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Benchmarking Enrichment Efforts in the US & Canada Across Species and Enrichment Categories

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Enrichment is important for animal welfare and data quality. Provision of enrichment opportunities varies between species and enrichment category. However, data benchmarking these differences does not exist. Our objective was to characterize enrichment provision and associated factors across species in the US and Canada. Personnel who work with research animals (*n* = 1098) in the US and Canada voluntarily responded to online promotions and completed a survey about enrichment used for the species they worked with most, their control of and wish for more enrichment, stress or pain in the animals they worked the most with, and demographics. All participants (except those working with rats) received the same questionnaire regardless of species to allow objectivity, as the effects of many enrichment items on some species have not yet been determined. The questionnaire asked about enrichments that were beneficial to at least one species. The provision of enrichment was allocated into 2 outcome variables: diversity and frequency per enrichment category. Results showed a significant interaction between enrichment category and species. Generally, physical, nutritional, and sensory enrichments were provided less often than social enrichment. In addition, nonhuman primates received more diverse and more frequent enrichment than did other species (twice as much as rats and mice). Enrichment was provided less frequently by personnel who wished they could do more than the status quo. Both enrichment frequency and diversity were higher in respondents from Canada, those who had more control over provision, and those who had been in the field longer. While our results cannot be used to determine the quality of enrichment provided to various species, they do provide information on current enrichment practices in the US and Canada and identify differences in implementation by species and enrichment category. The data also indicate provision of enrichment is influenced by factors such as country and individual control over enrichment. This information can also be used to identify areas for greater enrichment efforts for some species (for example, rats and mice) and categories, with the ultimate goal of improving animal welfare.

Acronyms and Abbreviations: CCAC, Canadian Council on Animal Care

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Introduction

Enrichment is important for animal welfare, scientific quality, and even public approval. Keeping animals in captivity for various types of research can result in stress.[62] A recent meta-analysis indicates that conventional rodent housing itself as compared to enriched housing can increase morbidity and mortality.[15] However, providing biologically appropriate enrichments can reduce stress due to captive housing and improve animal welfare.[117] Furthermore, enrichment is an important way to implement the refinement pillar of the principles of the 3Rs (refinement, reduction, and replacement).[99] Some evidence also indicate that people are more likely to support animal research when animals have better living conditions.[100]

All stakeholders (for example, researchers, governmental agencies, and nonprofits) involved in animal-based scientific activities share the goal of implementing the 3Rs, including providing enrichment. However, determining where to best direct efforts is difficult without benchmarking current practices and understanding what factors influence enrichment provision.

Enrichment is critical to meet the needs of captive animals. In addition, effective enrichments often increase an animal's control of their environment through choice.[14,115] Although many definitions and goals have been used for enrichment,[95] in this article we consider animal enrichment to be any attempt to promote natural behavior and improve animal welfare.[101] To accomplish these goals, enrichments should be relevant and meaningful to the specific species.[9] Species-specific differences in enrichment inherently complicate making comparisons across species. Still, broad benchmarking and comparisons might help to guide improvement efforts.

Broad assessments of animal enrichment efforts often organize approaches into broad categories or forms. Categorization efforts are often based on the assumption that each category fulfills different behavioral needs or motivations, and that providing diverse enrichment opportunities more effectively promotes welfare). Although enrichment categorization varies among publications, categories often include: social, occupational or cognitive, physical or structural, sensory (sometimes

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split into auditory, olfactory, visual, and tactile), human-animal interactions, and nutrition or feeding.[8,9,54,118] Sometimes authors subdivide social enrichment into contact and noncontact forms or include human-animal interactions while considering all other enrichments subcategories of physical enrichment.[8] Two examples of distinct categories of enrichment are providing a social companion for rats, which benefits their social needs,[49,63] and providing nesting material (a physical enrichment) that allows mice to fulfill their drive to build nests.[37,38,98] Assessing animal enrichment across categories may let stakeholders determine if a wide range of behavioral needs are being fulfilled for diverse species.

Different species of animals receive different amounts and types of enrichment. Potential reasons for enrichment differences could be related to differences in governmental regulation (see below), physical and evolutionary closeness to humans, beliefs about particular species' mental abilities, everyday relationships with animals (for example, mice/rats are viewed as pests while dogs/cats are viewed as companions), relative animal numbers (for example, far more rats and mice are used in research as compared with dogs, cats, and nonhuman primates (NHP),[18] and the perceived "cuteness" of some animals.[31,32,44,64,88,90]

Several regulations influence enrichment provision. In the US, the 1985 amendment to the Animal Welfare Act requires "exercise for dogs" and that NHPs receive "adequate physical environment to promote psychological well-being of primates," thereby requiring each facility to have a formal environmental enrichment plan.[67] In 2020, US public law 116-69-249 required that research involving NHPs, dogs, and cats receive additional oversight by the Department of Veterans Affairs.[36] Mice, rats, birds, and fish are not covered under the Animal Welfare Act and, therefore, are not subject to USDA inspection.[2,18] While federal laws do not regulate animal research in Canada, some provinces have regulations that affect use but not welfare. However, the Canadian Council on Animal Care (CCAC), a nonprofit, independent organization that provides national oversight of animal-based scientific activities in Canada, requires that animal-based science takes place only when necessary and that the animals in the studies receive optimal care according to high-quality, research-informed standards. CCAC publishes guidelines that establish the basic requirements for institutional animal care and use programs in Canada. Compliance with these standards is a requirement for CCAC certification. CCAC has 2 categories of guidelines: general guidelines, which serve as the basis of animal care, procedures, and program management, and guidelines that provide information on specific species. Although these guidelines aim to provide similar guidance for all species, discrepancies are present in the enrichment required for different types of animals. For example, positive reinforcement training is required for NHPs but not for mice and rats. To our knowledge, a formal comparison of enrichment levels and uses across species has not yet been performed.

The provision of enrichment could also be related to personnel, workplace, and research-related factors. Staff members who have more control over enrichment provision, or who are in a role that allows them such control, may be more likely to provide more enrichment. In addition, animals experiencing higher levels of stress or pain may receive either more or less enrichment. Highly stressed animals may receive more enrichment in order to provide them with more positive experiences. Alternatively, they may be unable to benefit from certain types of enrichment and so may receive less. To our knowledge, neither of these potential factors has been systematically investigated.

Our objective in this study was to benchmark the frequency and diversity of enrichment across species and identify factors that influence current practices US and Canadian animal research facilities. The project was not designed to evaluate enrichment quality, determine the best enrichment per species, or imply that high total enrichment frequency or diversity is equivalent to good animal welfare. Some types of enrichment may be biologically relevant and beneficial to only some species, but to provide objectivity we used the same questionnaire for all species.

