Journal of Veterinary Behavior 75 (2024) 1–19

Contents lists available at ScienceDirect

Journal of Veterinary Behavior

journal homepage: www.elsevier.com/locate/jveb

Exploring pet rat care: A comprehensive survey of husbandry, health, behavior, and the associations between caretaker attitudes, attachment, and husbandry practices

Stephanie Schneidewind [a,*], Raffaela Lesch [b], Veronika Heizmann [a], Ines Windschnurer [a]

[a] Center for Animal Nutrition and Welfare, Clinical Department for Farm Animals and Safety of Food Systems, University of Veterinary Medicine Vienna (Vetmeduni), Vienna, Austria
[b] Department of Biology, University of Arkansas at Little Rock, Little Rock, Arkansas

ARTICLE INFO

Article history:
Received 23 March 2024
Received in revised form 27 May 2024
Accepted 25 June 2024
Available online 5 July 2024

Keywords:
Pet rats
Animal welfare
Husbandry
Behavior
Health
Human-animal relationship

ABSTRACT

Pet rats are still understudied in terms of animal welfare and human-animal interaction research. An extensive online survey targeting German-speaking rat caretakers was conducted (n = 978). One of the study's goals was to investigate husbandry practices, health indicators, rat behaviors that suggest either good or compromised welfare, as well as elements of the human-animal relationship, including interactions between humans and animals, caretaker attitudes, and attachment. The second aim was to explore the associations between caretaker attitudes and attachment, and caretaker behavior, encompassing routine health checks, interactions between humans and animals, as well as the activities and enrichment provided to rats. In some instances, welfare issues were identified: insufficient space (evident in 10.6% of rats), provision of unhealthy snacks (14.6%). The vast majority of rats enjoyed a variety of enrichment objects, e.g., huts/houses (98.4%), nesting material (92.7%), hammocks (91.7%), and tunnels/tubes (83.7%). The average amount of space and time provided for roaming in case of no permanent roaming possibility (13.9 m^2 and 2.5 h per day) was positive in terms of welfare. About 79.0% of rats did not suffer from a disease diagnosed by a veterinarian. Repetitive behaviors, which may represent stereotypies, were uncommon (plucking out own fur and cage bar chewing occurred "never" in 99.1% and 81.5%). Indicators of good welfare (e.g., self-grooming, rearing, eye-boggling) were observed several times/day in 89.6%, 46.7%, and 11.6% respectively. Caretakers who formed strong bonds with their rats tended to express positive general attitudes (such as finding rats "lovable" and "fun"), while showing little agreement with statements reflecting negative attitudes (like considering rats "dirty"). About 84.4% reported stroking their rat, 94.9% reported talking to it, and 70.9% mentioned hand-feeding their rat several times per day. Caretaker attitudes and attachment and human-animal interactions and caretaker behaviors correlated weakly but consistently ($P < 0.01$): respondents who felt more comfortable during positive interactions, stroked, hand-fed their rats, offered rat-friendly enrichment and performed health checks more often. In contrast, higher agreement to rats being "dirty" related to less frequent health checks and less frequent positive human-animal interactions. The identified relationships between caretaker attitudes and behaviors can help design interventions to promote caretaker behavior that is beneficial for rat welfare.

Introduction

Rats are among the most well-studied animals, yet there is limited knowledge regarding the welfare and human-animal relationship of rats kept as companion animals (Hou and Protopopova, 2022). A solid base of data on pet rat husbandry, health, behavior, human-rat interactions, and caretaker attitudes is crucial to provide a baseline for welfare assessments, husbandry practice recommendations, and finally, behavioral consultation.

In the scope of literature outlining husbandry practices for exotic pets, rats are represented by a small fraction (e.g., Normando and Gelli, 2011; Bläske, 2019). A study based on an online survey focused on the health and husbandry of pet rats kept in the United Kingdom (Neville et al., 2021). In the context of this study, the "good" aspects

* Address for reprint requests and correspondence: Stephanie Schneidewind, Center for Animal Nutrition and Welfare, Clinical Department for Farm Animals and Safety of Food Systems, University of Veterinary Medicine Vienna (Vetmeduni), Veterinärplatz 1, Vienna 1210, Austria.
E-mail address: stephanie.schneidewind@outlook.de (S. Schneidewind).

