

Appendix 5

Sentience, Cognition, and Agency

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A systematic review of the scientific literature on Sentience, Cognition, Agency



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A light orange circle containing the text "Sentience Cognition Agency" in a black, sans-serif font, centered within the circle.

Sentience
Cognition
Agency

Goals of the systematic review:

Q1—How are these terms used in science? Do they match/cover the concepts we are interested in?

Q2—Given a set of scientific research that uses these terms and roughly addresses the concepts at hand, what patterns do we find?

Q3—Beyond the specific term-concept overlap, what other relevant terms may feed into these concepts when the study itself doesn't use specific term of interest?

METHODS & LIMITATIONS



Performed a search for each term in the Web of Science (WoS) database to identify articles that contain the term in any of the following:

- Title
- Abstract
- Key Words
- Keywords Plus*

*The process to generate Keywords Plus (KWP) is proprietary to Clarivate Analytics and is an algorithm based on a supervised machine learning approach that automatically assigns a set of keywords to each article in its database. Some believe this to be advantageous over regular keywords (eg, can cover more knowledge; see Cosmo, et al., 2021, *Animals*), but it also introduces its own quirky biases that are hard to trace because we don't know the algorithm. That said, it's nearly impossible to do a complete search in WoS without also searching KWP, so we are left with casting a slightly broader net than may be ideal.

(ISI is Web of Science)

Table 3.2. Adequacy of ISI coverage from the point of view of research evaluation

<i>Excellent</i>	<i>Good</i>	<i>Moderate</i>
Molecular biology and biochemistry	Applied physics and chemistry	Other social sciences
Biological sciences primarily related to humans	Biological sciences primarily related to animals and plants	Humanities and arts
Clinical medicine	Psychology & psychiatry	
Physics and astronomy	Other social sciences primarily related to medicine and health	
Chemistry	Geosciences	
	Mathematics	
	Engineering	
	Economics	

Biological sciences related to animals and plants includes amongst others plant sciences, ecology, biology and agriculture. Applied physics & chemistry includes amongst others the journal categories applied physics, materials science, chemical engineering, applied chemistry and instruments & instrumentation. Other social sciences related to medicine & health includes amongst others public environment and occupational health, nursing, and sport sciences. Other social sciences includes amongst others sociology, education, political sciences, and anthropology. Humanities include law.

From: Moed, H. F. *Citation Analysis in Research Evaluation*; Springer: Dordrecht, The Netherlands, 2005; Vol. 9 doi:10.1017/CBO9781107415324.004.



WEB OF SCIENCE™

ISI/WoS searches for articles, not books, which introduces a **bias against the humanities and social sciences**

Other search engines include Scopus (wide range of journal articles, but only since 1995) and GoogleScholar (in addition to academic works, it gathers non-academic sources, obscure works, and often double counts entries, so is likely too broad and lacks high quality analytic tools) and PubMed (strong, narrow focus on human medicine)

Web of Science has trade-offs as noted above, but has more strengths than weaknesses, especially if one is interested in scientific literature *per se*.

References:

Bakkalbasi, N.; Bauer, K.; Glover, J.; & Wang, L. Three Options for Citation Tracking: Google Scholar, Scopus and Web of Science. *Biomed. Digit. Libr.* **2006**, *3*, 1–8, doi:10.1186/1742-5581-3-7.

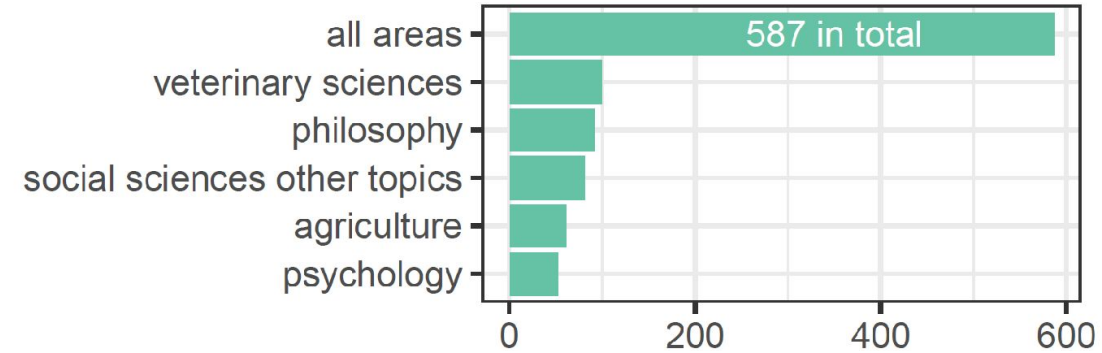
Falagas, M. E.; Pitsouni, E. I.; Malietzis, G. A.; & Pappas, G. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and Weaknesses. *FASEB J.* **2008**, *22*, 338–342, doi:10.1096/fj.07-9492lsf.

RESULTS

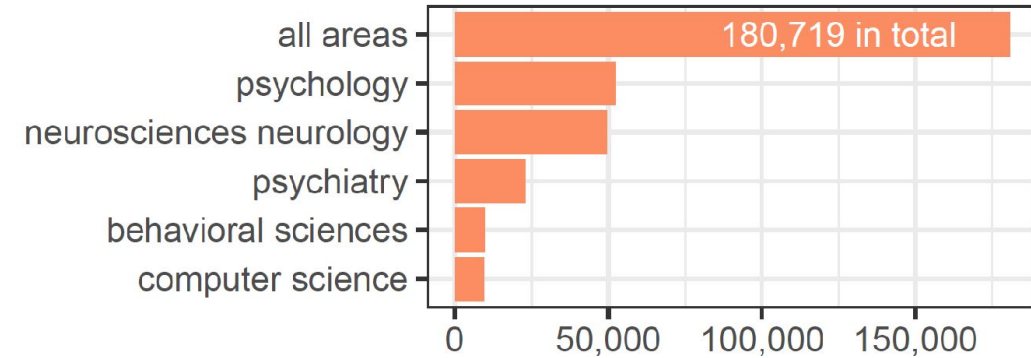
Q1—How are these terms used in science? Do they match/cover the concepts we are interested in?

Number of Publications: By top 5 areas of research (using WoS research areas)

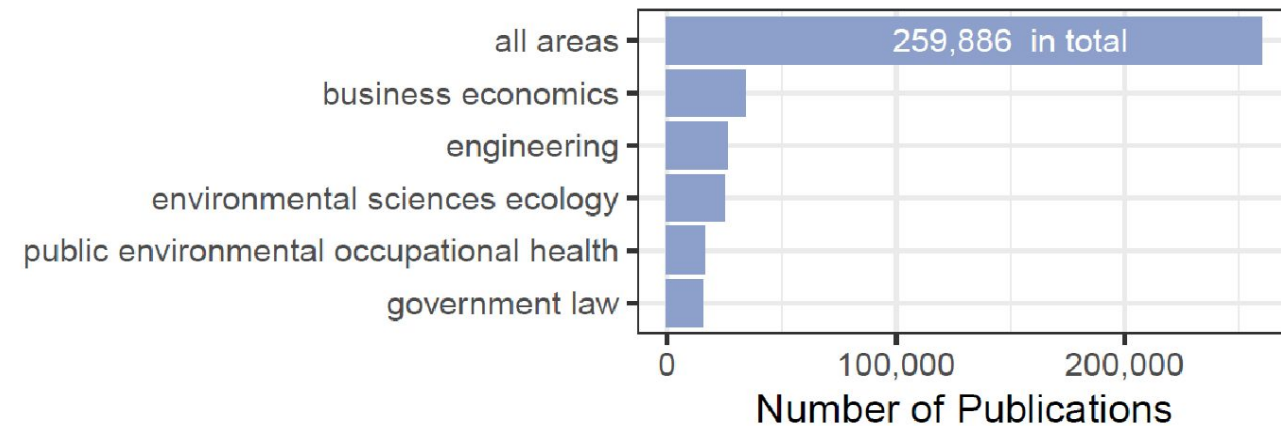
Sentience



Cognition



Agency



Q1—How are these terms used in science? Do they match/cover the concepts we are interested in?