Based on previous research,[88] current regulatory requirements, and experience with current practices, we hypothesized that NHPs would receive greater frequency and diversity of enrichment than would rodents. We also hypothesized that the frequency and diversity of enrichment would be greater if personnel had greater control over enrichment provision, if personnel wished they could provide more enrichment to their animals than was currently permitted, and if animals were experiencing more stress or pain. We hope our results will identify promising areas for research, nonprofit, and governmental efforts related to enrichment.

Materials and Methods

All procedures and informed consent protocols were approved by Purdue University's Human Research Protection Program Institutional Review Board, protocol #1712020004. No interaction occurred between the research team and animals during the study; therefore, we did not seek approval from Purdue University's IACUC.

This study on provision of broad enrichment was a portion of a larger project designed primarily to investigate enrichment provided to rats (specifically rat tickling,[70]) and compassion fatigue in research personnel.[73] The data for all 3 aims were collected simultaneously in one continuous questionnaire, but only the broad enrichment data are presented in this paper. The broad enrichment questionnaire was created after designing the questionnaire for rat enrichment.

Participants and procedures. All participants gave their voluntary informed consent before completing a 30-min survey (Supplemental Table 1). To compensate them for their time, participants were entered into a drawing for a choice between $40 USD cash or an Amazon gift card. Participants were included in the study if they currently worked with research animals in the USA or Canada and were over the age of 18. The location restriction was used because enrichment requirements and use are substantially different in other parts of the world.

Participants were recruited via online promotion between February 22 and March 26, 2018. Seven methods were used: direct emails to known individuals, list serves (for example, CompMed, LAREF, etc.), email lists (for example, CALAS, MSMR), social media groups (for example, Laboratory Animal Sciences, Dog Spies on Facebook), LinkedIn (for example AALAS group, Animal Behavioral Biology), website advertising (CALAS and AALAS), and online webinars (for example, AALAS). The same study flyer with slightly different text was sent up to 4 times to each method based on following recommended survey procedures.[27] All study materials were translated into French by one of the authors (SC), a native French-Canadian speaker, to increase Canadian participation.

Measures. As no validated measures existed for the topics in this survey, we created new measures based on reviewing literature, consulting with experts in enrichment, survey

methodology, and behavior theory, and pilot testing. Survey text and scoring are available in Supplemental Table 1.

Demographic and work factors. Participants were asked to identify their age, gender, race, and highest level of education. They were also asked to indicate their country of work, role (for example, husbandry technician, veterinarian), type of institution (for example, academic, contract research organization), primary type of research (for example, basic, applied, regulatory), animal they spend the most time with, and both years and hours per week working with the animals in general. Participants were informed that work was defined broadly, including both hands-on and hands-off work (that is, anything from changing cages to approving research protocols on a review board).

Enrichment practices and factors. At the beginning of the enrichment section, to counter any misunderstandings about enrichment, participants were instructed that "in this study, we consider animal enrichment to be any attempt to improve animal welfare by enhancing the quality of a captive animal's care by providing stimuli necessary for psychological and physical well-being."[101]

Enrichment practices were assessed by asking participants to complete an enrichment diversity/frequency questionnaire (based off a review of previous zoo and research animal literature) about the type of animal they worked with most over the past year.[5,7,54,59] Specifically, participants were given a list of enrichments and asked how often (if at all) each one was used in their facility with that specific animal type (Figure 1). The enrichment checklist was created to encompass diverse types of enrichment from published literature and anecdotal experiences that could be beneficial for at least one species. Individuals working with rats were given slightly different questions based on the original study design. However, if they were not asked about a specific item, it was not included in the overall proportion average.

The enrichments were categorized based on previous literature (Figure 1) although the occupational and physical categories were combined because they could fall into either category depending on the animal. Enrichment values were averaged within category type to create a summary score that approximated the amount of time the enrichments in the category were generally provided (always = 100% of the time; never = 0% of the time).

Some participants did not provide an answer for all enrichment categories. For example, one participant provided answers for all enrichment categories except for nutritional. This was considered lost data for that specific participant and enrichment category. Ultimately, the numbers of participants that answered at least 50% of the questions were as follows: 1087 for social housing, 1029 for human-animal interaction, 1069 for nutritional, 1073 for physical, and 1059 for sensory. We also summed the number of different types of enrichments used to approximate enrichment diversity.

Enrichment factors were assessed by asking participants first about their degree of control or influence over the type or amount of enrichment provided. Second, participants were asked if they wished they could provide more enrichment to their animals than they currently do. Finally, participants were asked to self-assess the degree of stress and pain that the animals they work with most experience, using categories based on the official United States Department of Agriculture (USDA) pain and distress categories for animal research and CCAC Guidelines.[16] The categories were little to none, minor, moderate, or severe.