https://doi.org/10.1016/j.jveb.2024.06.009

of rat husbandry included the finding that pet rats were predominantly housed with a conspecific, offered enrichment items, and enjoyed a strong caretaker-rat bond. Factors compromising rat welfare included potential inadequacies in meeting nutritional requirements, a high incidence of keeping rats near predator species, and the use of potentially dusty litter, which could negatively impact rat health. Though the research conducted by Neville et al. (2021) is extensive, further research on feeding, housing (e.g., type of enclosure), and healthcare practices is necessary to gain a more in-depth insight into husbandry practices concerning pet rats. In addition, it is unclear whether the findings by Neville et al. (2021) are likely to represent the status quo of husbandry practices in other countries. The most recent insights into the husbandry of pet rats in German households were provided by a survey on exotic pets, where 2.2% of participants (64 of 2,939) answered questions regarding pet rats (Erhard, 2017). These questions covered housing, enrichment, and nutrition. The study found that not all pet rat caretakers met nutritional requirements, nor the basic legal requirements for housing size, some did not provide physical enrichment, and a small number kept their rats in solitary housing (Erhard, 2017). Solitary housing affects behavioral and physiological indicators of rat welfare negatively (Burman et al., 2008). Thus, scientific literature agrees that single housing impairs rat welfare, especially if enriched housing environments are not implemented to reduce the effects of social isolation (Krohn et al., 2006). Erhard (2017) demonstrates that there are problems regarding pet rat husbandry practices, based on a low sample size. A larger sample size in a questionnaire focusing solely on pet rats is necessary to further identify widespread and/or common problems of rat-keeping more clearly in German-speaking countries.

Concerning the health of pet rats, respiratory disease is a common clinical presentation in pet rats (Donnelly, 2004; Graham and Schoeb, 2011; Rey et al., 2015), which can result from stress, poor nutrition, and environmental factors (Rey et al., 2015; Schoeb, 2000). Neville et al. (2021) identified a high prevalence of health issues in pet rats in the UK, with a particular emphasis on respiratory issues. Rey et al. (2015) reported that apart from rhinitis, mammary gland tumors were the most common diagnoses among rats presented in three French clinics. Moreover, dermatological problems are a common issue veterinarians face when treating pet rats (Donnelly, 2004; Hoppmann and Barron, 2007; Palmeiro and Roberts, 2013; Sinclair, 2021). Khelik reported that reproductive disease in female rats was relatively frequent. Research looking into premature death in pet rats found respiratory and neoplastic diseases to be the most common underlying condition (Everaars, 2011; Benato, 2012; Reavill and Imai, 2020; Sinclair, 2021). Overall, quantitative data concerning the prevalence of diseases commonly described in pet rats are still limited and may differ in different regions. Furthermore, no study has looked into weight in pet rats (McPherson et al., 2019), although weight is highly relevant to a rat's health status.

Regarding behavioral indicators of welfare, research on lab rat behavior identified self-grooming, rearing, eye boggling and teeth chattering ("bruxing") as indicators of good welfare (Mason et al., 2006; Turner, 2014; Kalueff et al., 2016; Neville et al., 2022). In contrast, repetitive behaviors, agonistic behavior, aggressive grooming, and bar-chewing are commonly seen as indicators of impaired welfare in lab rats (Hurst et al., 1999; Burman et al., 2008; Abou-Ismail et al., 2010). To our knowledge, the only extensive study on the frequency of various behaviors concerning pet rats, apart from the information about three rats in a study on exotic pets by Normando and Gelli (2011), is an online survey on pet rats in the United Kingdom (Neville et al., 2022). These authors investigated 16 different rat behaviors and identified potential indicators of welfare in pet rats. For instance, they described that digging, bounding (a ricocheting jump), pinning, and teeth chattering were significantly reduced by greater exposure to predator species, while biting humans was significantly increased. Repetitive behaviors, such as running in continuous circles, tail-chasing, doing somersaults, whipping of the tail, and trembling of the body or tail, were not addressed in the study.

Neville et al. (2022) also addressed three types of human-animal interactions, namely handling frequency, training the rat to perform tricks, and the frequency of the rat climbing onto hands, arms, or shoulders. Further aspects should be addressed in greater detail. Caretakers actively interacting with their rats is a part of a rat's social enrichment and an important aspect of the human-animal relationship, thus a crucial part of rat welfare (Cloutier et al., 2013; LaFollette, 2020). Passive interactions, such as resting next to or on the caretaker, also provide information on the human-animal relationship but have not been investigated so far.

Neville et al. (2022) collected information about what rat caretakers liked and disliked about rats, which allowed the first insight into attitudes towards pet rats. This is another aspect that warrants further systematic investigation. Caretaker attitudes and attachment toward animals affect human-animal interactions and decision-making, including which housing conditions and activities they provide (Waiblinger, 2019; Windschnurer et al., 2022). This aspect has not been investigated specifically for rats so far.

One of the aims of the study was to provide an insight into the husbandry, health, and behavior of pet rats and into the human-animal relationship using an online survey. We placed a focus on potential welfare issues such as inappropriate housing or health problems as well as the occurrence of behaviors indicative of impaired or good welfare. We further aimed to investigate associations between caretaker attitudes and attachment and husbandry practices, represented by caretaker behavior including routine health checks, human-animal interactions, activities, and enrichment provided to their rats. With this study, we aim to provide a baseline from which we can further develop and refine rat welfare assessment tools, guidelines for the pet rat community, and further knowledge to support behavioral consultation. Finally, we also aim to identify attitudes that could be targeted to promote caretaker behavior that is beneficial for rat welfare.