The area-of-research analysis indicates that the search term “**sentience**” is used to cover topics related to animal sentience and that on its own, the term “sentience” overlaps with publications of potential interest. We can retain the term “sentience” on its own for further analyses.

For the two other search terms, the areas of research indicate that in WoS publications, these words are used to cover much broader topics than those of interest to the present investigation—e.g., human cognition for cognition and studies that relate to regulation from governmental agencies for agency.

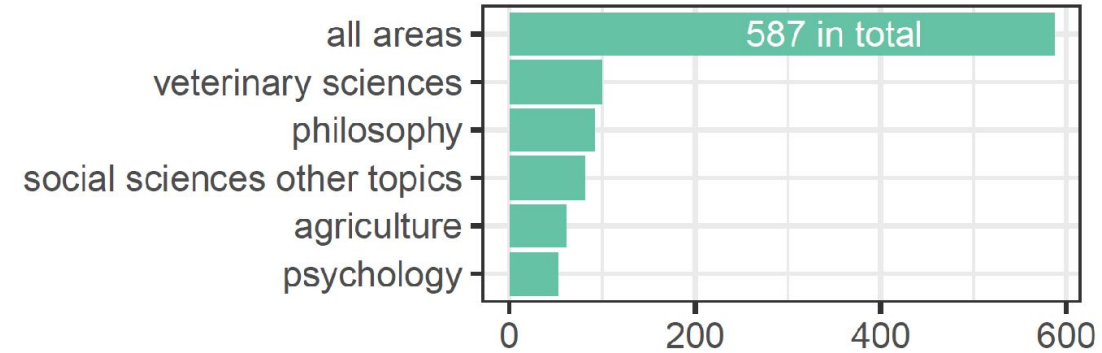
Further refinement of the “**cognition**” and “**agency**” searches are required.

In the next iteration, we add in the word “animal” as a criteria such that we will now look at the subset of articles that also include the word “animal” anywhere within the search fields (i.e., title, abstract, key words, key words plus).

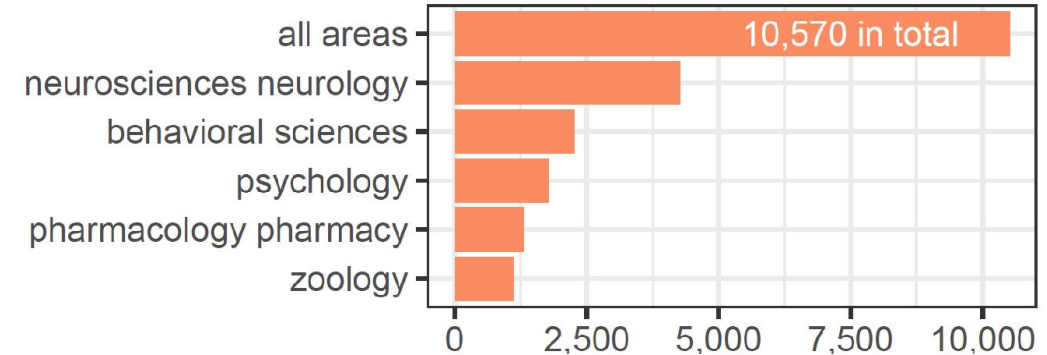
Number of Publications: By top 5 areas of research (using WoS research areas)

Refined Search Terms Round 1

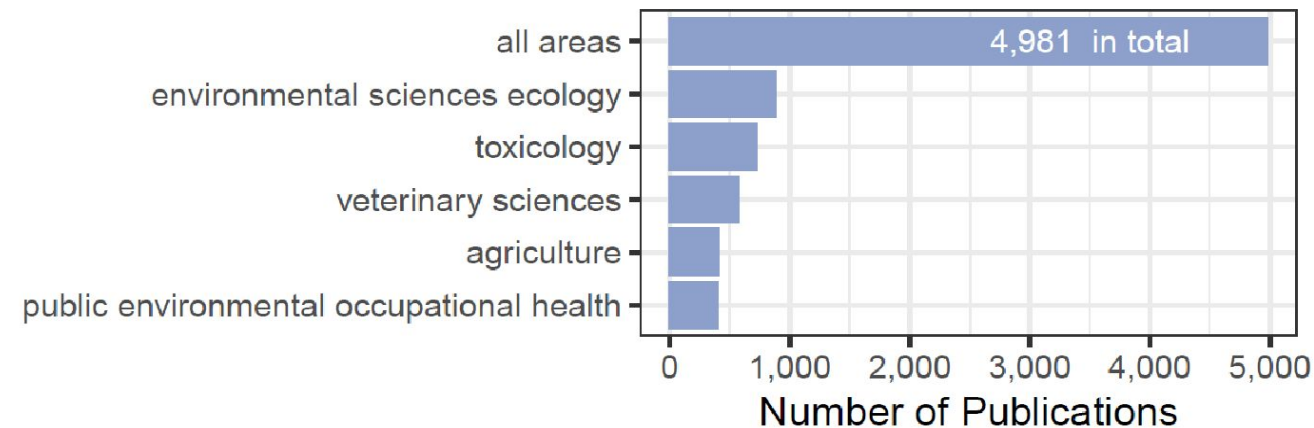
Sentience



Animal Cognition



Animal Agency



Q1—How are these terms used in science? Do they match/cover the concepts we are interested in?

Including the word “animal” with the other two search terms dramatically refined the results.

For “animal” and “**cognition**”, the area-of-research analysis indicates that the combo of these terms can be used to cover the topic of interest and that the combination overlaps with publications of potential interest. We can retain the combo search of “animal” and “cognition” for further analyses.

For “animal” and “**agency**”, the areas of research indicate that this search is still too broad: that these words are used to cover much broader topics than those of interest to the present investigation—e.g., research and studies that relate to agencies that regulate animals.