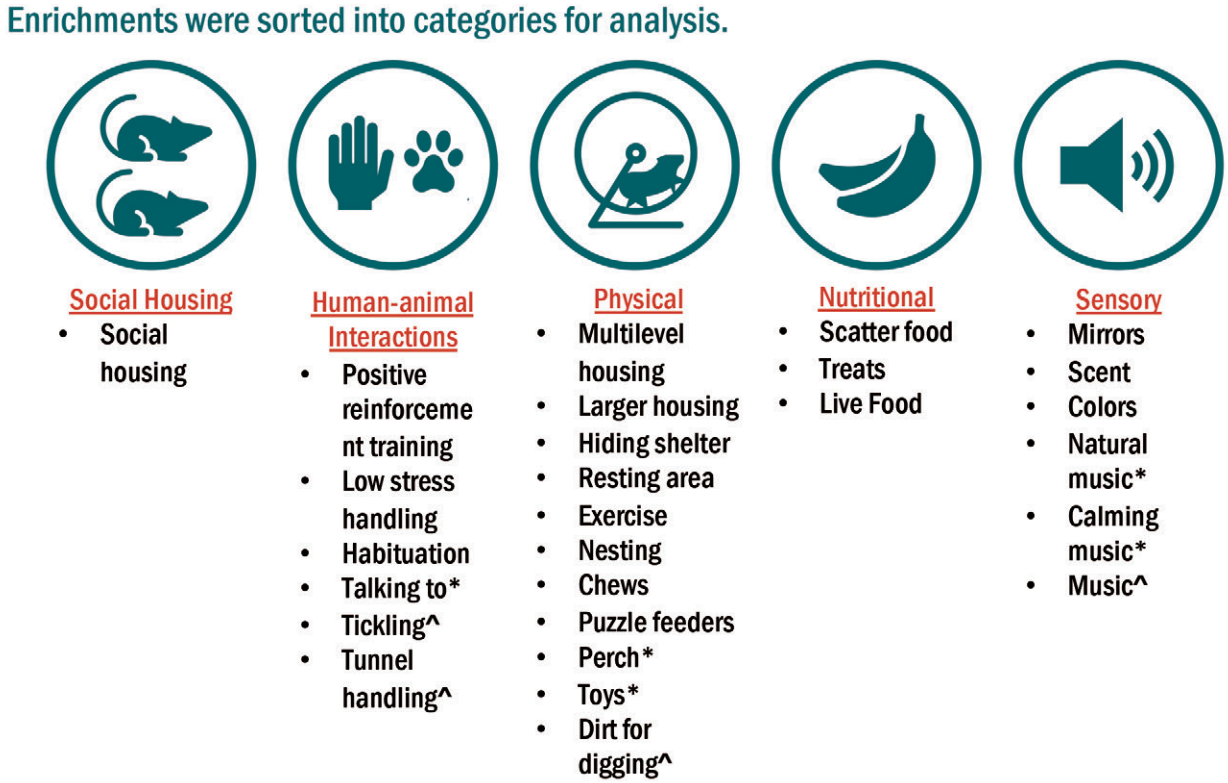

Figure 1. Composition of enrichment categories. Respondents (n = 1098) reported the types of enrichments used with the animal type they worked with most. For analysis, these enrichments were grouped into 5 main categories. * Asked for all species other than rats. ^ Asked only for rats.

Data analysis. ***Variable coding.*** To ensure that our descriptive data reporting and summary scores were all derived from the same respondents, only those who answered at least 50% of questions were included in the analysis. Categorical response options that had fewer than 25 responses were collapsed into larger categories. For example, gender categories of prefer not to answer, transgender man, transgender female, nonbinary, and blank were collapsed into an "other" category. Similarly, if fill-in answers had more than 25 similar responses, they were combined into a single category. For example, a "trainer" category was added to participant role. Missing data for categorical variables (gender, race) were coded as "other." In addition, race was coded as "mixed" for individuals who selected multiple race categories.

Furthermore, the types of animals that participants worked with were coded into logical categories for clear and consistent interpretation. Rats, mice, and NHPs remained in their own category as they are either a very commonly used research species or are animals of particular interest. Pigs (n = 48) and sheep (n = 7) were collapsed into the category of farm animals. Dogs (n = 49) and cats (n = 6) were collapsed into the category of companion animals. Rabbits (n = 24) and guinea pigs (n = 5) were collapsed into the category of small mammals. Birds (n = 14), fish (n = 13), amphibians (n = 2) and any other animals (n = 13) were coded as others.

Quantitative analysis. Data analysis was conducted in JMP Version 14 (SAS Institute Inc., Cary, NC) using descriptive statistics and general linear mixed models. The data for each analysis are provided in Supplemental Table 2. Prior to testing, all linear model assumptions were confirmed including independence of residuals, homogeneity of variance, normality of residuals, and multicollinearity in the data.

General linear mixed models were used to test associations between enrichment frequency or enrichment diversity and potential explanatory factors. ParticipantID, nested within species type, was considered random. The fixed, independent variables included in the model were species type, animal stress/pain, control over enrichment, desire to provide more enrichment, demographic factors (gender, race, age, highest education, country), and work factors (institution type, research type, job type, years worked). A sensitivity analysis approach was used to determine our final model.[106] If explanatory factors (such as research type or gender) were not significant, they were dropped from the final model.[43] Significance level was $P < 0.05$.

Significant main categorical effects were further analyzed post hoc with Tukey adjusted pairwise comparisons. Descriptive data (for example, demographic or work factor categories) are presented as mean ± SD unless otherwise noted. Data from mixed model analyses are presented as least square means ± SE.

Results

Demographics and work. A total of 1449 individuals began the survey and met the inclusion criteria of currently working with vertebrate research animals in the United States or Canada. Of those, 1164 provided complete demographic data and their cleaned, deidentified data are provided in Supplemental Table 3. Of those, data were analyzed only for the 1098 who answered at least 50% of questions for each enrichment category. Table 1 displays the detailed demographic and work data for all included participants. In summary, study participants were primarily white females with an average age of 40 y and had been working with research animals for 14 y. A variety of institution types (for example, university, industry) and roles (animal care, veterinarian, etc.) were represented.

Table 1. Demographic and work information for qualifying study participants (n = 1098).

Variable	Categories	*n*	%
Country	USA	776	71%
	Canada	322	29%
Gender	Female	868	79%
	Male	215	20%
	Other	15	1%
Race	White	933	85%
	Asian	46	4%
	Mixed	32	3%
	Other	87	8%
Highest level of education	High school diploma, Associate's, or technical degree	355	32%
	Graduate degree	307	28%
	Bachelor's degree	436	40%
Institution	University	703	64%
	Contract Research Organization	250	23%
	Nonprofit	60	5%
	Government	28	3%
	Other	57	5%
Research type	Applied	545	50%
	Basic	200	18%
	Product	94	8%
	Regulatory	82	7%
	Education or training	76	7%
	Other	101	9%
Animal type worked with most	Mice	626	57%
	Nonhuman primates	168	15%
	Rats	123	11%
	Farm	55	5%
	Companion	55	5%
	Small mammal	29	3%
	Other	42	4%
Role	Animal care or laboratory technician	289	26%
	Veterinary technician	219	20%
	Manager	201	18%
	Veterinarian	135	12%
	Trainer	33	3%
	Principal investigator	30	3%
	Other	191	17%
Continuous Data	**Mean ± SD**	**Range**	
Age (M ± SD)	40 ± 11 y	20–78	
Years working with research animals	14 ± 108 y	0–50	

Enrichment frequency. Participants were asked to describe the proportion of time that different categories of enrichment were provided to the animal type they worked with most. Overall, many major research animals were well represented, including mice (57%), NHPs (15%), and rats (11%).

Overall, specific enrichments were provided at varying frequencies to different animal types. Table 2 provides descriptive data on the percentage of participants indicating that their species received each specific enrichment item per category at least sometimes. The percentages ranged from 0% (no participants provided live food to small mammals) to 100% (all participants talked to companion animals at least sometimes). Of all

Table 2. Specific enrichment provided at least sometimes by animal type. This table describes the percentage of participants (n = 1,098) that reported providing each specific enrichment at least "sometimes" to the animal type they worked with most. ^ Indicates this item was only asked for rats. * Indicates this item was asked for all species other than rats. Blanks indicate that the participants were not asked about that enrichment item for that animal type. Each enrichment is grouped by category as analyzed in this publication. A darker teal fill indicates higher provision and very light teal fill indicates lower provision.

