to assess animal welfare based on notation systems feeding into calculations of cumulative pain (i.e., NA) and pleasure (i.e., PA) for the affected individual and the 'average' population member. Affective experiences are suggested to be evaluated by human experts using evidence from multiple research domains (ethology, pharmacology, physiology). In general, the framework provides a very structured and systematic approach, and tools for integrating different states (four positive and four negative), but of course the usefulness depends heavily on valid indicators leading to informed expert judgements[1]. The 'proportion of occurrences principle' is taken into account by dividing time into windows during which an animal (or a group) is supposed to be in a constant state and evaluating this state (or the dominant state). Then the proportion of time spent in one state is reported. The creators of the WFF acknowledge that an integration of PA and NA may be relevant and that integration is hindered by the challenges to establish equivalence between PA and NA. Each state must be objectively emphasised from multiple behavioural/physiological indicators, and the intensity of the state is documented.

Conversely, the integration of PA and NA may lead to the consideration of trade-offs that may breach important aspects of welfare, suggesting that PA can somewhat compensate for NA. It was not within the scope of the present study to further dive into human studies that only consider estimates of PA and NA frequency separately and forfeit any form of integration.

5. Discussion and conclusion

In the present study, we: 1) explained human AB and briefly touched upon its correlates; 2) examined existing methods to assess AB and extracted four underlying principles that we feel capture the essence of this methodology; and 3) evaluated the potential of this methodology for application in other species via these underlying principles. In summary, we find the AB methodology to be of interest for other species, but many practical limitations currently curb the application of this methodology to animals. The main limitation is likely our need for validated indicators of momentary PA and NA that can be repeatedly collected across time. Having said that, we must remember that AB scores in humans are based solely on estimates, sometimes computed over very short periods, and susceptible to various biases when based on recall. It is conceivable that in animals we may also rely on incomplete and imperfect assessments of PA and NA frequencies, as long as we can demonstrate that these correlate well with other cumulative affect measures.

As in humans, AB has the potential to offer an effective measure for the affective/hedonic component of animal welfare for several reasons. AB provides a more comprehensive understanding of an animal's welfare than many traditional methods, by considering both PA and NA (Cooper and Wemelsfelder, 2020) as opposed to only NA (see methods such as the Cumulative Pain Framework proposed by Alonso and Schuck-Paim, 2022, and the Lifetime Stress Score proposed by Polanco, 2021): AB shifts hence the focus from merely avoiding NA (e.g. distress) to also promoting PA (e.g. comfort), which is crucial for assessing and improving animal welfare (Watters et al., 2021; Webber et al., 2022). AB can moreover theoretically be adapted to different species, allowing for a broad application in welfare assessments.

As mentioned above, for any indicator or proxy measure, it is crucial that it is valid (Browning, 2023; Mason and Mendl, 1993; Nielsen et al., In press). Würbel (2017) describes three types of validity (termed the '3Vs'): construct validity, internal validity, and external validity. Internal validity assesses

[1] see suggested application here: https://www.nature.com/articles/s41598-025-04272-1#ref-CR5

whether the research has been conducted with sufficient scientific rigour to allow accurate and unbiased interpretation of results (e.g. use of control groups, randomisation, appropriate statistical analyses). External validity assesses whether the research has been set up for extrapolation or generalisation of results to populations outside the study population. Both of these types of validity do not offer any special challenges for research into AB, but should be carefully considered by researchers when designing and implementing studies. The type most associated with common usage of the term 'validity' is construct validity, which refers to whether or not the indicator is actually measuring the target state as opposed to something else. Here, an indicator will be valid when it reliably correlates with the target state (even under interventions); this will occur when it stands in a causal relationship with the target (either a cause of, an effect of, or an effect of a common cause) (Bollen and Lennox, 1991). Validation will then proceed by testing for one of these causal relationships. Methods to assess AB may present a special problem for construct validation. In the first instance, the indicators for PA and NA must themselves be validated to ensure they are representing the affects they claim to do (as well as their frequency, intensity, and/or duration, as applicable), which is something that will still require much research effort. However, this is not enough, as we must also ensure that the assessment method:

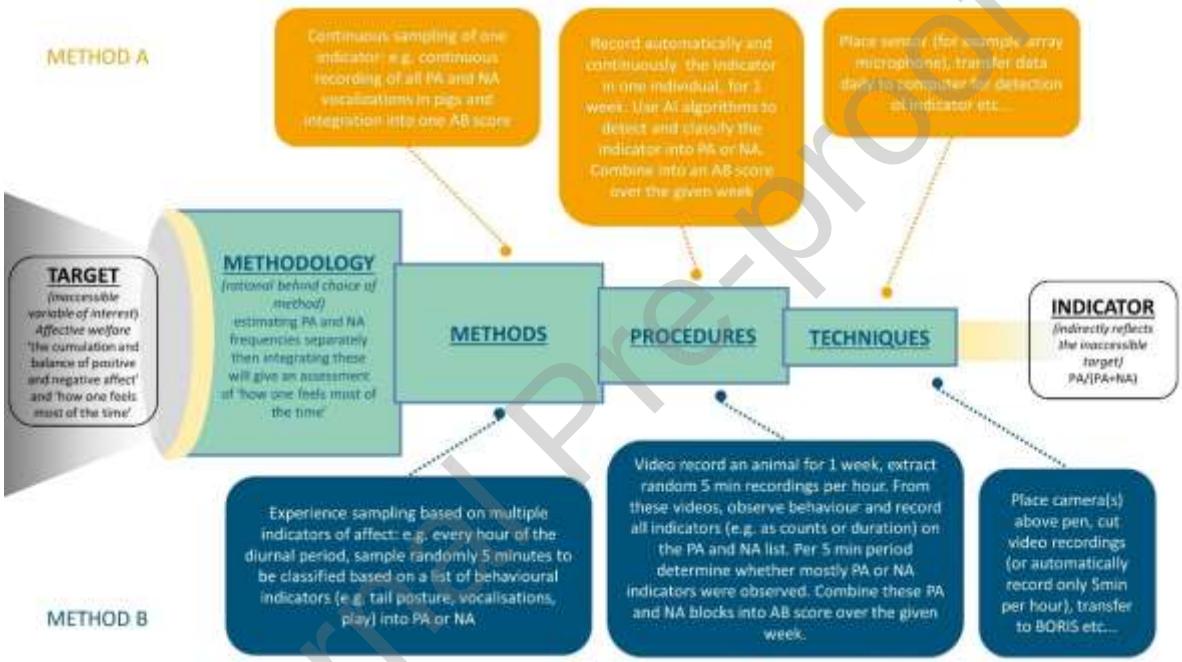
1. Equally assesses PA and NA without bias towards one valence (equal valence principle)
2. Is a good estimate of overall PA and NA, e.g. sampling frequency must be validated
3. Integrates PA and NA in a manner that captures an estimate of the proportion of occurrences of PA (proportion of occurrences principle)

A promising group of behavioural indicators for highly vocal species such as rats and pigs, are affect-driven vocalisations which have received much research attention (see a proposed method to assess AB based on vocalisations in Fig.1) (e.g. Briefer et al., 2022). Several approaches for validating the overall AB measure are envisaged. The AB scores could be assessed for correlation with other potential measures of cumulative affect (criterion validity), for example those reflecting biological aging and cumulative stress such as telomere length (Bateson, 2016) or brain plasticity assessed via hippocampal volume/neurogenesis (Poirier et al., 2019), or judgment bias (Mendl et al., 2009) and WFF. One advantage of the AB method relative to biomarkers of cumulative affect is that they may open a window into the affective experiences of an animal throughout time, i.e., greater temporal granularity. This may allow for use of this method to identify welfare issues in a timely fashion. Use of these alternative indicators for validation of AB relies on the assumption that they are themselves valid and accurate measures of the same underlying psychological/affective state that AB methods are attempting to measure; an assumption that may of course be faulty. Use of multiple correlations, across independent methodologies, could help raise confidence in the results if stable correlations are found. Other validation methods involve manipulating the inputs to alter an animal's AB, and looking to see whether the AB measure responds appropriately. This relies on background assumptions about which inputs will impact AB, but these can also be tested against one another (Browning, 2023).