Methods

The project was submitted to the ethics committee of the University of Medicine, Vienna. Due to the study design, an ethics vote was not necessary, following guidelines for Good Scientific Practice and with Austrian national legislation. In the introduction of the questionnaire, participants were informed about the aims and conditions of the study and that they could end their participation at any given time. They were asked to provide informed consent before they could continue with the actual questionnaire.

Questionnaire development

A questionnaire was developed to outline aspects of housing, husbandry, health, behavior, and the human-animal relationship, including human-animal interactions as well as caretaker attitudes and attachment towards their rats. The questionnaire was based on an extensive literature review and a questionnaire for caretakers of pet ferrets. In a sample survey that was run as a trial before the actual survey, four rat caretakers completed the questionnaire. Feedback regarding the comprehensibility of questions and whether the answer options were appropriate and sufficient was provided. Based on the feedback, the questionnaire was revised to eliminate ambiguities. The survey software "SurveyMonkey" was used to program the final questionnaire online.

Questionnaire content

The questionnaire included both closed-ended questions (single-choice, multiple-choice, and scale questions) and open-ended questions, gathering specific and detailed information on housing, husbandry, health status, behavior, the human-animal relationship, and demographic data. To reduce drop-out rates and to increase the quality of answers, the forced choice answer format was avoided throughout the questionnaire. As a result, the sample size of responses varied. The final questionnaire contained 71 question blocks with sub-questions, leading to a total of 240 questions. For an overview of the questionnaire sections and their content see Table 1. The survey was designed to take approximately 25 min. Participants who indicated that they currently own no rats were disqualified from the questionnaire. In the introduction of the questionnaire, which also contained the informed consent section, participants were informed that the survey was intended to provide an overview of the husbandry situation of rats, their behavior and the human-animal relationship, as well as to examine potential associations between these areas. The text reads as follows: "Dear Rat caretaker, this survey aims to provide an overview of the living conditions of rats, their behavior, and the human-animal relationship, as well as investigate possible associations between these areas. Please ensure that the primary caretaker of the rats currently living with you fills out the questionnaire. The primary caretaker is the person who takes care of the rat(s) the most (feeds them, spends the most time with the animal(s)). If the primary caretaker is a minor, we ask that an adult completes the questionnaire together with the minor."

After general questions concerning all rats living in the caretaker's household at the time of the survey, questions regarding housing, husbandry, health, and behavior related to only one animal, the so-called "A-rat" (cf. Rooney et al., 2014). In multiple-rat households, this refers to the rat whose name would come first if sorted in alphabetical order. This approach aimed to gather more objective data by preventing any unconscious bias toward selecting the oldest, most active, or most trusting animals. Henceforth in this paper, we will refer to the "A-rat" as the "focus rat".

Repetitive behaviors that could represent stereotypic behavior are referred to as "repetitive behaviors" from now on since no diagnosis is possible in the context of a survey. Attitude questions were created based on previous questionnaires assessing the human-animal relationship in cattle, cats, and dogs (Waiblinger et al., 2002; Windschnurer et al., 2009; Arhant and Troxler, 2014; Arhant et al., 2015). General attitudes that targeted beliefs about general characteristics of rats were assessed using a 7-point Likert scale ranging from "strongly disagree" to "strongly agree". A high score indicated that participants strongly agreed. For the assessment of affective attitudes, also a 7-point Likert scale was used, ranging from "feel very uncomfortable" to "feel very comfortable". A higher score indicated that participants rated contact during a certain situation as more comfortable. Attachment to the focus rat was assessed using the "*Comfort from companion animal scale*" originally used in cats and dogs (Zasloff and Kidd, 1994; Zasloff, 1996), using a Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). Two of the 13 items ("My pet makes me feel safer" and "I get more exercise because of my pet") were not included because these items were excluded in a second analysis by Zasloff (1996) since they seemed to be more relevant in the context of dog owners.

Recruitment of participants

The questionnaire was available in German for five weeks with a permanent web link between September 7, 2020 and October 14, 2020. The survey was advertised in online portals (German-speaking rat groups on Facebook and the official Facebook page of Vetmeduni) with an advertising text and a flyer. The advertising text was the following: "Attention Rat Owners! Join and Win: We are keen to delve into the care, behavior, and human-animal bond concerning

Table 1
Description of the survey sections.