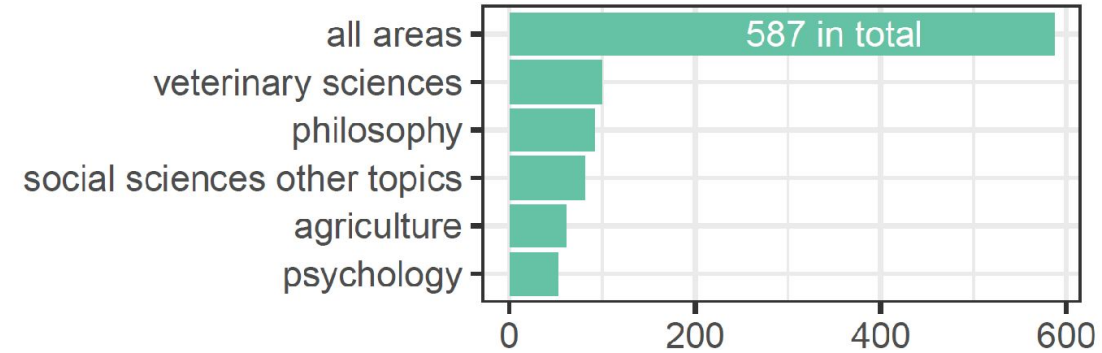
Further refinement of the “agency” search is required.

In the next iteration, we add the specification that the word “animal” must appear directly before the word agency in a phrase, title, keyword, or sentence: *animal agency*.

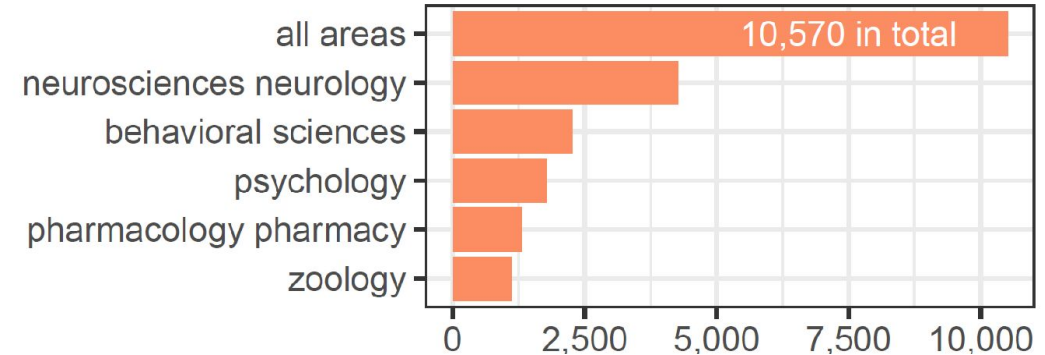
Number of Publications: By top 5 areas of research (using WoS research areas)

Refined Search Terms Round 2

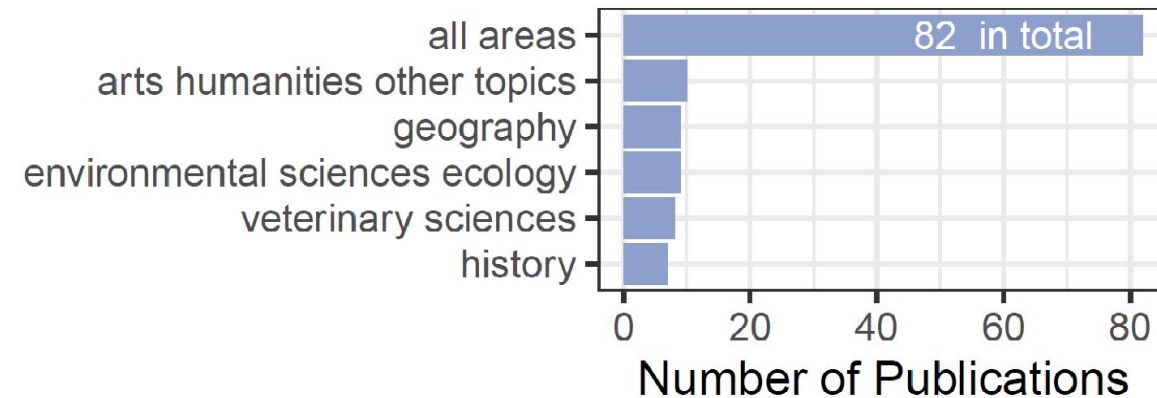
Sentience



Animal Cogntion



Animal Agency



Q1—How are these terms used in science? Do they match/cover the concepts we are interested in?

The area-of-research analysis indicates that these terms are used for various purposes within science. “**Sentience**” on its own appears to relate to publications about animal sentience. Publications that include the word “**cognition**” *and* the word “animal” appear to relate to relevant articles about cognition in nonhuman animals. Publications that include the specific phrase “animal **agency**” refined the search to an appropriately narrow degree.

Q2—Given a set of scientific research that uses these terms and addresses the concepts at hand, what patterns do we find?