		Animal types							
		NHP	Companion	Farm	Small Mammal	Rats	Mice	Other	% Average
Social housing		97	96	95	79	88	98	90	92
Human-animal interaction	Low-stress handling	93	96	96	72	79	80	88	87
	Talking to*	96	100	93	86		62	74	85
	Positive reinforcement training	97	89	78	41	40	30	43	60
	Habituation	85	62	71	55	85	44	48	64
	Rat tickling^					46			
	Tunnel handling^					37			
Nutritional	Treats	99	98	96	76	72	57	52	79
	Scatter food	94	5	76	52	69	79	79	65
	Live food	19	4	4	0	3	4	50	12
Physical	Toys*	99	98	95	83		45	43	77
	Larger housing	90	91	76	62	67	36	62	69
	Chews	92	78	85	62	72	55	19	66
	Hiding shelter	54	36	20	86	86	91	62	62
	Nesting	37	18	31	62	89	99	50	55
	Exercise opportunities	67	87	49	41	20	39	33	48
	Resting area	68	71	55	45	16	24	31	44
	Perch*	98	47	4	48		25	43	44
	Multilevel housing	86	25	9	48	25	27	29	36
	Puzzle feeders	96	53	35	34	8	8	12	35
	Dirt^					6			
Sensory	Colors	93	62	71	66	19	20	29	51
	Calming music^	82	51	51	45		12	12	42
	Scent	70	31	38	31	7	10	12	28
	Mirrors	98	9	38	21	5	5	17	28
	Natural music^	73	25	31	24		7	10	28
	Music*					16			
Sum of responses per species		168	55	55	29	123	626	42	

enrichment types, on average, social housing was provided most often and live food was provided least often. We encourage readers who may have a specific interest in a specific animal type, enrichment category, or enrichment type to examine this table. Because our survey analysis is meant to provide an overview of enrichment, and extensive information is displayed in Table 2, we will not go into great detail about specific enrichment types in this manuscript, but rather give interpretations for each category in the following paragraph.

We identified a significant interaction between enrichment category and species (Table 3). Details are provided visually in Figure 2. In terms of enrichment categories, in the category of social housing, mice were socially housed more often than rats or small mammals. In the category of human-animal interaction, NHPs, companion animals, and farm animals received these types of interactions more often than rats, mice, or other animals. Companion animals also received more human-animal interaction than small mammals. NHPs, companion, farm, and small mammals received more human-animal interaction than did mice or rats. In the category of occupational/physical enrichment, NHPs, companion animals, and small mammals received this enrichment more often than did farm animals, rats, mice, or other (approximately twice as often). In the category of nutritional enrichment, NHPs received this more often than all other animal types (about a third more often). Also, farm and other animals received more nutritional enrichment than rats or mice. Finally, in the category of sensory enrichment, NHPs received sensory enrichments more often than all other species (2 to 5 times as often); in addition, companion animals, farm animals, and small mammals received sensory enrichments more than rats or mice (approximately twice as often).

Differences in enrichment provision by animal type category are presented in Table 4. In brief, within animal type, social enrichment was provided more often than physical, nutrition, and sensory enrichment for all animals except small mammals. For all animals except rats, mice, and 'other', social enrichment was provided at equal frequency as human-animal interaction. For NHPs, companion, and farm animals, human-animal interaction was also provided more often than physical, nutritional, or sensory enrichment. For all animals except for NHPs, occupational/physical enrichments were provided more often than sensory enrichments. In addition, for companion animals and

Table 3. Associations of enrichment frequency and diversity. The associations from 2 general linear models on the provision of enrichment (proportion of time and diversity) based on respondent reports (n = 1,098). Participants were asked about the independent variables of social support, animal stress/pain, euthanasia, enrichment, human-animal interactions, and demographic, and work factors. F: F-statistic. (+): the continuous factor has a positive association with the dependent variable. (−): the continuous factor has a negative association with the dependent variable. Bold indicates a significant effect. n/a: the factor was not applicable in the model

	Dependent Variables	
Independent variables	**Enrichment frequency**	**Enrichment diversity**
Species	**$F_{6,1045}$ = 130.8, P < 0.0001**	**$F_{6,1080}$ = 125.0, P < 0.0001**
Category of enrichment	**$F_{4,4211}$ = 668.9, P < 0.0001**	n/a
Species*category of enrichment	**$F_{24,4211}$ = 52.9, P < 0.0001**	n/a
Control over enrichment	**(+) $F_{1,1060}$ = 63.1, P < 0.0001**	**(+) $F_{1,1080}$ = 60.4, P < 0.0001**
Desire to provide more enrichment	**(−) $F_{1,1038}$ = 19.6, P < 0.0001**	$F_{1,1080}$ = 1.2, P = 0.27
Animal stress and pain	$F_{1,1052}$ = 1.31, P = 0.25	$F_{1,1080}$ = 1.4, P = 0.24
Animal stress and pain*Species	**$F_{1,1052}$ = 2.4, P = 0.025**	n/a
Desire to provide more enrichment*Species	**$F_{1,1043}$ = 2.4, P = 0.024**	n/a
Country	**$F_{1,1042}$ = 40.9, P < 0.0001**	**$F_{1,1080}$ = 32.9, P < 0.0001**
Years working	**(+) $F_{1,1055}$ = 6.9, P < 0.02**	**(+) $F_{1,1080}$ = 4.8, P < 0.03**
Role	**$F_{6,1053}$ = 5.0, P < 0.0001**	**$F_{6,1080}$ = 5.1, P < 0.0001**