Section	Items included
General information about all rats currently living in the respondent's household	number of rats currently living in the household; hours/day respondent (main caretaker) spends caring for the rat(s), including supply with food, care, other activities such as training, play, petting, cleaning activities, reason(s) for keeping rats;
General information about the focus rat	sex, castration status, current age, amount of time under the care of the current caretaker, physical characteristics (fur type, color, coat type, special physical characteristics), where the rat was adopted from
Housing, roaming opportunities, enrichment, and social management	type of enclosure, dimensions of permanently accessible floor space, number of elevated spaces, access to additional space for roaming (if yes, frequency and duration), group composition (sex and castration status of additional rats kept in the same enclosure, age of the youngest, and oldest rat of the group, time of enlargement/reduction of the group size within the last year), frequency of various activities, frequency of availability of certain housing supplies and enrichment
Nutrition	type of food and frequency of feeding
Husbandry routines	frequency of various care and maintenance activities (e.g., cleaning of the enclosure, grooming, and certain health checks); veterinary visits
Health of the focus rat	current health status, potential diseases, body weight
Behavior of the focus rat	frequency of occurrence of certain behaviors in the past month selected as potential indicators of reduced (e.g., self-injury, chewing on cage bars) or good welfare (e.g., eye-boggling (eyeballs vibrate rapidly in and out of the socket), teeth chattering, rearing); frequency of occurrence of certain behaviors towards conspecifics and the main caregiver in the past month, which could indicate problems (e.g., aggressive behavior such as biting, scratching, chasing, tearing out fur of conspecifics) and indicators of a harmonious coexistence (e.g., playing, allogrooming, huddling)
Human-animal relationship	respondents' attitudes towards rats in general (level of agreement to statements such as "Rats are aggressive", "…intelligent" or "curious"; affective attitudes (degree of comfort felt during contact with the animals in different situations such as feeding, observing, stroking;), attachment to the focus rat (using the ("*Comfort from companion animal scale*" by Zasloff (1996), developed to measure the perceived level of emotional comfort that caretakers receive from their pets); time/day respondent spends directly/engaging with the focus animal (with activities like hand feeding, stroking, playing, training, observing), frequency of human-animal interactions (e.g., talking to the animal, stroking, carrying the rat around, teaching tricks)
Demographic information	details about the main caregiver (age, sex, education, occupation, country, size of place of residence, and number of persons in the household of the respondent

your beloved pet rats! By sparing just around 30 min of your time to complete our questionnaire, you stand a chance to win fantastic rat-related prizes such as toys and books, while also making a significant contribution to an ongoing scientific study at Vetmeduni Vienna. Access the survey through this link: https://de.surveymonkey.com/r/Rattenhaltung should you have any inquiries, do not hesitate to reach out via email at http://Rattenumfrage@vetmeduni.ac.at. Rest assured, your participation is entirely anonymous, and all your data will be handled with utmost confidentiality!". Furthermore, veterinarians specialized in small animal medicine in Germany, Austria, and Switzerland were contacted with the request to inform rat caretakers about the survey. To increase motivation among respondents, the opportunity to participate in a raffle for rat supplies and books about rat care was offered to those participants who completed the entire questionnaire. Participants could choose to participate or not in the raffle and in case of participation they were asked to provide their preferred choice of contact (e.g. email, telephone, postal address).

Data analysis

All data were exported into the current version of the statistics program IBM SPSS Statistics for Windows, Version 29.0 (IBM Corp., Armonk, N.Y., USA), in which the data was analyzed.

In total 984 questionnaires were analyzed. Originally, 1057 participants took part in the survey. However, 72 people were disqualified after stating that they currently kept no rats. After plausibility checks, the information provided by one participant was not included in the analysis due to a significant similarity to a previous questionnaire, suggesting a potential duplication. This individual likely abandoned the survey and responded a second time; thus, the data from the more complete questionnaire were used for data analysis. Participants were not excluded based on age.

Principal component analysis (PCA) with Varimax rotation was performed to reduce and summarize general and affective attitudes as well as caretaker behavior (frequency of offering different enrichment materials, frequency of health checks and care). We also performed a PCA with the attachment questionnaire items to test if all items would have sufficiently high component loadings on a single component to be able to compare the Comfort from Companion Animal scale similar to Zasloff's results (Zasloff, 1996). The data were suitable for Principal component analysis, as confirmed by the Kaiser-Meyer-Olkin criterion of sampling adequacy, which was 0.6 or above, and Bartlett's test for sphericity, being significant ($P \leq 0.05$) (Pallant, 2020). The components (factors) had to have an eigenvalue of more than 1.0 (Kaiser criterion). In addition to the interpretability of the components, the visual interpretation of scree plots was used to determine the number of relevant components (Pallant, 2020). As a result, we sometimes discarded PCA solutions with a higher number of components and in doing so decreased the proportion of explained variance. Variables were included in a component, if their loading was greater than 0.4 since both in psychological and behavioral studies a loading exceeding 0.3–0.4 is used frequently (Miller et al., 2006). If a variable's largest loading on one component exceeded 0.6 and the loading on another component was below 0.4, that variable was also included in the component on which it loaded higher. Variables that did not meet these conditions were not included in any component. We labeled the components by considering the semantic content of the variables. For each component, mean scores were calculated so that the averages were on the same Likert scales as the original question items to ease comparability.