Animal Cognition

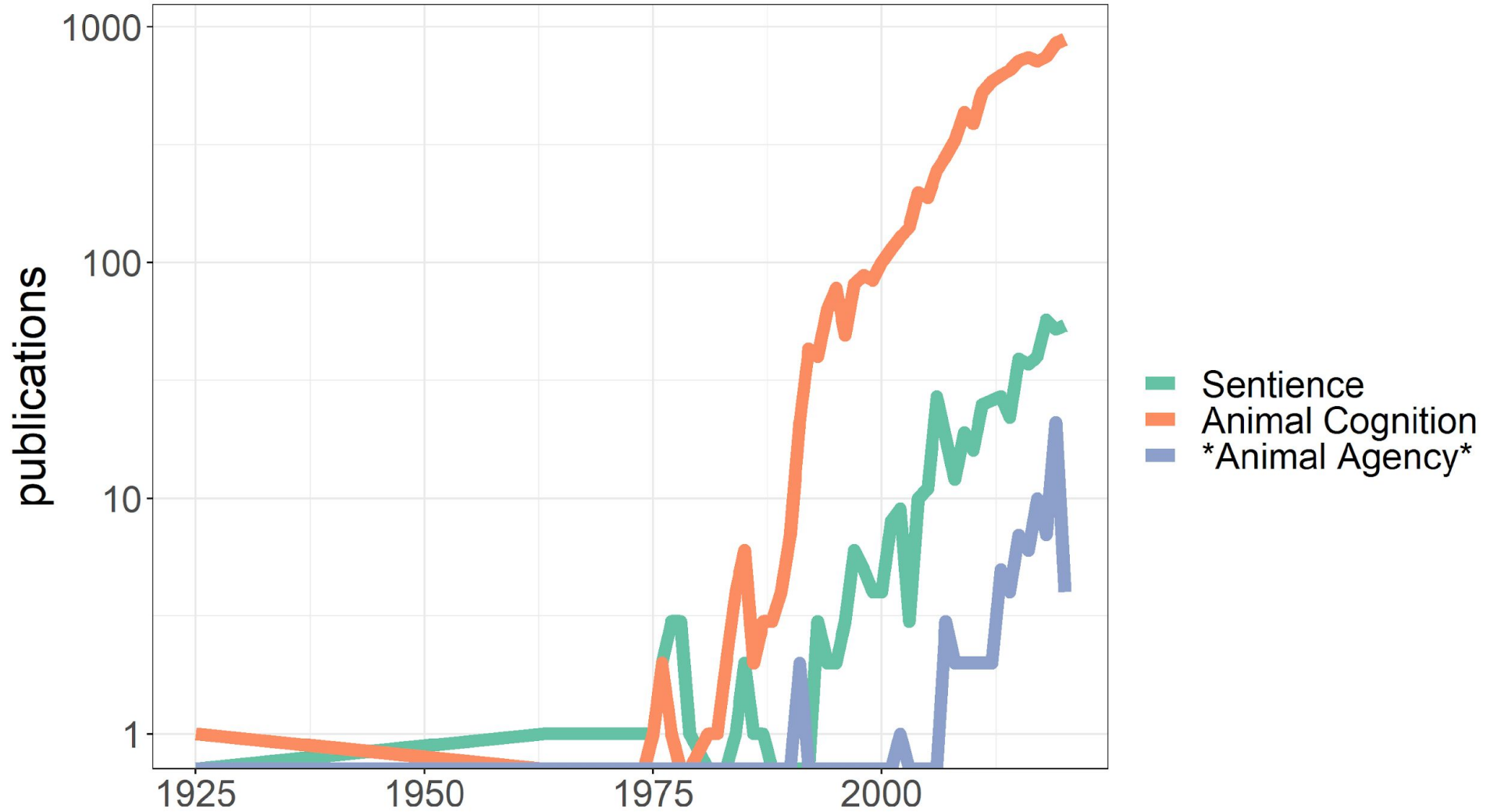
Sentience



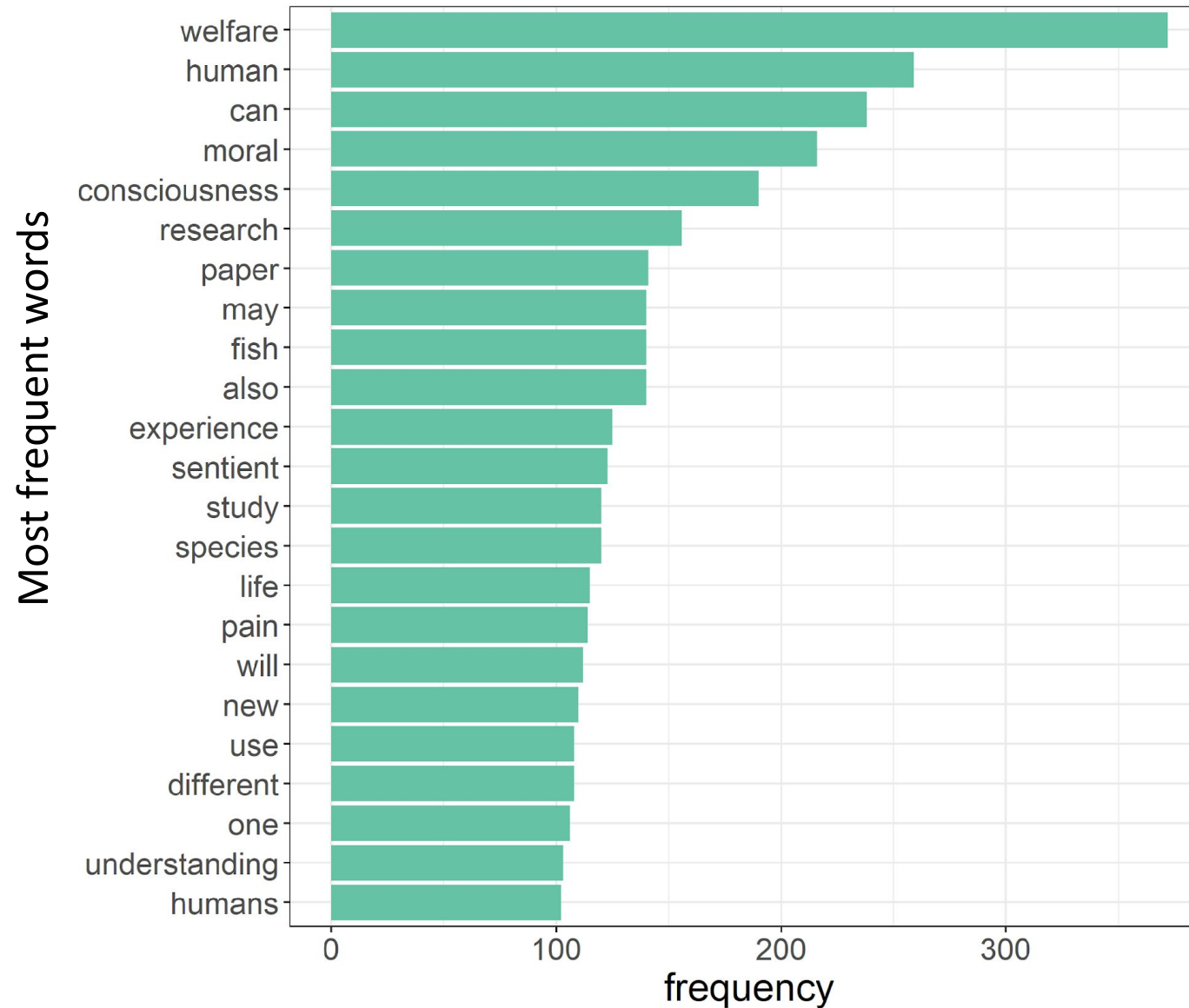
Animal Agency

*A Venn Diagram
representing the total
number of publications for
each area and their overlap*

