

Scientific Appraisal and Retrospective

Dirk Aue (1988): Confrontations between male tree shrews (*Tupaia belangeri*): consequences of social contacts for behaviour and physiology, and the influence of individual and external factors on dominance decisions

Doctoral thesis (in German), Georg-August-Universität Göttingen (oral examination 28 October 1988). E-book: Cuvillier Verlag, Göttingen 2026 (CC BY 4.0), 199 pages.

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Abstract

In 1988, Dirk Aue submitted a doctoral thesis on dyadic confrontations between male northern tree shrews (*Tupaia belangeri*), a territorial, primate-related mammal established as a model of psychosocial stress. Fifteen adult males were confronted in 31 encounters of three types (neutral, home and border confrontations) while behaviour, body weight, food and water intake, morning urine chemistry, telemetric EEG and nocturnal respiratory water loss were recorded against an individual baseline. A stable dominance relationship formed in 30 of 31 encounters. Subordinates lost weight, reduced food and water intake, stopped marking, showed less light sleep with more quiet wakefulness at night, and lost more respiratory water, whereas dominants also showed measurable costs, including increased urinary excretion of glucose, urea and N-acetyl-beta-D-glucosaminidase (NAG). Most changes reversed after separation. Baseline behaviour and urinary measures were reported to predict the outcome in a situation-dependent way, and residence in the home cage predicted dominance in all ten home confrontations.

This appraisal places the work in the state of knowledge of 1988 and compares it with 2026 standards. It judges the thesis a pioneering, original multi-level descriptive study with lasting heuristic value, particularly regarding the costs of dominance, stress-related sleep disruption and urinary markers of renal and metabolic strain. By current standards, small samples, repeated use of animals, uncorrected multiple testing and the lack of validation of the prediction rules limit the evidential weight of the individual findings, which are best treated as testable hypotheses. Recommendations for a preregistered, adequately powered replication with telemetry, hormonal and renal biomarker panels are given.

Keywords: social stress; dominance; tree shrew; *Tupaia belangeri*; animal model; prediction of social outcome; sleep; EEG; urinary biomarkers; NAG; renal function; homeostasis; resilience; replication; retrospective appraisal

Basis and limits of this appraisal. Examined in detail were the introduction, animals and methods, statistics, the discussions of urinary parameters, sleep and respiratory water loss, the conclusions and the summary. The chapters on body weight, behaviour and food intake were covered mainly through the results sections and the summary; figures, appendix tables and the reference list were not examined individually. The comparison with the state of research in 2026 rests on my training knowledge (up to about mid-2026) without a new literature search. The references named are compiled from memory. This is an expert opinion, not a formal peer review.

1. Summary assessment

The thesis is a careful, broadly designed basic study that considers behaviour, urinary physiology, nutrition, sleep and water balance of tree shrews together in standardised dyadic confrontations. This multi-level approach was unusual for 1988. It relies mostly on non-invasive methods, that is, methods that are again particularly valued today with regard to animal welfare and data quality.

Lasting strengths: (1) the first quantitative behavioural analysis of dominant and subordinate animals in the confrontation model; (2) the finding that dominant animals also bear measurable physiological costs (consistent with later literature showing that dominance does not automatically mean lower stress); (3) the prospective approach of collecting baseline data before the confrontation and comparing them with the outcome later; (4) the demonstration of sleep loss and nocturnal hyperarousal in subordinates, apparently one of the earliest such demonstrations in a mammal; (5) urine as a non-invasive window on the internal milieu, including the observation of altered NAG, glucose and urea excretion in dominants.

Main limitations from today's perspective: very small samples (15 animals, 31 confrontations; EEG n = 4; respiratory water n = 6), repeated use of the same animals, many parameters tested without apparent correction for multiple testing, and no independent validation of the prediction rules. The statement “dominance can be predicted” should therefore be read as a *hypothesis-generating finding*, not as established prediction. In several places the thesis itself is more cautious than the summary of the e-book.