Associations between caretaker attitudes and attachment and caretaker behavior related to husbandry (including human-animal interactions) were investigated using Spearman rank correlations due to the non-normality of most measures. We decided against correcting for multiple testing due to the exploratory nature of the study. In the discussion, correlation coefficients of ≥0.1 are interpreted as weak, ≥0.3 as moderate, and ≥0.5 as strong. Regarding significance levels, we refer to $P \leq 0.05$ as statistically significant.

Results

Respondent characteristics

A total of 72.9% of the respondents (of n = 612) stated that their country of origin was Germany, followed by Austria (18.1%), Switzerland (8.2%), Italy (0.3%), Luxembourg (0.3%), and other countries (0.2%). "Other countries" were then specified as the Netherlands and Belgium. Around 91.7% of respondents identified as female, 7.3% as male, 0.6% as diverse. Ninety one percent of participants were under 45 years old. Around 2.4% of the main caretakers were younger than 18 years. Eighty percent of respondents reported having heard about the survey through social media. Respondents also participated after being informed about the study in online rat forums (23.6%), by acquaintances (7.5%), other sources (1.6%), a veterinarian (1.3%), and the homepage of the University of Veterinary Medicine Vienna (1.1%). Ninety two percent of participants reported being the main caretaker of the pet rat.

General information on all rats currently living in the respondent's household

At the time of the survey, the average number of rats per household was 7.0 ± 9.4 (mean ± SD) and ranged from one to a maximum of 140 rats (median: 5 of n = 981). Around 97.4% of participants kept rats as a pet for themselves, followed by keeping them for their children (12.9%), to provide a temporary foster home (6.4%), for breeding purposes (2.6%), for animal-assisted therapy (2.5%), as feed for other pets (0.3%) and for "other reasons" (3.3%). The mean time respondents spent caring for all rats was 2.5 ± 1.4 h per day (min–max: 0.5–15; median: 2; of n = 938).

Characteristics of the focus rats

Participants were instructed to answer detailed questions about their focus rat only (this refers to the rat whose name would come first if sorted in alphabetical order). The median age was 1.4 years (min–max: 0.1–4.4; mean ± SD: 1.4 ± 0.7 of n = 866). A proportion of 53.1% of rats were intact females, followed by intact males (32.3%), neutered males (12.4%), neutered females (1.8%), and females with an unknown castration status (0.3%). Around 21.9% of rats (n = 790) were bought from a breeder; 20.1% from an animal welfare organization; 20.0% from a private pet caretaker, 15.8% from a pet shop, 9.1% from an animal shelter, 3.5% from an animal-testing facility, 2.3% had been found, 1.9% of rats had been bred by the current caretakers, 0.9% from a garden center, 0.3% from a fair, 0.1% from a hardware store, and 3.0% were unaware of where the rat had been bought/adopted from 1.0% originated from "other" sources.

Husbandry of focus rats

Group size, group constellation, and reasons for single-housing

The median number of rats kept per group, including the focus rat, was four (min–max: 0–54; mean ± SD: 5.1 ± 3.9 of n = 759). Eight percent of rats were kept in pairs. Around 19.8% of the participants kept seven or more rats in the same enclosure. Only a small proportion of the focus rats (4.1%) were housed solitarily at the time of the survey. Participants who reported single housing named the following reasons for doing so: lack of social compatibility (53.1%); death of the partner animal (37.5%); the rat was housed solitarily before adoption into the current home (12.5%); geriatric age (9.4%);

lack of space (6.3%). Around 3.1% did not specify the reasons for single housing. In the current study, 81.6% kept same-sex groups and 97.5% of the rat groups were mixed ages. On average, there were 2.8 ± 3.3 (mean ± SD) intact females in the group (min–max: 0–26; median: 2; n = 755) and 0.1 ± 1.1 neutered females (min–max: 0–28; median: 0; n = 755). For intact male rats, the mean number of individuals was 1.6 ± 3.1 (min–max: 0–54; median: 0; n = 755) and 0.6 ± 1.4 for neutered males (min–max: 0–11; median: 0; n = 755). The average age of the youngest rat kept together with the A rat was 12 ± 0.6 months (min–max: 0–3.5 years; median: 10 months; 0–3.5 years; n = 736). The average age of the oldest rat kept together with the focus rat was 1.6 ± 0.8 years (min–max: 0.2–4.2 years; median: 1.7 years; n = 715). The average age difference between the youngest and oldest rats living together with the focus rat was 0.7 ± 0.7 years (min–max: 0–3.1 years; median: 0.5 years; n = 707). For 15.4% of the rats, there had been a change in the group composition within the last month because a rat was added to the group. For 19.5%, a rat was added within the last 1–4 months before the participant took part in the survey, for 14.1% within the past 5–8 months, for 8.8% within the past 9–12 months, and for 5.7% this occurred over a year ago. For 17.4% of the rats, the group composition changed due to a rat having died or being removed from the group. Around 23.4% of participants stated that a rat was removed from the group within the last 1–4 months before taking part in the survey, 9.9% stated that a rat was removed within the past 5–8 months, and 3.6% stated that a rat was removed within the past 9–12 months, and 2.7% stated that a rat was removed over a year ago.