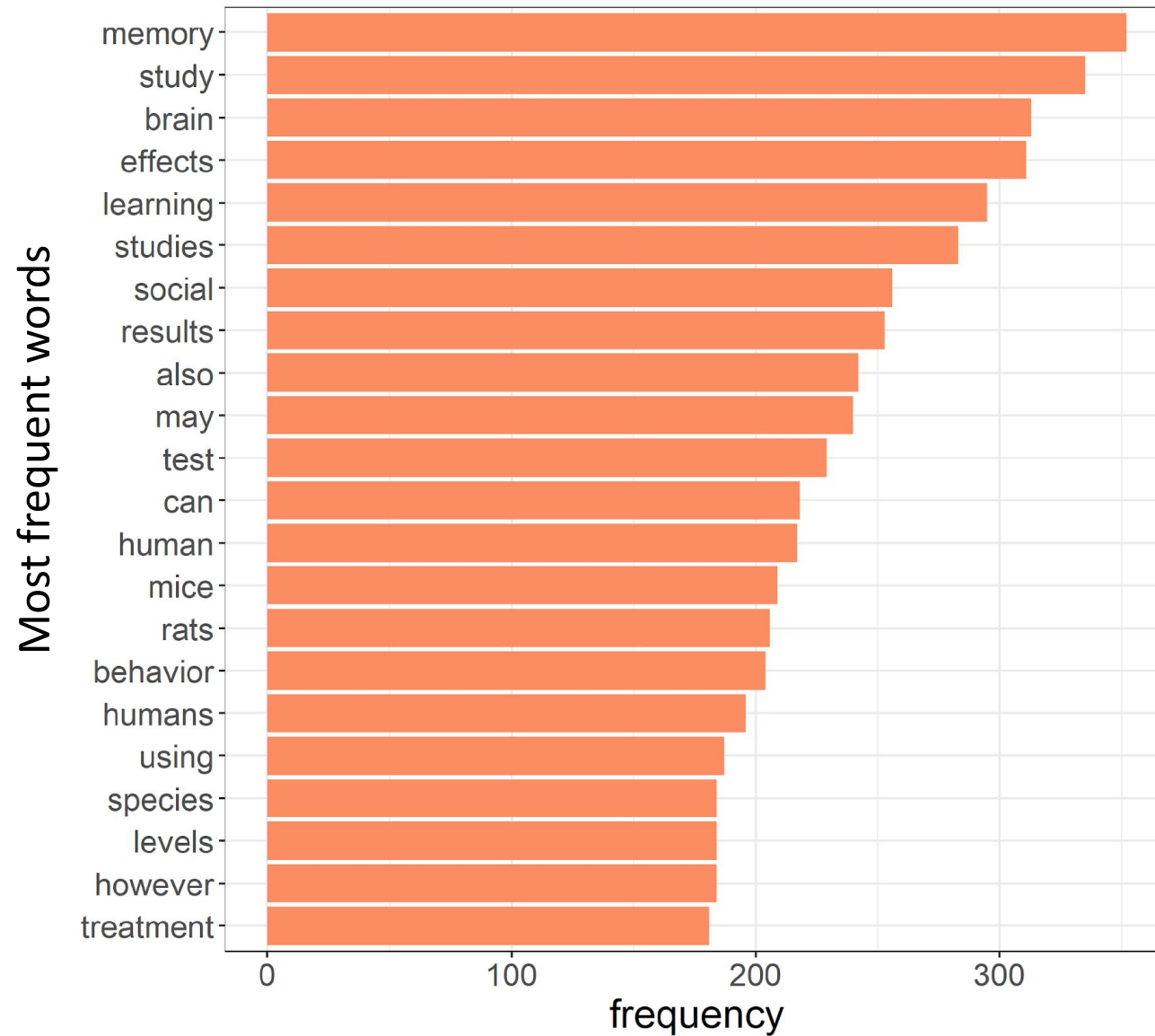
Number of Publications Over Time



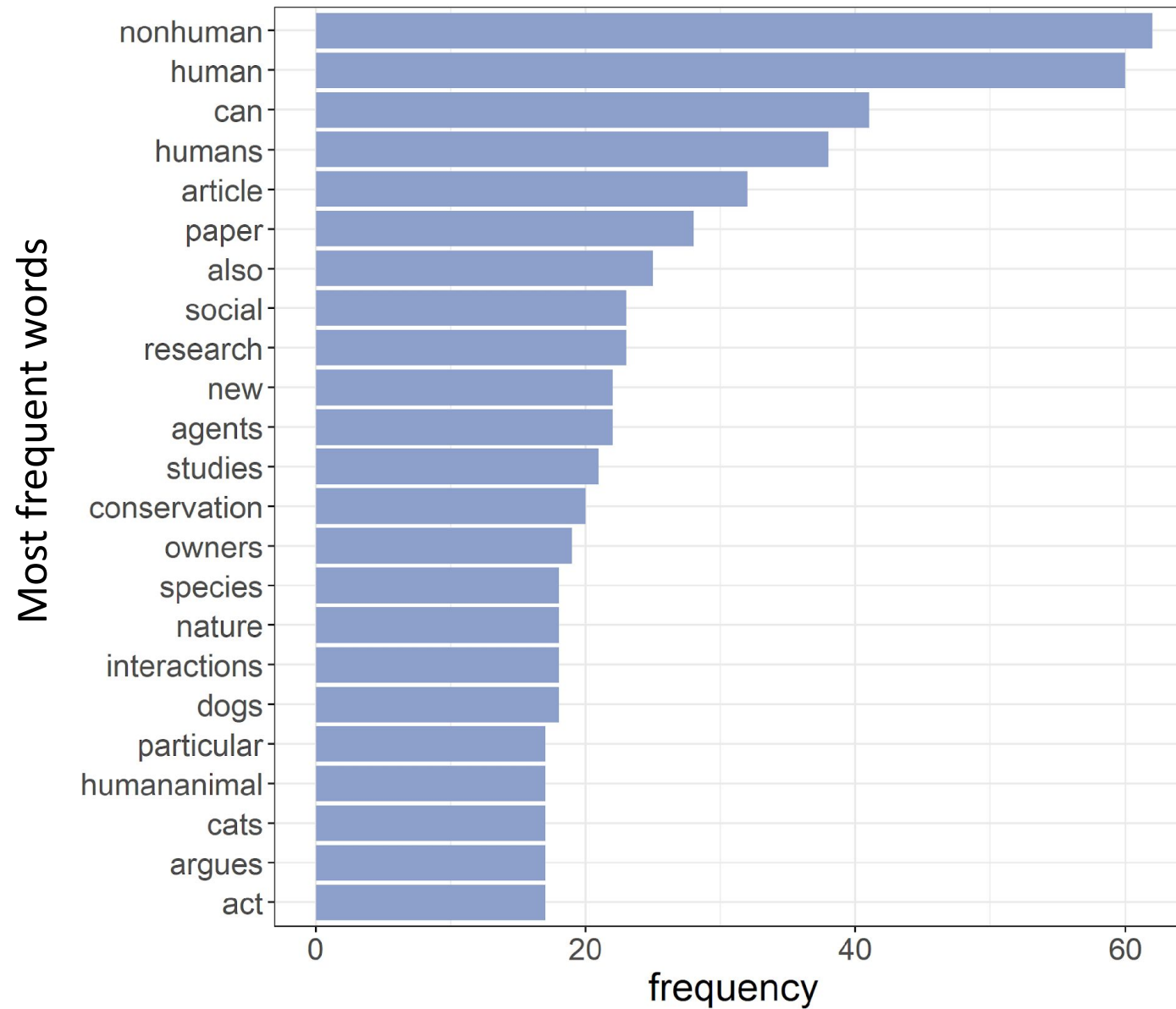
Textual Analysis of Word Frequencies in the Abstracts of the Sentience Publications