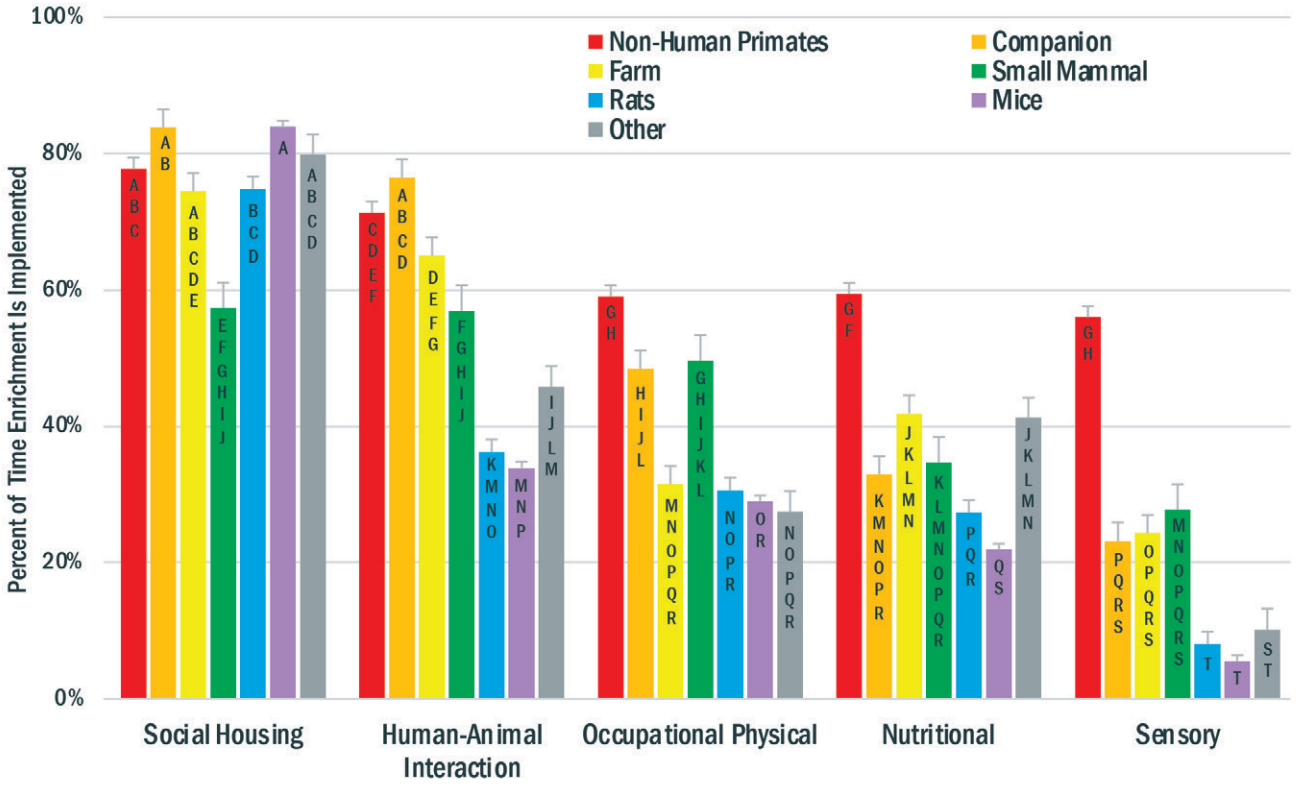

Figure 2. The interaction between animal type and enrichment category on proportion of time enrichment is provided. For most animals, physical, nutritional, and sensory environment is provided much less than social. NHPs generally receive more enrichment, more often than other animal types. Respondents (n = 1098) reported the proportion of time they used different types of enrichments with the animal type they worked with most. The data graphed are least squares means and standard error. Different letters indicate a significant difference in a Tukey HSD test.

mice, occupational/physical enrichments were also provided more than nutritional enrichments.

In terms of work factors and demographics, enrichment was provided more frequently by personnel with more control over enrichment, those who had worked longer in the field, and those working in Canada. Enrichment was provided *less* frequently by personnel who wished they could provide *more* enrichment than they currently do. In terms of role, those in "other" roles provided enrichment more frequently than veterinarians or managers.

Enrichment diversity. Data on the different types of enrichment given to the animals that participants worked with most are summarized as total diversity. Enrichment diversity was significantly associated with species (Figure 3), country, and control (for model details and test statistics see Table 2). NHPs received a higher diversity of enrichment overall. Companion, farm, and small mammals received the second highest diversity,

Table 4. Provision of enrichment to each animal type. In decreasing order of frequency, the significant differences in enrichment categories for animal type as determined with a posthoc Tukey test ($P < 0.05$). The greater-than symbol ">" indicates a significant difference between enrichment categories. The equal symbol "=" indicates that there was no significant difference between the enrichment categories. Parenthesis "()" indicate a grouping of items. A vertical bar "|" indicates an additional comparison grouping. HAI = human-animal interaction

Animal type	Tukey differences
	Comparison Group 1
Nonhuman primates	(social = HAI) > (nutrition = physical = sensory)
Companion	(social = HAI) > physical > (nutritional = sensory)
Farm	(social = HAI) > (nutritional = physical) | nutritional > sensory | physical = sensory
Small mammal	(social = HAI = physical) > sensory | (social = HAI) > nutritional | physical = nutritional
Rats	social > (HAI = physical) > sensory | (physical = nutritional) > sensory
Mice	social > HAI > physical > nutritional > sensory
Other	social > (HAI = nutritional) > sensory | (nutritional = physical) > sensory| HAI > physical

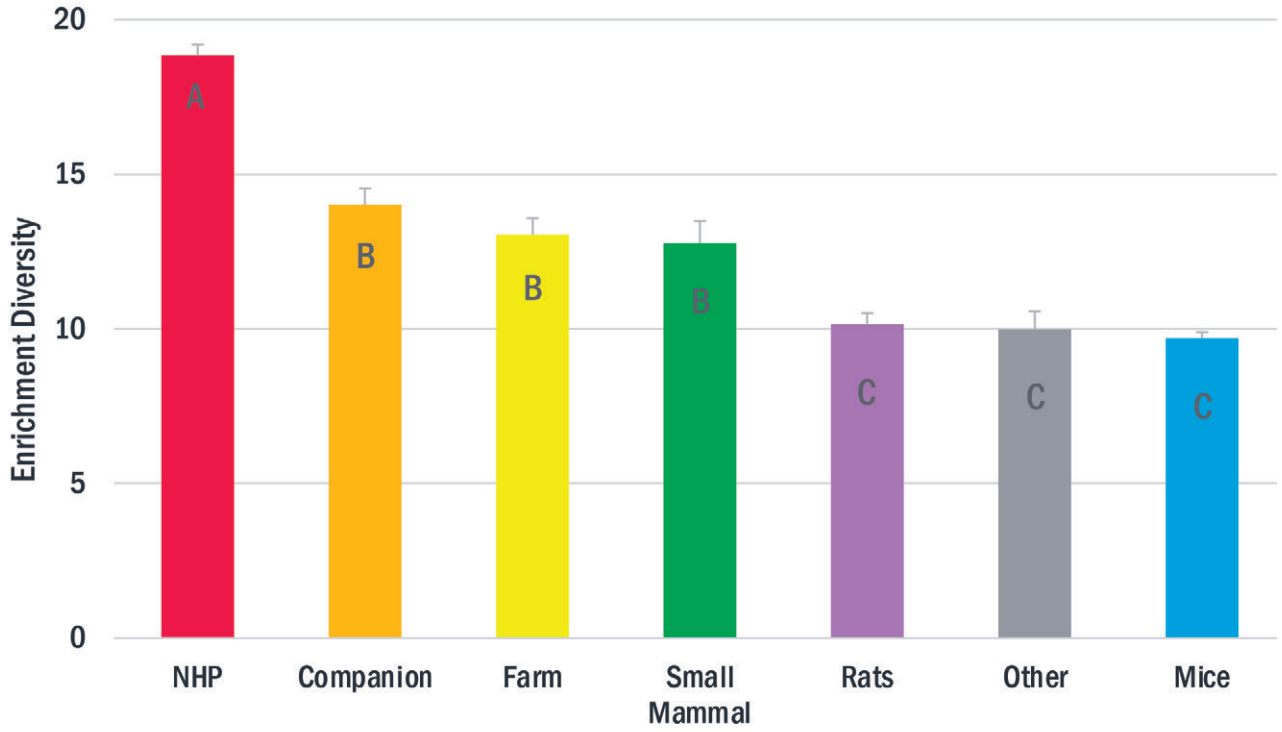

Figure 3. Enrichment diversity by animal types. Rats, mice, and other animals receive half the enrichment diversity of nonhuman primates. Respondents ($n = 1098$) reported the types of enrichments used with the animal type they worked with most. Approximate enrichment diversity was calculated as a sum of the number of different types of enrichments used. The data graphed are least squares means and standard error. Different letters indicate a significant difference in a posthoc Tukey HSD test ($P < 0.05$).

whereas rats, mice, and 'other' received the least. Greater diversity was provided by individuals with greater control over enrichment, those working longer in the field, and those working in Canada compared with the US. In terms of role, principal investigators provided less enrichment diversity than trainers, veterinarians, veterinary technicians, laboratory technicians, or other workers (Tukey, $P < 0.05$).