Housing conditions

The most common location for housing was the living room (49.7% out of n = 815), followed by the "rat room" (20.2%), bedroom (10.9%), and study (8.3%). Participants very rarely reported housing the rat in a winter garden, bathroom, or on a balcony. No participant selected the garden or the garage, meaning there were no cases of outdoor housing. The most common housing types were an aviary or redesigned wardrobe and a wire cage (37.7% and 36.7%, respectively, out of n = 758), followed by a multi-level housing system (German: "Kaskadendom") (10.3%), rat room or free-roaming housing (8.8%), a wooden cage (4.9%), and others (1.6%). The following options were not chosen by any participants in the questionnaire: aquarium, terrarium, and outdoor enclosure. The most common floor types in the housing system were the following: newspaper (49.1%), litter (43.1%), and washable carpet mats (42.1%). Most participants reported to use hemp bedding as bedding material (32.5%), followed by "other" (14.7%). Among "other", newspaper (18% out of n = 110), coconut bedding (9.1%), and hemp mats (8.2%) were mentioned most frequently. The median amount of time the rat had been living in the current housing type at the time of the survey was 1.4 years (min–max: 0.1–4.4; mean ± SD: 1.4 ± 0.7 years; n = 757). The average size of the permanently accessible area for all rats (including an extension for roaming, if directly connected to the housing system and constantly accessible) was 2.0 ± 7.2 m^2 (min–max: 0.3–97.6 m^2; median: 0.7 m^2; n = 613). About 10.6% of participants provided an area smaller than 0.5 m^2. Rats with no permanent extension to the housing system for roaming directly connected to the housing system were given an average of 1.1 ± 3.4 m^2 of space at all times (min–max: 0.2–64.0; median: 0.7; n = 584). The average amount of space permanently available to rats housed in a "rat room" or kept freely in the apartment was 19.3 m^2 (min–max: 1.4–97.6 m^2; median: 11.1 m^2; SD: 22.9 m^2 of n = 30).

Concerning roaming opportunities outside of the enclosure, 51.7% of caretakers (360 of n = 696) provided their rats an opportunity to roam seven days per week. Around 0.3% (n = 2) reportedly "never" provided an opportunity to roam, 0.3% (n = 2) did so "less than 1x/month"; 1.6% (n = 11) "1x/month"; 10.8 (n = 75) "3 days/week"; 7.2% (n = 50) "4 days/week"; 11.5% (n = 80) "5 days/week", 9.9% (n = 69) "6 days/week" and 6.8% (n = 47) indicated that roaming is always possible since the focus rat lives in a rat room. The average duration of time caretakers allowed rats to roam per roaming bout was 2.5 h (min–max: 0–16 h; median: 2.0 h; SD: 1.9 h, of n = 589). This applies to rats that did not have permanent access to roam outside of the housing system and were not housed in a rat room or lived in the apartment. The average amount of space provided for roaming outside of the housing systems in case of no permanent roaming possibility was 13.9 m^2 ± 9.8 m^2 (min–max: 0.3–64 m^2; median: 0.7 m^2, n = 584).

Information on how often other animal species are allowed in the same room as the focus rat was provided for a variety of animals, including predatory species. About 69.3% of the participants (of n = 658) stated that dogs are never in the same room as the focus rat. In cats, the proportion was 86.4%. In contrast, 8.5% of participants said that dogs are allowed in the focus rat's room multiple times a day or live there (8.2%) and 6.8% said cats are granted access several times per day or live in the same room (4.2%).

Housing supplies and enrichment including activities with the caretaker

Respondents could select which housing supplies, enrichment items, and activities they provide from a list of potential items. The following housing supplies were provided constantly by participants by the percentage written in brackets: small houses located inside the enclosure (made of wood, clay, ceramics, or plastic) (98.4%), nesting material (92.7%), hammocks (91.7%), a toilet (83.4%), stairs (88.7%) of participants, tunnels or tubes (83.7%), caves (71.1%), and other supplies which can be used by rats as hiding spaces (59.1%). Salt lick, mineral block, or hay in racks were rarely offered as housing supplies, while bridges and ramps were frequently offered (Table 2). The most common enrichment items were newspaper, cardboard boxes, kitchen paper, toilet paper, or cardboard rolls (Table 3). The following supplies, which are known to impair animal welfare, were reportedly never provided by the percentage of participants written in brackets: running plates (95.8%), running wheels (95.7%), hamster cotton (94.9%), and jogging balls (88.6%). Less than 7% provided these supplies at least once per week respectively (see also Table 3).