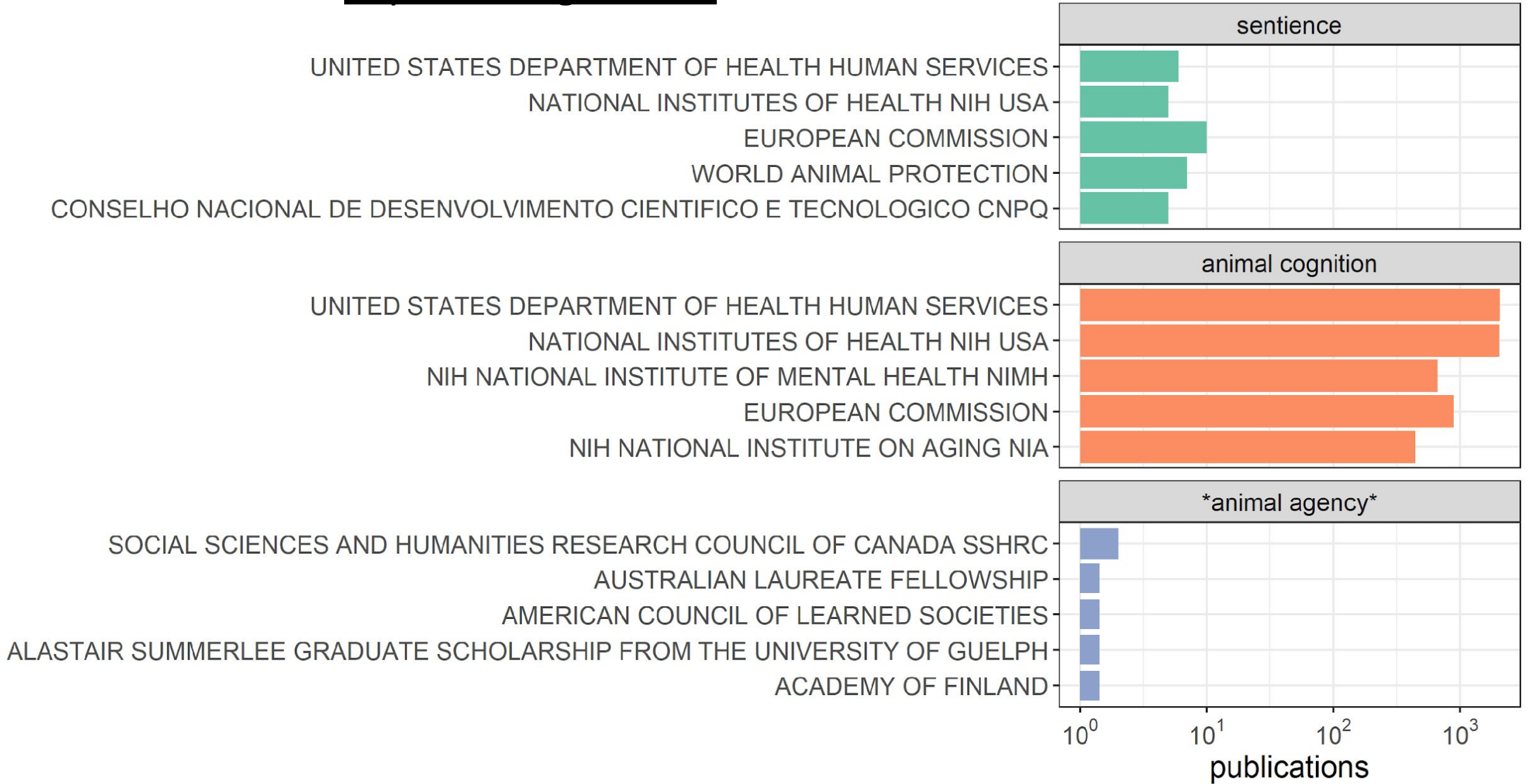
Textual Analysis of Word Frequencies in the Abstracts of the **Animal Cognition Publications**



Textual Analysis of Word Frequencies in the Abstracts of the ***Animal Agency* Publications**



Top Funding Bodies



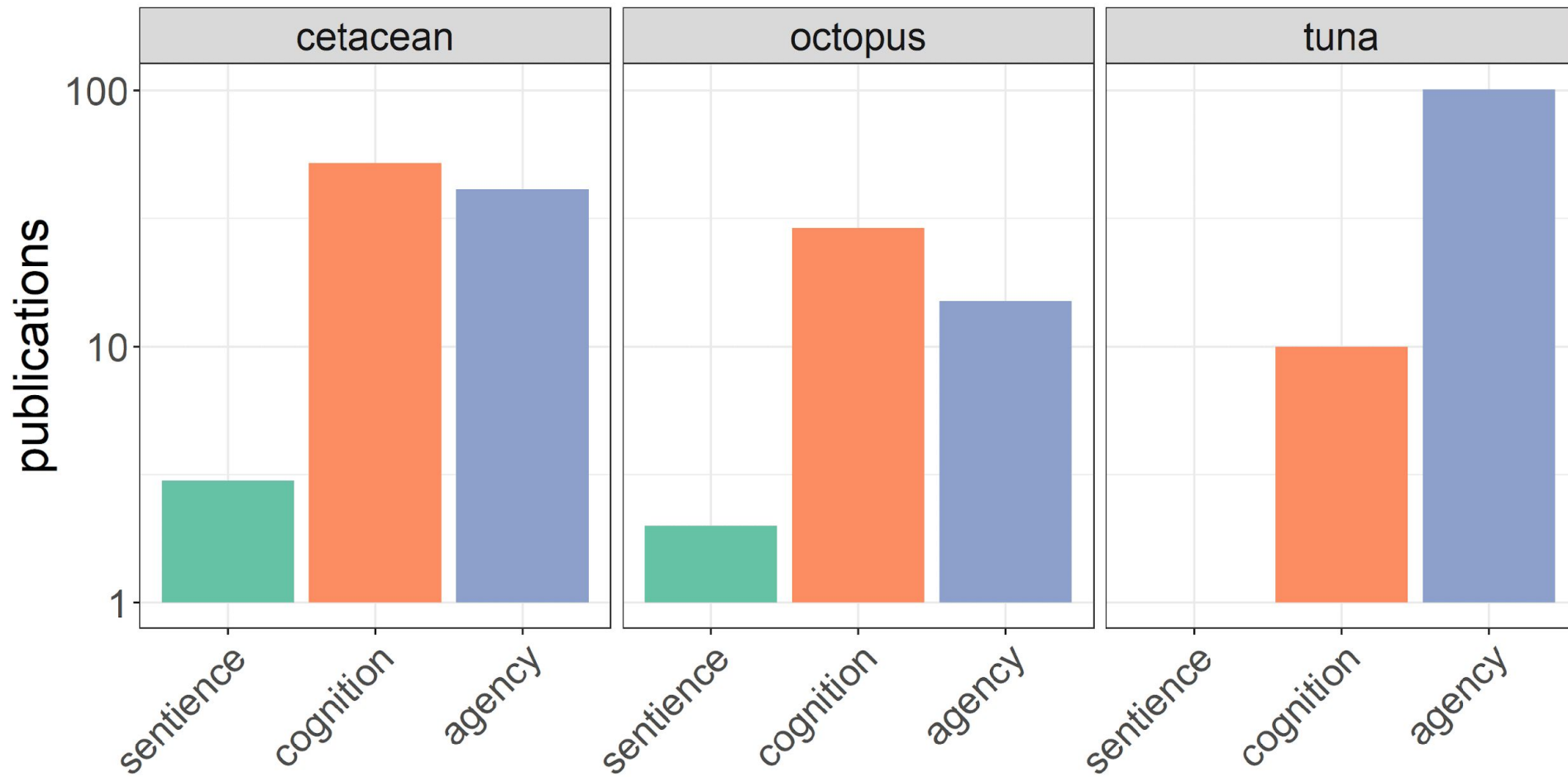
Search Terms x Specific Animals

Because of their varied use within science, the search terms *on their own* may not be very useful in determining the amount of research by specific animal taxa.

For example, “sentience” is not used often, so may not pick up relevant science on a specific species.

Conversely, “agency” is used in relation to regulatory agencies and may have nothing to do with what is of interest to this report.