Dimension	Assessment	Brief justification
Originality and novelty in 1988	high	Combination of quantified behaviour, urinary parameters, sleep EEG and respiratory water in a social stress model
Methodology by 1988 standards	sound to good	Prospective baseline phase, three confrontation types, mostly non-invasive, detailed description of methods
Statistical robustness by today's standards	limited	Small n, pseudoreplication, multiple testing, no cross-validation
Prediction of dominance	plausible, not confirmed	Some high hit rates, but statistically fragile with 6 or 10 pairs; effect of cage residence is unequivocal
Physiological findings (urine, sleep, respiratory water)	valuable, descriptive	Consistent with later stress, sleep and kidney research; mechanisms only inferred
Heuristic value today	high	Provides clearly testable hypotheses for modern replications

2. Subject, design and key results

2.1 Research question and experimental set-up

The starting point was the model established by D. von Holst (Bayreuth): two male tree shrews, which as territorial animals tolerate no same-sex conspecifics in the wild, are brought together in the laboratory. The subordinate animal cannot escape, so a sustained psychosocial load arises. Von Holst had described dominant, subdominant and submissive reaction types, but a quantitative behavioural analysis was missing, as was the question whether the outcome can be predicted in advance.

Confrontation type	Number	Duration	Natural analogy
Neutral confrontation (unfamiliar, unmarked cage)	6	17 days	Competition for an unoccupied territory
Home confrontation (animal is placed in the partner's cage)	10	17 days (3x), 5-6 days (7x)	Intruder in a foreign territory; 4 confrontations in a “ring experiment” with swapped roles
Border confrontation (partition between neighbouring cages removed daily)	15	10 days	Border dispute between territory holders

Fifteen adult males from the breeding colony of the German Primate Center were used, housed singly with visual barriers, 12 h light (8:00-20:00), 27 ± 1 °C. Recorded were: daily body weight; behaviour by video analysis (locomotion, marking, grooming, total motor activity, agonistic interactions, looking at the partner,

distances); food and water consumption; morning urine (urea, uric acid, glucose, protein, cholesterol, N-acetyl-beta-D-glucosaminidase (NAG), Na^+ , K^+ , Ca^{2+} , Mg^{2+} , pH, osmolality; organic substances related to creatinine); telemetric EEG (4 animals); nocturnal respiratory water loss via air humidity in the sleeping box (6 animals). The baseline phase (single housing) served as individual control; recovery data were collected after separation.

2.2 Key results

Parameter	Dominant animals	Subdominant animals
Stability of the rank relationship	A stable dominance relationship formed rapidly in 30 of 31 confrontations	
Body weight	approx. 98 % of baseline (neutral/home); slight losses possible	approx. 90 % (neutral/home); approx. 6 % loss in border confrontation; submissive weight losses of 30 % did not occur
Behaviour	More sternal/abdominal marking; grooming reduced at first (2 days)	Marking ceased, partly grooming as well; locomotion and total activity reduced; rest exposed and watch the dominant almost constantly
Food and water (border confrontation)	Slight decrease in food intake; increased feeding afterwards	Food approx. -26 %, water approx. -10 %; almost baseline values after separation
Urine	Ca^{2+} , urea, NAG (approx. +60 %), glucose increased; urine more acidic, uric acid lower; NAG and urea still raised after separation, Na^+ lower	Cholesterol and protein decreased; cholesterol still low after separation
Sleep (EEG)	No significant change	Light sleep reduced, more quiet wakefulness, especially in the 2nd and last third of the night
Nocturnal respiratory water loss	Hardly changed	Strongly increased
Reversibility	Largely return to baseline ("on-off effect"), except individual urinary parameters	Weight, behaviour, food/water intake returned

2.3 The prediction statements in detail

The methodologically most interesting element is the attempt to predict the outcome from baseline data. The findings depend on the situation and are partly even opposite:

Situation	Finding of the thesis	Comment
Neutral (6 pairs)	Later dominants had, in the baseline phase, more grooming, less urine marking, lower total activity and lower food intake; in 5 of 6 cases the heavier animal was dominant; in urine higher glucose and lower protein concentration, sorting correctly in all pairs	Dominance here correlated with a rather calm, "serene" profile
Home (10 pairs)	The cage owner always dominated, independent of weight, behaviour and urinary parameters	Very clear effect of place ("prior residence")
Border (10 evaluable pairs)	In 7 of 10 cases, animals with more running and sternal marking in the baseline phase dominated; weight without predictive value; cholesterol and osmotic pressure in urine: 70 % hit rate	Profile almost the reverse of the neutral situation

This opposite direction is interesting in content (dominance depends on individual *and* situational factors, as the thesis itself emphasises), but it also raises the demands on any replication.