Principal component analysis of the various enrichment items revealed six components, explaining 49.0% of the total variance. Bartlett's test for sphericity was significant (Chi square = 1358.3, $P < 0.001$) and the Kaiser-Meyer-Olkin criterion of sampling adequacy was 0.68. The first component was labeled 'litter' and comprised the frequency of offering deep litter, rodent grass, digging boxes, and dried leaves. The second component comprised only two items (kitchen roll/toilet paper and cardboard boxes) and was labeled "paper". The third component comprising three items was labeled "cat and dog toys" because it included the frequency of offering dog as well as cat toys/supplies, and food balls. The fourth was the single-item component "food tree". The fifth and the sixth components comprised two items each and were labeled "labyrinth/obstacle course" (based on the respective enrichment) and "running wheels/plates" (because it included running wheels and running plates). Cronbach α coefficients ranged from 0.24 ("running wheels/plates") to 0.65 ("paper"). The components that had low Cronbach α coefficients were kept because Cronbach α coefficients generally tend to be low, when there are few items in a scale, as was the case for "running wheels/plates" (Pallant, 2013). For further details, see Table S1.

Around 66.3% (out of 674) provided water ad libitum using water bowls, 77.6% reported using a drip dispenser and 45.4% of participants provided both a drip dispenser and a water bowl. Nevertheless, there was a small proportion of caretakers who

Table 2
An overview of how often caretakers reportedly offered different housing supplies. The higher the percentage, the darker the shade of orange.

Supplies	N	never	less than once per week	once per week	multiple times per week	once per day	multiple times per day	constant access
Salt lick	659	91.4 %	1.1 %	0.6 %	0.6 %	0.0 %	0.3 %	6.1 %
Mineral block	656	89.0 %	1.5 %	1.5 %	0.5 %	0.2 %	0.2 %	7.2 %
Hey in a rack	653	86.8 %	4.0 %	2.6 %	1.8 %	0.3 %	0.5 %	4.0 %
Rope	652	37.9 %	9.5 %	1.5 %	2.8 %	1.4 %	0.8 %	46.2 %
Bridge	658	19.6 %	5.6 %	0.9 %	2.3 %	1.8 %	2.3 %	67.5 %
Roots	643	53.3 %	7.2 %	1.6 %	2.2 %	0.6 %	1.1 %	34.1 %
Basket	649	42.1 %	5.4 %	1.4 %	2.3 %	2.5 %	2.5 %	43.9 %
Ramp	658	14.0 %	0.8 %	0.2 %	2.0 %	2.1 %	2.4 %	78.6 %

reportedly never offered a drinking bowl or a nipple drinker (1.5%). It is unclear whether they provided another source of water or whether water was only offered intermittently.

Regarding human-animal interactions, 84.4% of participants reported stroking their rat, 94.9% talking to it, and 70.9% feeding it out of their hands several times per day. Less than one percent of participants reported walking their rat on a leash, 4.4% reported going on walks with their rat without a leash, and 1.4% reported allowing their rat to roam freely in public green spaces at least once per week. For further details, see Table 3. The average time caretakers engaged with the pet rat (e.g., by feeding by hand, stroking, playing, training, observing) was 1.6 ± 1.5 h per day (min–max: 0–17; median: 1 h, n = 636).

Nutrition

Rats were fed ad libitum with commercial rat food by 40.6% of participants and with seeds by 30.3% of participants. Constant access to vegetables, fruits, and herbs was reported by 13.7%, 7.4%, and 15.5% of participants respectively. The following foods were fed once per day by the percentage of participants written in brackets: seeds (17.4%), vegetables (44%), fruits (21.4%), and herbs (13.0%). About 10.7% reported feeding insects such as mealworms once per day as a source of animal protein. During the month preceding the study, 14.6% of participants reportedly offered their pet rat unhealthy snacks, such as chocolate and cookies, at least once. However, over 70% reportedly never fed these products. A detailed breakdown of foods available is presented in Table 4.

Cleaning the housing environment

The majority of participants (58.6%) stated that they clean the entire rat enclosure once per week. The feeding dish and the water bowl were reportedly cleaned every day by 52.0% and 62.5% of participants, respectively. The entire roaming area was cleaned and the litter of the underlay was changed multiple times per week by 47.2% and 51.8% of participants, respectively. Only 0.2% reported never cleaning the entire rat enclosure. A more detailed breakdown of husbandry practices is available in Table 5.