Number of Publications Using “Sentience”, “Cognition” and “Agency” by Specific Taxa



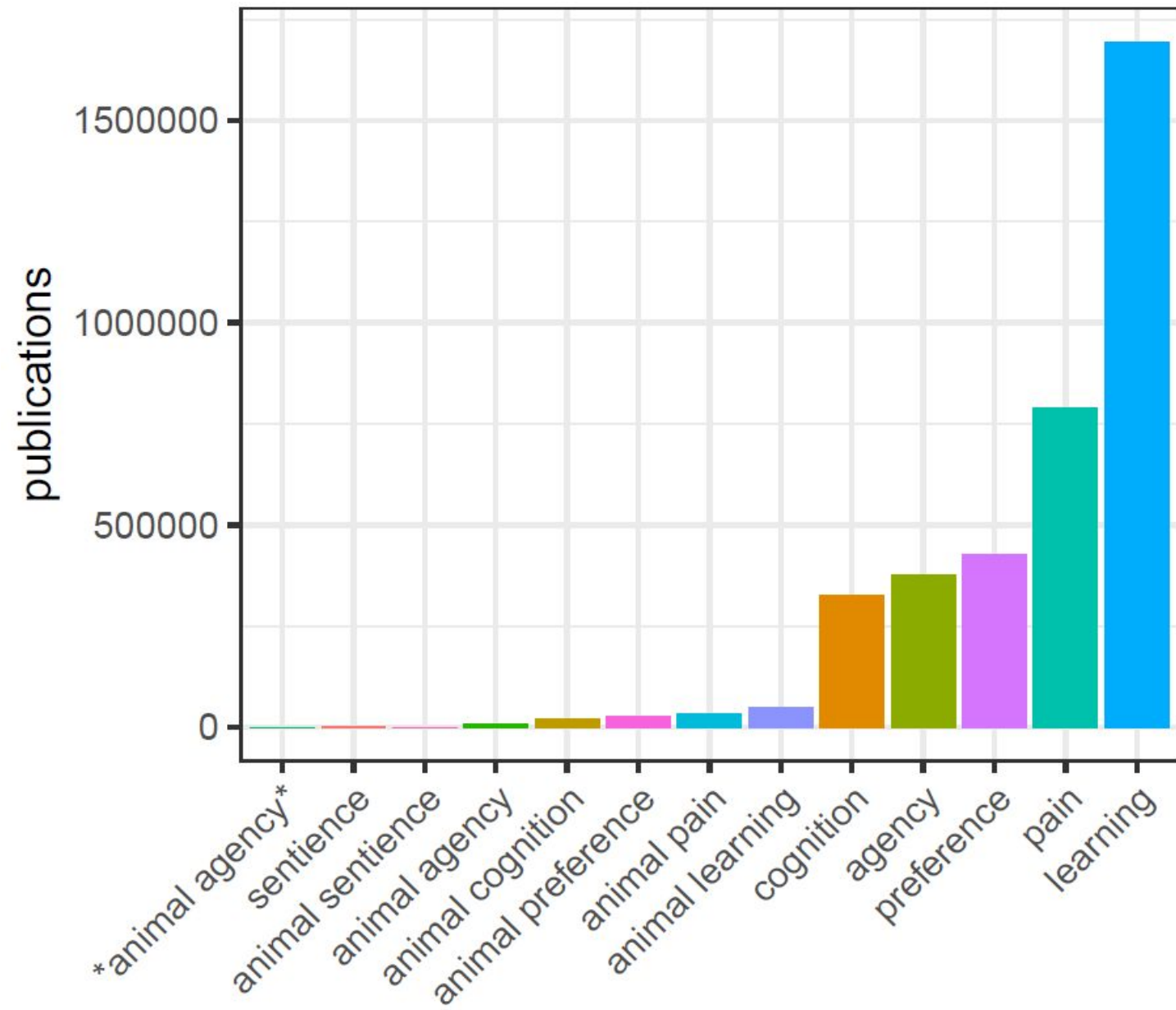
NB: Almost all “agency” publications are due to studies mentioning regulatory agencies. Most of the cognition publications on tuna have to do with the potential for eating tuna to improve human cognitive abilities.

Q3—Beyond the specific term-concept overlap, what other relevant terms may feed into these concepts when the study itself doesn't use specific term of interest?

New Search Terms

To expand out the search and to test other, related terms for their use in science, we included an additional analysis including the terms “preference” (related to agency), “pain” (related to sentience), and “learning” (related to cognition).

Total number of publications in WoS by search terms



**10 Most Recent Publications
(as of fall 2021)
by Search Term**

Sentience (588)

1. Neural Design Principles for Subjective Experience: Implications for Insects
2. Recognition for sentience at last
3. The boundary of the 'economic': Financial accounting, corporate 'imaginaries' and human sentience
4. Ritual Slaughter: The Tradition of Pilot Whale Hunting on the Faroe Islands
5. Evolutionary transitions in learning and cognition
6. Identifying targets for interventions to support public adherence to government instructions to reduce transmission of SARS-CoV-2
7. Moving forward in the ethical consideration of invertebrates in experimentation: Beyond the Three R's Principle
8. My pigs are ok, why change? - animal welfare accounts of pig farmers
9. Pets as family and pigs in crates: Public attitudes towards farrowing crates*
10. Biomolecular Basis of Cellular Consciousness via Subcellular Nanobrain

Animal Cognition (10,413)

1. Children's sleepiness facilitates the effect of vicarious learning on the development of fear
2. Minocycline alleviates Gulf War Illness rats via altering gut microbiome, attenuating neuroinflammation and enhancing hippocampal neurogenesis
3. Effects of caloric restriction on monoaminergic neurotransmission, peripheral hormones, and olfactory memory in aged rats
4. The cultural evolution of cultural evolution
5. Core knowledge of geometry can develop independently of visual experience
6. Caffeine - treat or trigger? Disparate behavioral and long-term dopaminergic changes in control and schizophrenia-like Wistar rats
7. *Saccharomyces boulardii* ameliorates gut dysbiosis associated cognitive decline
8. Rats with elevated genetic risk for metabolic syndrome exhibit cognitive deficiencies when young
9. Protective effects of *Lycium barbarum* polysaccharide on ovariectomy-induced cognition reduction in aging mice
10. Effects of O-16 charged-particle irradiation on cognition, hippocampal morphology and mutagenesis in female mice

Animal Agency (82)

1. Hamster numbers: biopolitics and animal agency in the dutch fields, circa 1870-present
2. Guarding crops from monkey troops: farmer-monkey interaction near a nature reserve in Guangxi, China
3. Interrelated agencies in an animal-centred organisation: the case of hunting with hounds
4. Interspecies justice: agency, self-determination, and assent
5. Encounters with a canine other: performing domestication in transnational animal rescue and rehoming
6. What does human-animal studies have to offer ethology?
7. Approaching Other Animals with Caution: Exploring Insights from Aquinas's Psychology
8. Agency, Intelligence and Reasons in Animals
9. Demystifying the Non-human Animal: Analyzing Animal Agency through the Select Narratives of Jim Corbett
10. Interspecies Sustainability to Ensure Animal Protection: Lessons from the Thoroughbred Racing Industry

Animal Sentience (328)