Discussion

This is the first large, cross-sectional study to benchmark and identify factors associated with the frequency and diversity of enrichment provided to research animals. We received survey responses from 1098 personnel in the US and Canada who worked with a variety of different species, research types, and institutions. Results indicate that in this sample, implementation of enrichment is associated with animal type, category of enrichment, personnel control over enrichment, desire to provide more enrichment, country, role, and years working in the field. For enrichment diversity, rats, mice, and other animals received only half of the amount of enrichment diversity as compared with NHPs. The frequency of provision of enrichment showed a complex interaction between animal type and category. Overall, NHPs received enrichment more often than other animals in most enrichment categories. In addition, physical, nutritional, and sensory enrichment was provided much less frequently than other categories, especially for species other than NHPs. Finally, enrichment frequency and diversity were not associated with the reported research pain/invasiveness category. We will briefly review some key enrichment recommendations for several species based on category. However, this discussion is

not a comprehensive review and does not recommend specific enrichment protocols for any particular species.

Enrichment categories and species types. Before discussing our results and relevant literature, we want to emphasize a few key principles of enrichment provision that should be considered across enrichment categories. The ideal enrichment program is based on familiarity with the animal's natural environment and its species-specific behaviors in that environment. In turn, enrichments should be designed to promote these behaviors and improve animal welfare.[101] Many effective enrichments increase an animal's control of their environment through choice.[14,115] For any enrichment, the physical items should be safe and available in an adequate number per animal, and the animals' behavior should be carefully monitored after introduction of any new items. These principles of enrichment provision are important because natural but unwanted, behavior can develop, such as guarding of highly valued physical enrichments[34] which can potentially lead to aggression.

Social housing. In this survey, social housing was the enrichment that was used most often for most types of animals, although with differences in total frequency. Social housing allows social species to express key species-specific behaviors and is also one of the most inherently dynamic types of enrichment that animals can receive. Furthermore, social housing is required by *The Guide*[58] and *CCAC Guidelines: Husbandry of animals in science*.[17] Single housing must be justified and approved by institutional review bodies.

Nonetheless, our results indicate the potential to provide more social housing. For example, NHPs only received social housing 77% of the time despite considerable evidence that social housing is crucial for their welfare.[4,29,97] Our results are similar to those of a 2014 survey of NHP facilities in the US in which 83% of primates were housed socially.[3] This percentage could be deemed low given community and regulatory efforts to disseminate housing and management strategies to facilitate social housing. Generally, single housing is used due to either research protocol requirements (for example, after surgery or for monitoring) or animal-related adjustment problems, such as aggression.[3,28,76,111] However, strategies are available for establishing and maintaining harmonious social groups for NHPs, mice, rats, and rabbits.[45,60,77,111] Many types of animals benefit from stable groups,[80] especially with siblings.

Our results indicate an opportunity to refine housing and management practices in order to increase the use of social housing for all social species. Our results also indicate that more strategies may be needed for mitigation of intraspecies aggression and safe social housing after surgical procedures. With the expansion of in-cage monitoring technology,[6] research situations that are currently considered incompatible with social housing should be reevaluated.

Human-animal interactions. Human-animal interactions were the second most frequent type of enrichment provided to most animal types. Human-animal interactions are a significant part of the lives of all research animals and can have a large impact on welfare.[51,69,113] All species can likely benefit from positive reinforcement training and low-stress handling, both of which promote control and predictability in their environments.[113] However, frequency of overall human-animal interaction also had the largest variation in use among animal types, ranging from 33% of the time in mice to 76% of the time in companion animals.

NHPs received human-animal interactions 71% of the time. Participants reported providing their NHPs, at least sometimes, with positive reinforcement training (97% of participants), low-stress handling (93%), habituation (85%), and verbal interaction (96%). In particular, training NHPs with positive reinforcement techniques has been well established as beneficial to care, management, and welfare.[91] Human-animal interaction enrichments were also commonly provided to companion animals and farm animals. For both animal types, the benefits of human-animal interaction have also been relatively well established.[11,35,46,48]

Animals in the small mammal (rabbits and guinea pigs) and other (birds, fish, amphibians, and reptiles) categories received human-animal interactions in intermediate frequency. This frequency may be related to a less robust literature on enrichment in these species, which may, in turn, be related to their less frequent use in research (with the exception of zebrafish). Conversely, enrichment-related human-animal interactions were provided even less often to rats and mice, despite recent publications on refined handling methods[42] and rat tickling.[71,72] Thus, our results and published literature suggest an opportunity to increase implementation of positive human-animal interactions for mice, rats, small mammals, and possibly other animals.

Physical and occupational enrichments. Physical and occupational enrichments were provided less frequently than social or human-animal interactions, but more often than the other categories of enrichment. Physical enrichments are well known, commonly promoted in regulatory documents, and may take less time to implement than do human-animal interactions. Our results again could indicate an opportunity to use physical enrichments more often. Beneficial enrichments could include providing nesting material to mice or rats to allow them to build nests,[39,95] providing chews to rats to allow them to gnaw,[53] and providing multilevel housing or elevated platforms for primates, cats, and dogs to allow them better visual vantage to survey their environment.[26,52,55,60,92,96,105] Multilevel housing or elevated platforms also allow better control of interactions with cage mates, such as allowing mothers to move away from their offspring.[94] Based on this published literature and our survey results indicating relatively low provision of these enrichments, the opportunity exists to increase provision of chews to rats and multilevel housing for companion animals, rats, and mice.

Several other types of physical enrichments could also benefit a variety of species. Enclosures like tunnels and huts generally seem to be beneficial for cats, rats, and mice.[52,95] Primary enclosures that are greater than the minimal size can allow more choice and movement options for mice and rats, including the ability to better segregate clean and dirty areas.[96,95] Straw is considered an enrichment that provides rooting opportunities for pigs[112] and that promotes both play and provide a comfortable resting area for cattle.[80] Running wheels provide mice and other rodents with the opportunity for exercise,[86,110] although these should be used with caution due to potential contraindications.[75,81,109] Some additional beneficial physical or occupational enrichments may include objects that provide cognitive stimulation and physical conditioning,[82] such as puzzle feeders, exercise opportunities, and play pens.[50,93] Puzzle feeders, such as food pellets embedded in a wooden board, may be beneficial for rats.[61,68] This published literature and our survey results suggest an opportunity to provide larger housing, resting areas, and exercise opportunities for mice and rats. Puzzle feeders could be beneficial for companion animals, mice, rats and some farm animals.