3. Placement in the state of knowledge of 1988

3.1 The scientific environment

The work arose in a field that combined three lines of development:

- **Stress concept and coping.** Selye's general adaptation syndrome, Lazarus' transactional stress theory and the emphasis on individual coping capacity (Haan, Lazarus and Launier) shaped the question. The thesis explicitly places itself in the "interactionist approach": not only the stressor but also properties of the individual determine the consequences.
- **Social stress in animals.** The population-physiological tradition (Christian, Barnett, Bronson and Eleftheriou) had been developed mostly in rodents. Henry and Stephens had shown in mice that dominant animals, too, can develop hypertension under sustained social stimulation; in primates, findings from the groups around Kaplan and Manuck on atherosclerosis in socially dominant macaques were available. Tree shrews had been established by von Holst as a model of psychosocial stress, with the three-way division into dominant, subdominant and submissive and the corresponding activation patterns of the sympathetic-adrenomedullary and pituitary-adrenocortical axes.
- **Dominance and fight outcome.** Parker's concept of resource-holding potential (RHP, listed in the thesis's list of abbreviations), asymmetric contests and the advantage of the territory holder formed the ethological framework. In humans, stress vulnerability was then discussed largely via the Type A behaviour pattern (Friedman and Rosenman), which the thesis uses as an analogy.

3.2 What was new?

- **Quantification.** Von Holst had described reaction types via weight and hormone profiles; no systematic, quantitative behavioural analysis existed. The thesis provides one (marking, grooming, locomotion, interactions, distances, looking at the partner).
- **Dominants are not "unburdened".** Von Holst (1987) had assumed that dominant animals bear no negative consequences. Aue found weight loss, reduced food intake, increased NAG/glucose/urea excretion and (with Fuchs) raised blood pressure in border confrontations. This was a relevant correction of the model and is today an established motif of dominance research.
- **Prediction.** Von Holst (1986) had held that before the experiments neither behaviour nor physiology pointed to later dominance. Aue found situation-specific indicators, albeit on a narrow data basis.
- **Sleep under social stress.** The thesis notes that apparently no animal model had previously examined how social load affects sleep. To my knowledge, systematic research on sleep after social defeat (e.g. in rats) began only in the 1990s; the priority is thus plausible, but I have not checked it against the literature of the time.
- **Urine as a window on homeostasis.** According to the thesis, the combination of creatinine-related organic substances, electrolytes, osmolality and NAG in the context of social load was absent from the literature.
- **Nocturnal water loss and metabolism.** Measuring respiratory water loss via air humidity was a pragmatic, low-disturbance indicator that usefully complemented findings by Stöhr (heart rate) and Fuchs/Kleinknecht (oxygen consumption).

3.3 Methodology in the context of the time

For 1988 the following elements were progressive: video documentation with later evaluation; radiotelemetry of the EEG without restraining the animals; habituation of the animals to handling; identical daily measurement times; explicit prioritisation of non-invasive procedures; a baseline phase per animal as own control; testing for homogeneity of variance (Bartlett) and choice of parametric or non-parametric procedures. The discussions are rich in literature and, as a rule, cleanly separate observation from interpretation (for NAG, for example: "cannot be clarified here", with reference to the histology needed).

3.4 Scientific significance at the time of origin

I would assign the work in 1988 a **high significance as a basic and complementary study** within tree shrew stress research, **medium to high significance** for general social stress research, and a special role as a **bridge** between behavioural biology, physiology and (via urine and sleep) nephrology and sleep research. Its main value lay less in individual significance tests than in showing that a social stress model can be broadly phenotyped by non-invasive means and that reaction types can be characterised behaviourally and physiologically.

4. Methodological appraisal by today's standards

The following criticism measures the work against standards that did not apply in 1988. It does not diminish the achievement of the time, but it matters for the present usability of the data. As far as apparent from the parts read:

Aspect	Situation in the thesis	Current standard and assessment
Sample	15 animals; 6 neutral, 10 home, 15 border confrontations; urine in 8, food intake in 4, EEG in 3 experiments (4 animals), respiratory water 6 animals	A priori sample-size planning (power analysis), preregistration and reporting of effect sizes with confidence intervals (ARRIVE 2.0). The data are hypothesis-generating, not confirmatory.
Independence of data	The same animals in several confrontations; dominant and subordinate of a pair depend on each other	Linear mixed models with animal and pair as random factors. Without them, the risk of pseudoreplication and overestimated significance is increased.
Multiple testing	About 15 urinary parameters, numerous behavioural variables, several time windows; no apparent correction	Correction (Holm, Benjamini-Hochberg) or a confirmatory hypothesis hierarchy. Individual significances should be weighted cautiously.
Choice of tests	Analysis of variance, t-tests; for non-normality the Kruskal-Wallis H test (developed for independent groups)	For repeated measures, Friedman or Wilcoxon tests or mixed models would be more suitable; a procedure that was common in the 1980s.
Prediction rules	Parameters were used as predictors after the fact, from group comparisons (e.g. glucose and protein: all 6 pairs; cholesterol and osmolality: 70 %)	Prediction requires separate training and test data (cross-validation or an external data set), reporting of ROC/AUC and pre-specified parameters. See table below.
Controls	Individual baseline phase; no separate unchallenged control group over the same time and with transfer to a new cage	Parallel controls are needed to separate effects of novelty, transfer, time and season from effects of the partner; particularly relevant for the findings in dominants.
Blinding and randomisation	Not apparent from the parts read	To be reported today. Positive: baseline data were collected before the outcome was known, which acts as natural blinding for the prediction question.
Sex and population	Males only, breeding colony, single housing	Sex as a biological variable; females and field relevance remain open (the thesis sees field studies as an outlook).
Hormonal mechanisms	Sympathetic and HPA involvement inferred from the literature (v. Holst, Fuchs) and personal communication, not measured in the same animals	Today corticosterone/cortisol, catecholamines or metanephrines and, where possible, telemetry (blood pressure, ECG, temperature) would be collected in the same animal.
Sleep measurement	One cortical EEG signal plus EOG/EMG, visual classification into light sleep, deep sleep, wakefulness with/without activity; only 4 animals	Standard are NREM/REM scoring, spectral analysis (including delta power), automatic scorers and longer recordings; the author himself points to the need to verify the prognostic value.

Aspect	Situation in the thesis	Current standard and assessment
Respiratory water as metabolic indicator	Rise in air humidity in the sleeping box, one sensor for all pairs, hence dominant and subordinate measured in separate confrontations	Indirect calorimetry, core-temperature telemetry, thermography. The humidity rise is co-determined by box volume, ventilation, body position and temperature.
Urinary analytics	Morning spontaneous urine, creatinine reference (Jaffé method), pH by test strip	Creatinine reference was and is standard but is not neutral when weight and food intake change (the thesis discusses this). The Jaffé reaction is known to be more susceptible to interference than enzymatic methods, among others from glucose and proteins. Today: 24-h or timed collection, metabolomics, albumin-creatinine ratio.
Animal welfare	Confrontation up to 17 days with up to about 12 % weight loss in subordinates, mostly non-invasive measurements	Today prospective severity classification, defined humane endpoints and ethical approval. The thesis stresses non-invasive methods and limited load intensity; this corresponds to the spirit of the 3Rs, which were only emerging then.

4.1 How robust are the hit rates?

For orientation: the probability of correctly sorting at least as many pairs under purely random assignment (50 %) is, for a *single, pre-specified* parameter (one-sided):

Finding of the thesis	Hits / pairs	Probability by chance (one-sided)
Glucose and protein in urine (neutral)	6 / 6	approx. 1.6 %
Higher weight (neutral)	5 / 6	approx. 11 %
More running and sternal marking (border)	7 / 10	approx. 17 %
Cholesterol and osmolality (border)	7 / 10	approx. 17 %
Cage ownership (home)	10 / 10	approx. 0.1 %

The home finding is thus robust. Without pre-specification and without correction for the large number of variables tested, the other rates were not sufficient to exclude chance hits: with about 20 independently tested parameters, there would be roughly a one-in-four probability that at least one sorts all 6 pairs correctly. The group comparisons in the thesis are to be considered separately; some were significant. For a genuine prediction claim, validation in new animals is missing. This is the most important limitation of the core thesis.

5. Retrospective: state of research in 2026

5.1 Social stress, dominance and coping

Dominance research has largely confirmed and differentiated the picture of the thesis:

- **Dominance does not equal low stress.** Reviews of dominance and stress hormones (Creel 2001) and of rank in primates (Sapolsky 2005) show that the relation between rank and stress load depends on species, stability of the hierarchy and costs of defending rank. Aue's finding that dominants also bear measurable costs lies in this line.
- **Coping styles and resilience.** The relation between individuality and reactivity addressed by the thesis was developed systematically in animal research through the concepts of proactive and reactive coping styles (Koolhaas and colleagues, 1999) and through the distinction between susceptible and resilient animals after chronic social defeat stress (Krishnan et al. 2007; Golden et al. 2011). Whether baseline characteristics predict the later stress response is now a central theme of resilience research.

