The Current State of Carnivore Cognition, *Animal Cognition*, Benson-Amram, S., Griebling, H., and Sluka, C. University of British Columbia, sarah.benson-amram@ubc.ca

Supplementary Material

Systematic Literature Search

Information regarding the methods used to create figures 1, 2, and 3 describing the lack of published research in carnivore cognition.

Summary

This publication is intended as a literature review of the current research on cognition in carnivores (Mammalia: Carnivora). To supplement our review, we present figures illustrating the number of publications on this topic over time as well as across different families and other criteria. Because this article is intended as a literature review, the data collection and visualization of these figures should not be considered as rigorous as those presented in meta-analysis papers. These data are simply for illustration purposes only and likely do not include every publication possible. However, great effort was taken to utilize data collection methods that would produce as accurate an illustration of the current body of work as possible. These analyses are in good faith, as accurate as possible under the time constraints of this paper and special issue. This review intends to provide an illustration of the current disparity of research on cognition in carnivores compared to the number of publications produced in the same time frame for cognition in primates and birds.

Methods

These methods are illustrated in Supplementary Figure 1 along with the sample number and the number excluded at each step.

- *Obtaining Data*

Google Scholar, Scopus, and PubMed were searched for the inclusion of study topic related terms in the title or abstract (see Supplemental Material Table 1 for search criteria per search). These words were selected because of their relation to the topic of animal cognition, their status as a grammatical variation on these words, and these words were based on the sections and topics covered in this review. Results of these searches were saved from the databases as .csv files for incorporation into R via R Studio (R Core Team, 2022; RStudio Team, 2022). The following phases occurred in R Studio.

- *Data Cleaning*

Next the CVSs for each search were combined and cleaned. Cleaning involved removing duplicated entries from multiple databases, removing entries that were missing authors, titles, abstracts, or publication years. Entries were also filtered to include only those entry types that could be novel research articles (See Supplementary Material Table 2). This helped to reduce the number of non-research article documents in the results such as book chapters, conference proceedings, and government reports. All csv results from each database were combined. Extraneous columns unneeded for the analysis were removed to simplify the datasets. Lastly the Title, Author, and Abstract columns were converted to known English characters to facilitate word searching. This process removed special characters such as Greek letters and converted accented letters to their non-accented counterparts.

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Additionally, those citations with non-alphanumeric characters even after the conversion were removed and citations with nonsensical titles (often a string of characters and symbols) were removed.

- *Filtering by Exclusion Criteria*

Basic exclusion criteria were applied and entries that include these words in the title were removed. A full list of these criteria is in Supplemental Material Table 2. These words helped to remove erroneous entries that were nonsensical or where the title indicated that the citation was not a publication such as "Symposium", "Chapter", or "Signature". Other content related words like "Human", "Archaeology" or "Childhood" were also selected as exclusion words because of a propensity of these words in publications that were not related to the topic of animal cognition. Citations with these exclusion criteria were removed from the dataset.

- *Identifying Study Criteria*

The fourth phase involved identifying which study words occurred in the title and abstract of each paper. The title and abstract of each paper were searched for the study words (See Supplemental Material Table 2)

- *Identifying Common Name and Taxonomic Words*

Next, we identified the common name and taxonomic words that occurred in the title of each paper. Common names and taxonomy were obtained from the Integrated Taxonomic Information System (https://www.itis.gov/). Taxonomy and common names were obtained for Carnivora, Primates, and Aves.

- *Human Repairing Taxonomic Entries*

Next, a human researcher checked the taxonomic entries for multiple orders and that the order is labeled correctly. In many cases, species like the Lion Tamarin and Sea Lions would be labeled as Carnivora: Felidae. These were corrected by a human researcher. Additionally, papers unrelated to the topic of animal cognition but that made it through the previous phases of filtering were removed.

- *Labeling Domestic Species Studies*

Lastly, papers were labeled as studying domestic animals such as dogs or cats if they included words such as "Domestic", "domestic cat", "Domestic dog", "canis familiaris", "canis lupus familiaris", or "Felis catus" etc.

Sources:

Google Scholar, Scopus, and PubMed. Data was collected from these search engines using the free software "Publish or Perish'' (POP) (Harzing, 2007). Because POP is limited in the extent and type of Boolean search criteria possible for each database, only Google Scholar, Scopus, and PubMed were searched for this review due to ease of obtaining data, the free and open nature of these databases, and the databases' ability to accept Boolean search criteria. See Supplemental Material Table 1 for specific search criteria used for each site. Variations occurred even when using POP because of each site's ability or inability to accept multiple Boolean criteria for different sections of a paper (such as title and abstract or title and keywords). Searches were most often undertaken in the "Keyword" section because all three databases could accept Boolean criteria in this category, databases may search either author-given

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official keywords and/or keywords identified as commonly used in the publication through an algorithm. This field was used most in the first phase of data collection because of its broad nature to capture most papers that studied animal cognition including many papers on other, unrelated subjects.

Risk of Bias and Limitations:

Bias is likely in a few different directions in this study. Bias likely occurred often because of confusion between words that can be used as both nouns and verbs in English. For example, searching for the word "bear" will give you both publications on bears (Mammalia: Carnivora: Caniformia: Ursidae) and those that use the verb "to bear'' such as in the phrase "these people bear witness to…". Similar issues with automation of word searching such as that used in both databases like Google scholar and in the programs written for this study's purpose were common. These issues were mitigated by also searching titles and abstracts for key taxonomic words as well as the study words. This helped to eliminate studies on completely different subjects such as teaching or computer science. These studies were further eliminated after commonly mistaken phrases such as "machine learning" and "classroom learning" were identified and could be used to further filter the dataset. Another flaw discovered with "confused words" was the use of the word "learn" and its variants in the abstract of a study that investigated some other aspect of a species. For example, a publication may include the words "hyaena", "Crocuta crocuta", and the sentence "we intended to learn" in the abstract and be flagged for inclusion in the study (because of its use of taxonomically relevant words and study relevant words) even though the paper may have been on Hyaena metabolic patterns, a topic not directly related to carnivore cognition. While these situations were removed whenever possible, it is likely that some papers are still erroneously included because of these flaws in word searching. Other issues such as papers being removed because of language barriers, removed due to lack of abstract populated to the downloaded data, or vagueness of the title and abstract could also erroneously remove relevant publications with other non-relevant ones. Thus, it is likely that because bias occurred in both directions in our automated programs that there are both irrelevant papers included and relevant papers missing. Given these issues, we still propose that these data provide a representation of the current state of the study of carnivore cognition as viewed through publication numbers. The inclusion of a few extra and exclusion of a few should not influence the overall trend observed and discussed in this review.

Query Timeline

Queries of each database including their search criteria are presented in Supplemental Material Table 1 These data represent the publications available to these search engines at these dates and may not include publications that have since been released. The databases were queried between September 8, 2022, and October 9, 2022.

References

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