Nutritional enrichments. Nutritional enrichments were the second least frequent enrichment for most animal types, which

could indicate an opportunity to provide more enrichments of this type. However, "live food" was one of the 3 possible categories under nutritional enrichment. The use of live food was extremely low for most animal categories, which lowered the overall frequency of provision for nutritional enrichment. Many types of animals do not normally eat live food in nature, and potential welfare issues arise even with regard to animals that do. Therefore, the lower frequency of this category compared with others may be both expected and appropriate.

We evaluated 2 other types of nutritional enrichments that could be beneficial for many animals: scattered food and treats. Foraging is a strongly motivated natural behavior since research species in their natural environments would spend a large proportion of time searching for, obtaining, and consuming food. Many studies on a variety of species have shown that food puzzles reduce stereotypes, increase behavioral diversity, mitigate obesity, and reduce a variety of 'problem behaviors.'[10,23,56,79,104] In addition, several types of animals, including most farm animals, guinea pigs, rabbits, and hamsters, benefit from roughage, often in the form of hay.[7] Strategies such as scatter feeding or mixing food with bedding or nesting material requires minimal effort and is highly beneficial for most animals. In addition, few animals would eat a completely repetitive diet in nature, such that providing treats could introduce variety and stimulation and can be combined with positive reinforcement training. However, neophobia to new food items can arise in several species,[80] and some areas of research may have strict food requirements; both factors may affect implementation of nutritional enrichment. In our survey, puzzle feeders were categorized in the physical/occupational category of enrichment, although it could be considered to overlap between categories. Despite these limitations, knowing the current use of different types of nutritional enrichments is nonetheless useful.

Sensory enrichments. Sensory enrichments were used the least often for nearly all animal types. However, some specific enrichments such as mirrors and colors may be inappropriate for species with poor visual acuity. Therefore, a lower frequency for this category may be expected and appropriate. In addition, this lower frequency of use of sensory enrichment may be related to relatively scarce research, especially for some species, and research that sometimes has unclear conclusions[114] that are perhaps attributable to study designs.[66]

For auditory enrichment, music can be used for differential effects such as masking aversive sounds, providing stimulation and environmental complexity, and modulating arousal.[66] There is relatively limited evidence to indicate that 'natural' music has welfare benefits.[114] However, 'calming' music in the form country and classic music have a somewhat greater literature base showing benefits for certain species such as cattle, poultry, and pigs.[19,65,80,114] Audiobooks have also shown some potential for enrichment for dogs.[13] In addition, although the prevalence of this strategy was not evaluated in this survey, there is some evidence that simply reducing ambient noise, such as clanging metal, may be beneficial.[80,114]

For visual enrichment, some data suggest that mirrors can be beneficial, especially for single-housed animals and for cattle,[80] rabbits,[21] sheep,[89] NHPs, and pigs,[114] but they may be aversive to mice.[102] The color red may also be aversive to some species[114] including mice.[41,103] We did not evaluate visual enrichment in the form of viewing conspecifics in adjacent housing, which may be especially beneficial for animals that cannot be pair housed. One subtype of sensory enrichment that was not evaluated in this survey is tactile enrichment such as access to various surfaces or brushes; this type of sensory enrichment could also be beneficial to some species.

In natural environments, odor is essential for finding food, recognizing social partners, and avoiding predation. Thus, olfactory enrichment provides the potential to promote beneficial behaviors. Olfaction can be stimulated from scents from a natural environment, essential oils, or pheromones.[114] However, current research into olfactory enrichment is sparse.[20,80,85] For cats, some evidence suggests that cinnamon, catnip, and prey scent can promote activity.[22,33,119] For dogs, some evidence supports welfare benefits of using dog-appeasing pheromone and a variety of scents (such as prey scents, vanilla, and lavender).[1,12,84] For NHPs, the evidence supporting essential oils is unclear.[108,116] Diverse smells could be part of the reason that periodic access to play pens or novel environments is beneficial for mice, cats, and dogs.[25,93] However, new approaches should be carefully evaluated for each species, especially because some scents that humans find pleasant (for example, lavender) can result in aggression in some species.[40]

Based on our survey results and published research, implementation of sensory enrichment is beneficial for some species[20,85] and should be promoted. Ultimately, before implementing any new enrichment, consideration should be given to relevance to the species and to evaluating its effects on individual animals.

Enrichment diversity. Overall, NHPs received a higher diversity of enrichment than did other animal types. Furthermore, companion, farm, and small mammals received more diverse enrichment than did rats, mice, and other animals. This result is unsurprising due to more extensive regulatory requirements to provide diverse enrichment to NHPs.[2] The ratio of staff to individual animals may also be a factor. In addition, more items in our enrichment questionnaire were relevant to NHPs compared with other species. For example, colors, mirrors, and music are less likely to be beneficial to mice and rats based on their visual and auditory spectra.[74,107,114] Regardless, diverse enrichment might be beneficial for all species in order to promote a diversity of natural behaviors, thereby improving welfare.[83,118]

Broad differences in enrichment due to animal type. Data from this survey indicate that NHPs receive the most frequent and diverse enrichment. After NHPs, companion animals (and sometimes farm and small mammals) generally received more frequent and diverse enrichment. These findings may be due to increased regulatory oversight and targeted guidance for species that are covered under the Animal Welfare Act (NHPs and companion animals).[2] In addition, NHPs hold a closer phylogenetic relationship and, subsequently, have physical and behavioral similarities to humans that may invoke greater empathy and attention.[31,88] Furthermore, both companion and farm animals have close domesticated, societal relationships with humans[30,64,88] as compared with mice and rats, which are commonly viewed as pests. Both NHPs and companion animals are viewed as being cognitively more similar to humans and as having greater cognitive complexity.[32,64,88] Finally, far greater numbers of mice and rats are used in research,[18] such that the ratio of staff to individual animals is much lower, which may limit the opportunity to provide extensive enrichments.

Although we have already recommended the use of different enrichment types in preceding sections, we again highlight mice and rats. Despite being the most common mammalian species used in research, participants in this study reported that they received the least frequent and diverse enrichment per our questionnaire. However, not all types of enrichment that we asked

about would be relevant to these species. Nonetheless, mice and rats would potentially benefit from increased provision of many of the types of enrichment that NHPs and companion animals receive. This difference may indicate an opportunity to improve the welfare of millions of animals.