1. How Could We Know When a Robot was a Moral Patient?
2. From Pets to Pests: Testing the Scope of the Pets as Ambassadors Hypothesis
3. Moral circle expansion: A promising strategy to impact the far future
4. Neural Design Principles for Subjective Experience: Implications for Insects
5. Mary Robinson and the Costs of Animal Labor
6. Phenomenology and naturalism in autopoietic and radical enactivism: exploring sense-making and continuity from the top down
7. Ritual Slaughter: The Tradition of Pilot Whale Hunting on the Faroe Islands
8. Evolutionary transitions in learning and cognition
9. Moving forward in the ethical consideration of invertebrates in experimentation: Beyond the Three R's Principle
10. My pigs are ok, why change? - animal welfare accounts of pig farmers

Pain (790,359)

1. The efficacy of repetitive transcranial magnetic stimulation in treating patients with chronic daily headache
2. Behavior-analytic intervention for women with fibromyalgia and insomnia: a single subject design
3. Advanced compositional imaging T2 mapping sequence in detection of stages of medial knee joint compartments articular cartilage degeneration
4. Age-related differences in resting state functional connectivity in pediatric migraine
5. Prediction of unsuccessful endometrial ablation: random forest vs logistic regression
6. Comparing the Effect of Kinesiology Taping on Dynamic Balance and Pain of Men and Women With Unilateral Patellofemoral Pain Syndrome
7. Clinical relevance of depressed kynurenine pathway in episodic migraine patients: potential prognostic markers in the peripheral plasma during the interictal period
8. CGRP induces migraine-like symptoms in mice during both the active and inactive phases
9. Zoledronate-induced acute anterior uveitis: a three-case report and brief review of literature
10. Effects of chiropractic spinal manipulation on laser-evoked pain and brain activity

Animal Pain (32,112)

1. CGRP induces migraine-like symptoms in mice during both the active and inactive phases
2. Binge sucrose-induced neuroadaptations: A focus on the endocannabinoid system
3. A Decerebrate Preparation of the Rattlesnake, *Crotalus durissus*, Provides an Experimental Model for Study of Autonomic Modulation of the Cardiovascular System in Reptiles
4. Bimodal transcranial direct current stimulation reduces alcohol consumption and induces long-term neurochemical changes in rats with neuropathic pain
5. Central and peripheral pain intervention by *Ophiorrhiza rugosa* leaves: Potential underlying mechanisms and insight into the role of pain modulators
6. Ammonia emissions in poultry houses and microbial nitrification as a promising reduction strategy
7. Comparison of the anesthesia effects of ketamine, dexmedetomidine and tiletamine-zolazepam with or without tramadol in cats
8. *Lycii radice* cortex inhibits glucocorticoid-induced bone loss by downregulating Runx2 and BMP-2 expression
9. Exercise protects synaptic density in a rat model of Parkinson's disease
10. Arbiters of endogenous opioid analgesia: role of CNS estrogenic and glutamatergic systems

Learning (1,695,006)

1. The postmigrant generation between racial discrimination and new orientation: from hegemony to convivial everyday practice
2. Expanding the Scope of Statistical Computing: Training Statisticians to Be Software Engineers
3. How Students Use Statistical Computing in Problem Solving
4. What kind of support do I need to be successful as an ethnic minority medical student? A qualitative study
5. Deep multiple instance learning for foreground speech localization in ambient audio from wearable devices
6. Viral time capsule: a global photo-elicitation study of child and adolescent mental health professionals during COVID-19
7. Prediction of unsuccessful endometrial ablation: random forest vs logistic regression
8. Cognitive Orientation to Daily Occupational Performance Approach in Iranian Elderly Without Cognitive Impairment: A Single-Subject Study
9. The Impossibility of Automating Ambiguity
10. ConSafe4All: A framework for language friendly safety training modules

Animal Learning (47,835)

1. Hippocampal insulin resistance and the Sirtuin 1 signaling pathway in diabetes-induced cognitive dysfunction
2. Transfer of Odor Perception From the Retronasal to the Orthonasal Pathway
3. Impact of Buprenorphine on Learning and Memory Ability Related to the Acetylcholinesterase Change in the Hippocampus of Rats
4. Generating accurate in silico predictions of acute aquatic toxicity for a range of organic chemicals: Towards similarity-based machine learning methods
5. Combined treatment with valproic acid and estrogen has neuroprotective effects in ovariectomized mice with Alzheimer's disease
6. Learning allocentric representations of space for navigation
7. Ashwagandha (*Withania somnifera*) root extract attenuates hepatic and cognitive deficits in thioacetamide-induced rat model of hepatic encephalopathy via induction of Nrf2/HO-1 and mitigation of NF-kappa B/MAPK signaling pathways
8. Hunger games search: Visions, conception, implementation, deep analysis, perspectives, and towards performance shifts
9. *Boswellia serrata* suppress fipronil-induced neuronal necrosis and neurobehavioral alterations via promoted inhibition of oxidative/ inflammatory/apoptotic pathways
10. Sound-spectrogram based automatic bird species recognition using MLP classifier

Preference (427,501)

1. Determinants of optimum exclusive breastfeeding duration in rural India: a mixed method approach using cohort and content analysis design
2. On the Emergence of Intersexual Selection: Arbitrary Trait Preference Improves Female-Male Coevolution
3. Assessment of safety management system on energy investment risk using house of quality based on hybrid stochastic interval-valued intuitionistic fuzzy decision-making approach
4. A Caching Strategy Based on Many-to-Many Matching Game in D2D Networks
5. Utility-indifference pricing of European options with proportional transaction costs
6. First record of the enigmatic coleoid genus Longibelus from Sakhalin (Far East Russia): a contribution to our understanding of Cretaceous coleoid habitats in the Pacific Realm
7. Resequencing of 672 Native Rice Accessions to Explore Genetic Diversity and Trait Associations in Vietnam
8. Congress's Commissioners: Former Hill Staffers at the SEC and Other Independent Regulatory Commissions
9. Functional Frameworks for Socialized Digital Curation: Curatorial Interventions and Curation Spaces in Archives and Libraries
10. Where do localphiles shop? A mixed-methods case study of food-buying habits

Animal Preference (28,391)

1. Flaxseed Prevents Interferon-alpha Induced Depressive Behavior in Mice: the alpha-Linolenic Acid is Essential
2. Perceptions about meat reducers: Results from two UK studies exploring personality impressions and perceived group membership
3. Lowering barriers to plant-based diets: The effect of human and non-human animal self-similarity on meat avoidance intent and sensory food satisfaction
4. Sustainable food choice motives: The development and cross-country validation of the Sustainable Food Choice Questionnaire (SUS-FCQ)
5. Willingness to adopt a more plant-based diet in China and New Zealand: Applying the theories of planned behaviour, meat attachment and food choice motives
6. Community composition and structure along the environmental gradients of *larix gmelinii* forest in northeast china
7. Promotion of pellet-feed feeding in mandarin fish (*Siniperca chuatsi*) by *Bdellovibrio bacteriovorus* is influenced by immune and intestinal flora
8. Landscapes, climate and choice: Examining patterns in animal provisioning across the Near East c. 13,000-0 BCE
9. Binge sucrose-induced neuroadaptations: A focus on the endocannabinoid system
10. A multicriteria decision analysis for the evaluation of microalgal growth and harvesting