To conclude, the theory behind the AB methodology used in humans to assess hedonic/affective well-being is inspiring to animal welfare scientists and can be translated to other species, but this translation will lead to a number of important theoretical and practical considerations in the development and validation of potential assessment methods. These will have to rely on the availability of reliable indicators of PA and NA, which themselves have to be well validated. The validation of both indicators of PA and NA, and AB should be done using multiple pathways, due to our lack of a gold standard. Finally, it is important to highlight once more that AB, as in humans, is likely to reflect only the hedonic/affective

component of animal welfare, while other components of welfare, e.g. the development of competences (Rault et al., 2025) would require alternative assessment methods.

Figure 1 - Illustration of two possible methods to assess affect balance (A and B) in non-human animals. Here we use pigs as a case species because affect-driven vocalisations and other behavioural indicators have been well described in this species (Briefer et al., 2022; Reimert et al., 2023). Method A focuses on one category of indicator, here vocalisations, to continuously and automatically compute the end score. The assumption is that we have the required technology to record the vocalisations of individual pigs (e.g. using acoustic cameras). Method B describes an experience sampling method that randomly selects windows of 5 minutes, which based on multiple behavioural indicators are classified as either positive affect (PA) or negative affect (NA). The aim of this figure is to provide concrete examples of how affect balance could be theoretically assessed in non-human animals with existing behavioural indicators of positive and negative affect. Based on Andiappan and Wan, 2020; Keeling et al., submitted.



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Caption supplementary materials

Table S1A. Overview of human literature on affect balance (AB) identified through a narrative review. The table summarizes information on the included studies (column 1-7, green), the methods to assess affect balance (column 8-18, blue), the internal validation of these methods and/or their subscales (column 19 & 20, yellow), and the analysed correlates of affect balance (column 21-26, orange). The final column (27) provides comments from the authors of the present paper that are relevant for

interpreting the presented information. Both experimental/observational studies and meta-analyses are included. Consequently, some of the original studies may also be presented in the meta-analyses. Additionally, multiple observational studies may have made use of participants from the same study cohort.

Table S1B. Descriptions of columns from Table S1A.

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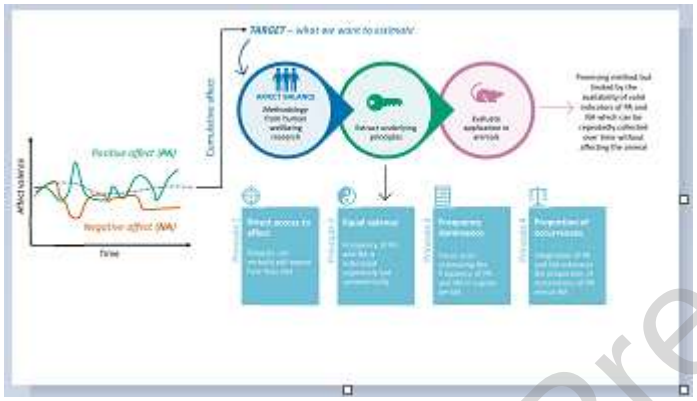

Highlights

- Affect balance may be a promising methodology to assess animal hedonic welfare
- Human methods to assess affect balance vary depending on study population
- Four underlying principles were extracted from this diversity in methods
- Affect balance is promising as an indicator of cumulative affect in animals
- Application to animals is limited by the need for valid indicators of animal affect