In previous studies, key barriers cited to providing more enrichment or 3Rs replacements included time, perceived ease of use with current resources, personnel buy-in or education, cost, and potential effects on research.[70,78,87] Despite these barriers, a few key actions could improve rodent enrichment based on our benchmarking dataset and related publications. Two recent independent reviews and meta-analyses indicate consensus and provide evidence supporting social housing, wheels, nesting materials, foraging opportunities, gnawing opportunities, shelters, and larger cages.[1,3] Although social housing of mice seems adequate in this dataset, rats received social housing significantly less frequently than mice. Mice and rats also received far fewer occupational and physical enrichments, including larger housing, chews, exercise opportunities or multilevel housing. Finally, human-animal interactions could be improved by using low-stress handling in the forms of tunnel handling or cupping for mice[57] and tickling for rats.[72]

Control over enrichment provision and desire to provide more enrichment than the status quo. Personnel who reported having more control over enrichment also indicated that they provided enrichment more frequently. This suggests that if given the opportunity, personnel would provide more enrichment for animals more and that empowering personnel across job categories to provide enrichment could create higher levels of enrichment. Previous research indicates that personnel enjoy providing enrichment for animals, even when it requires additional time.[71] Alternatively, institutions or roles that give individuals more direct control over enrichment may also have policies that provide more enrichment, which could be related to a positive culture of care.[47]

In addition, our results indicated that enrichment was provided less often by personnel who more strongly agreed with the statement "I wish I could provide more enrichment to my animals than I currently do." This result seems to indicate that personnel feelings about enrichment are related to the degree of its provision. That is, staff who felt that their animals were adequately enriched and therefore did not need additional enrichment also reported high levels of enrichment provision. The personnel who wished they could provide more enrichment also reported higher compassion fatigue. High burnout has also been associated with less diverse/frequent enrichment provision.[73] Conversely, personnel desire to provide enrichment beyond the status quo was not related to reported enrichment diversity. This lack of correlation may indicate that staff may not consider diversity of enrichment when assessing the overall adequacy of enrichment.

Animal stress/pain. The level of stress or pain that animals may experience, as reported by survey participants, was not associated with enrichment diversity or frequency. However, a low number of respondents worked mostly with animals that experienced severe pain and distress ($n = 34$) and therefore conclusions about this category of pain/stress should be made with caution. However, these findings could be related to institutional standardization in that all animals of a given species receive a predetermined enrichment repertoire regardless of their pain or stress. However, the specific type of enrichment provided could be adapted to animals in greater stress or pain (for example, providing a hut instead of a nest) or additional refinements that traditionally are not viewed as enrichments (for example, easier food/water access, pain relief). These types of modifications would not have been detected in our study.

US compared with Canada. In this survey, higher overall levels of enrichment were reported in Canada as compared with the US. Anecdotally, animal research professionals have made this assertion, but we are not aware of any prior publications that have confirmed this assertion. This finding has several possible explanations. It may be related to differences between assessment and certification of institutions in the US and Canada, particularly in terms of what guidelines are followed. In the US, the *Guide for Care and Use of Laboratory Animals* is used by most institutions; it was last updated in 2011 and generally addresses environmental enrichment across species with relatively limited recommendations for particular species. In contrast, in Canada work is ongoing to replace the cross-species *CCAC Guide to Care of Use of Experimental Animals vol. 2* (1984) with specialized guidelines for each species. Updated guidelines have been developed for farm animals (2005), and NHPs (2019), amphibians (2021), mice (2019), rats (2020), and zebrafish (2020); guidelines for dogs, fish, hamsters and guinea pigs, reptiles, and wildlife were all in final draft stage in early 2023. Although several of these guidelines were released after our survey was conducted (February/March 2018), revisions of guidelines typically take several years and include public consultations. In addition, a general guideline regarding husbandry that was published in 2017 emphasized the importance of environmental enrichment, exercise, and human contact for all species. In Canada, CCAC assessments provide an opportunity to share good practices related to husbandry, care, and experimental procedures.

Limitations. Our study has a few limitations that are inherent in trying to compare enrichment across animal types and categories. First, we asked about the same specific types of enrichment for every species (except for rats) even though all of these enrichments would not necessarily be beneficial to all species. For example, participants were asked about the provision of mirrors for mice, even though mirrors are unlikely benefit mice due to their poor visual acuity[74] but they may be beneficial for other species such as pigs,[24] NHPs, cattle, and rabbits.[114] Thus, even though rodents had lower enrichment scores than NHPs, they could still be receiving an adequate level of species-appropriate enrichments. A second limitation is that each category of enrichment in the survey had a different number of individual items. For example, social housing had only one item while the physical category had 11 items (for example, nesting material, multiple levels). Therefore, categories with more items could inherently have lower frequency scores because they were averaged across a diverse list of items. We recommend that readers who are interested in a specific species delve into the data included in Table 2. Despite these limitations, our study nonetheless provides valuable, broad-scale data on current enrichment practices across a wide range of conditions. This information can be used to prioritize areas for improvement of an enrichment program, identify areas where data are lacking, develop standards, and coordinate stakeholder efforts.

Our study was also limited with regard to the survey design. First, as this study was cross-sectional, we could not determine the causation of the identified associations. For example, we cannot determine whether giving personnel with more control over enrichment would actually lead to more enrichment, or if institutions or roles that provide an individual with more control over enrichment also have policies that allow greater animal enrichment. However, future studies could investigate

this using an empirical intervention study in which individuals are randomly assigned with more or less control to evaluate causality. In addition, we cannot provide a definitive reason for why some animal types, or enrichment categories, were provided or used more often. Future studies could conduct interviews asking participants to provide the rationale for enrichment choices or provide education to some individuals to test whether their practices change.

Finally, because this was a voluntary, survey-based, convenience sample study, the participants may not be representative of the population and results could have been affected by sampling bias. Although we had a substantial number of respondents (1098), multiple individuals from a single institution, all working with the same species, could have answered our survey, thus biasing results. The open survey strategy used in this experiment and our desire to retain anonymity for institutions and work affiliations precluded overcoming this limitation. Thus, the data presented here are not facts but rather are a first glimpse into the types of enrichment and diversity of enrichments that are provided to different species.

Conclusion: A Potential Opportunity to Provide More, Diverse Enrichment

Taken together, our results provide benchmarking data regarding key differences in the frequency and diversity of enrichment provided to different species used in research. This data may suggest that more frequent and more diverse enrichment could be beneficial, especially for species other than NHPs. The study provides the research animal field with valuable exploratory benchmarks on enrichment across animal types. Clearly, a one-size-fits-all approach is not warranted when providing environmental enrichment. Enrichment should be carefully evaluated for each institution, species, and facility type. However, more efforts could be warranted to improve the frequency and diversity of enrichments for all species and to ultimately allow animals improve their wellbeing by expressing important species-specific behaviors.

Supplemental Materials

Supplemental Table 1. Complete questionnaire and coded values.

Supplemental Table 2. Summarized data used in analysis. (One response per participant and enrichment category).

Supplemental Table 3. Cleaned participant responses. (One response per participant).

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