- **Conflicts over territory and rank.** Prior-residence and winner-loser effects (review e.g. Hsu, Earley and Wolf 2006) are well documented; the 10:10 finding on cage ownership matches this pattern. The owner's advantage is now interpreted as an interplay of motivation, familiarity and information advantage.
- **Type A.** The analogy to the Type A behaviour pattern of the time has held up only in part. Later meta-analyses (e.g. Chida and Steptoe 2009) see mainly hostility and anger as cardiovascularly relevant components, less the overall pattern. The analogy should be read as a document of its time, not as a load-bearing pillar of the thesis.

Tree shrews as a model. After 1988, tree shrew research continued mainly through the group around E. Fuchs. Chronic psychosocial stress led in tree shrews to changes in the hippocampus (volume, cell proliferation, metabolites) that could be influenced pharmacologically (e.g. Czéh et al. 2001; review Fuchs and Flügge 2002). The tree shrew genome was published in 2013 (Fan et al.) and confirmed the closer relationship to primates than to rodents. Aue's thesis provides the behavioural-physiological baseline description on which such studies could build, but naturally does not cover the central nervous levels.

5.2 Prediction of dominance and stress vulnerability

Current studies use behavioural data from automated video analysis (for example pose tracking with DeepLabCut, Mathis et al. 2018), telemetry and machine learning to predict outcome or vulnerability, and test the prediction in separate animals. The situation dependence found in the thesis (a calm profile wins in the neutral, an active profile in the border conflict) would in such a framework be modelled as an *interaction between phenotype and context*. From the perspective of 2026, the thesis is thus an early demonstration that simple single-factor predictions are inadequate. A replication with pre-specified characteristics would be informative.

5.3 Sleep

The observation that subordinates have less light sleep and more quiet wakefulness, above all in the later part of the night, fits today's hyperarousal model of sleep disturbance. Together with the nocturnal heart-rate doubling known at the time (Stöhr) and the increased oxygen consumption (Fuchs and Kleinknecht), it describes a pattern that would today be called loss of the normal nocturnal decline in autonomic activity. Social defeat changes daily rhythms, sleep architecture and sleep pressure in rats and mice (Meerlo and colleagues from the mid-1990s; review Meerlo, Sgoifo and Suchecki 2008). Poor sleep in turn feeds back on stress reactivity, so the relationship is bidirectional.

What the thesis cannot deliver today: spectral analyses, separation of REM from non-REM sleep, consideration of sleep pressure and recovery sleep after the confrontation, and long-term time courses. With $n = 4$, the sleep findings are to be understood as well-founded indications, as the thesis itself says.

5.4 Homeostasis of the internal milieu and kidney function

In retrospect, the urine part of the thesis is the most forward-pointing in content. The following interpretations are obvious from today's perspective; they are **interpretive offers, not proven mechanisms**:

- **Sympathetic activity, glucose and kidney.** The increased glucose excretion in dominants is compatible with catecholamine-driven hyperglycaemia (the thesis itself refers to Fuchs' catecholamine findings). Today renal glucose transport (SGLT2) is a central physiological and pharmacological target; glucosuria also burdens proximal tubules. The coupling of glucose reabsorption to sodium discussed in the thesis is now textbook material.
- **NAG as a tubular marker.** The NAG rise of about 60 % in dominants was discussed in 1988 as a possible sign of renal changes, with the recommendation of histology. NAG is still regarded as a lysosomal tubular marker but is today usually combined with KIM-1, NGAL, cystatin C and albuminuria

(review e.g. Bonventre et al. 2010). A NAG rise can reflect tubular activation or damage, but also increased diuresis or glucosuria. Together with the blood pressure rise reported by Fuchs and Aue, haemodynamic strain on the kidney would be a testable hypothesis; this link is not elaborated in the thesis and remains speculation here.

- **Water and electrolyte balance.** Reduced intake and increased respiratory water loss in subordinates point to a deficit in water balance. Current studies would add osmolality, vasopressin (or its surrogate copeptin), haematocrit and body composition.
- **Creatinine reference.** With weight loss and reduced food intake, creatinine excretion changes; the thesis discusses this limitation at length. Modern approaches rely on timed collection with volume measurement (metabolic cages, telemetry) and enzymatic or mass-spectrometric creatinine determination.
- **Circadian perspective.** It is now well documented that the kidney is subject to strong daily rhythmicity and that the sleep-wake rhythm influences blood pressure and excretion; a missing nocturnal blood pressure dip is regarded in human medicine as a risk marker for end-organ damage. From this viewpoint the “hyperarousal night finding” of subordinates fits well with an autonomic uncoupling from the day-night pattern.
- **Human epidemiology.** Observational studies link chronic psychosocial stress and disturbed sleep to hypertension and to less favourable renal outcomes; causality is not established in detail. Animal models such as the one described here become interesting again as a starting point for mechanistic questions.

5.5 Comparison of methods (then and now)

Area	1988 (Aue)	2026 (typical standard)
Behaviour	Manual evaluation of video recordings, ethogram	Automatic pose tracking, AI-supported behaviour classification, continuous round-the-clock recording
Autonomic physiology	Weight, breath humidity; heart rate/oxygen from parallel studies	Implantable telemetry (ECG, blood pressure, temperature, activity) in the same animal
Sleep	Single-channel EEG, visual scoring, 4 animals	EEG/EMG telemetry, NREM/REM scoring, spectral analysis, automated scorers, long-term recording
Kidney and urine	Spot urine, 12 analytes, NAG, electrolytes, osmolality	Timed urine collection, KIM-1, NGAL, cystatin C, albuminuria, metabolomics, histology and GFR measurement where needed
Hormones	Inferred from parallel studies	Corticosterone/cortisol and catecholamines in the same animal, also non-invasively (urine, faeces)
Statistics	ANOVA, t-test, Kruskal-Wallis; software of the time	Mixed models, effect sizes, correction for multiple testing, cross-validation, preregistration
Reporting standard	Doctoral monograph	ARRIVE 2.0, open data, preregistration

6. Overall appraisal

6.1 Strengths

- Broad, integrative research question combining behaviour, physiology, sleep and water balance in one model.
- Detailed description of methods and transparent discussion of the limits of individual parameters (e.g. creatinine reference, interpretation of NAG, origin of the water losses).

- Prospective data collection and consistent return to baseline (“on-off effect”) as evidence for the reversibility of the induced load.
- Correction of a detail in the model's assumptions (dominants without costs) and extension to food intake, sleep and respiratory water.
- Predominantly non-invasive data collection, a feature that accords with today's animal welfare logic.

6.2 Weaknesses

- Small samples and repeated use of animals; pseudoreplication and multiple testing not addressed.
- Prediction rules were derived from the same data on which they were evaluated; no independent validation.
- Mechanistic statements (sympathetic system, HPA axis, kidney) rest on literature and parallel studies rather than on measurements in the same animal.
- Missing parallel controls without confrontation; effects of novelty and transfer are not cleanly separated from partner effects.

6.3 Overall picture and significance today

As a **pioneering and baseline study**, the thesis has an independent place: for the first time in this breadth it describes how social defeat and social victory in a primate-related mammal affect behaviour, excretion, sleep and water balance, and it formulates questions that are central today (resilience, sleep-stress interaction, stress and kidney). As a **source of evidence** in today's sense, its individual findings are to be used mainly as hypotheses: likely to replicate are the cage-owner effect, the weight and food loss of subordinates, the sleep changes and the cessation of marking behaviour; the specific urinary predictors should be reused only after preregistration and validation.

6.4 Recommendations for a modern replication or continuation

- Pre-specified predictors (e.g. baseline activity, marking behaviour, glucose/protein in urine) and sample-size planning; validation in an independent animal cohort.
- Parallel control group without confrontation and consideration of cage and pair effects in mixed models.
- Telemetry of blood pressure, ECG, temperature and EEG/EMG in the same animal, including nocturnal decline and recovery after separation.
- Hormone profiles (glucocorticoid, catecholamines) and a kidney panel (NAG, KIM-1, NGAL, cystatin C, albuminuria), supplemented by histology at the end of the experiment, as suggested in the thesis itself.
- Inclusion of females and, where possible, field comparisons, to examine the ecology of conflicts (territory, border, intrusion).

7. References

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