Weight, health status, health checks, and subjection to passive smoking

The weight distribution of focus rats was as follows: 31.2% of focus rats weighed between 100 g and 349.9 g, 54.2% weighed between 350.0 g and 599.9 g, 14.0% weighed between 600.0 g and 849.9 g, and 0.6% of focus rats weighed over 850.0 g (min–max: 100–870 g; mean ± SD: 453.2 ± 197.2 g out of n = 500). Among male focus rats, 13.4% weighed between 100.0 g and 349.9 g (n = 247), 59.1% weighed between 350.0 g and 599.9 g, 26.7% weighed between 600.0 g and 849.9 g, and 0.8% weighed over 850.0 g (min–max: 260–870 g; mean ± SD: 545 ± 165.3 g out of n = 411). For female focus rats, 48.6% weighed between 100.0 g and 349.9 g (n = 253), 49.0% weighed between 350.0 g and 599.9 g, and 2.0% weighed between 600.0 g and 849.9 g (min–max: 128–850 g; mean ± SD: 333.9 ± 161.6 g out of n = 253). One participant reported that their female focus rat weighed 55.0 g. The majority (79%) of the rats were healthy at the time of the survey. Twenty one percent of participants stated that the rat was currently ill with a disease diagnosed by a veterinarian. The most commonly diagnosed diseases were respiratory diseases (29.9%), including further specifications such as “mycoplasmosis”, “chronic respiratory disease”, “respiratory infection”, “runny nose”, “chronic sneezing” or “cold”. *Mycoplasma spp*. was the most commonly reported infectious agent causing respiratory disease (35.4%). The second most frequent diagnosis was tumor with 23.9%. Among specified tumors, the mammary tumor was the most common (14.3%).

Hindlimb paralysis made up 7.7% of current diseases and abscesses made up 5.1%. Head tilts and dental problems were relatively uncommon, with 4.3% and 2.6% respectively. In a few cases, skin problems (0.9%), ulcerative pododermatitis (Bumblefoot) (0.9%), chromodacryorrhea (blood eye) (0.9%), and injuries such as bite wounds (0.9%) were reported.

The most commonly performed health checks were eye, nose, and ear checks: 61.0% of rat caretakers reported performing an eye check and 60.9% reported examining the nasal environment daily. The following care routines were reportedly performed once per week by the percentage of participants written in brackets: ear checks (32.1%), paw checks (24.3%), anterior teeth checks (38.3%), anal region checks (28.6%) and palpation for masses (31.0%). Table 5 provides a detailed breakdown of healthcare variables. In terms of veterinary care, the majority (85.5%) of the participants stated that they only visit a veterinarian when their rat has a health problem. Around 7.3% of participants reported visiting a veterinarian multiple times per year. Some rats were subjected to passive smoking; 3.4% (23 of n = 671) of participants reported smoking in the room where the rat is kept multiple times per day. However, 93.0% (n = 624) of participants reported never smoking in the room where the rat’s housing system is located, 1.6% (n = 11) reported “less than 1x/month”, 0.6% (n = 4) reported “multiple times/month”, 0.6% (n = 4) reported “multiple times/week”, and 0.7% (n = 5) reported “once per day”.

After running a PCA, variables assessing the frequency of health checks and fur and claw care were summarized to two components explaining 60.4% of the total variance. Bartlett’s test for sphericity

Table 3
An overview of how often caretakers provided various enrichment items and activities (human-animal interactions). The higher the percentage, the darker the shade of orange.

Enrichment and activities provided	n	never	< 1x / month	1x / month	multiple times / month	1x / week	multiple times / week	daily	multiple times / day	constant access
Kitchen roll/ Toilet paper	663	2.6 %	4.4 %	5.1 %	15.7 %	9.7 %	20.8 %	6.2 %	2.0 %	33.6 %
Cardboard boxes	661	3.0 %	4.1 %	3.3 %	15.9 %	6.5 %	13.9 %	8.9 %	3.0 %	41.3 %
Paper bags	656	41.3 %	10.5 %	7.0 %	14.0 %	6.7 %	8.8 %	2.4 %	0.5 %	8.7 %
Newspaper	660	15.5 %	3.2 %	1.1 %	5.3 %	2.6 %	9.4 %	5.6 %	1.8 %	55.6 %
Jogging ball	643	88.6 %	2.2 %	1.1 %	1.2 %	1.9 %	1.4 %	1.1 %	0.3 %	2.2 %
Food ball	659	54.0 %	7.4 %	6.5 %	9.7 %	5.8 %	7.4 %	4.4 %	0.5 %	4.2 %
Running wheel	658	95.7 %	0.3 %	0.2 %	0.2 %	0.2 %	0.3 %	0.3 %	0.0 %	2.9 %
Running plate	659	95.8 %	0.8 %	0.0 %	0.3 %	0.2 %	0.2 %	0.8 %	0.0 %	2.1 %
Dog toys/supplies	650	52.6 %	6.9 %	4.6 %	8.2 %	4.5 %	9.8 %	4.8 %	1.4 %	7.2 %
Cat toys/supplies	658	26.9 %	7.4 %	4.3 %	15.0 %	5.5 %	20.5 %	8.2 %	2.3 %	9.9 %
Labyrinth	651	65.7 %	12.0 %	5.2 %	6.1 %	1.2 %	3.2 %	2.3 %	0.9 %	3.2 %
Deep litter	654	27.4 %	9.2 %	6.3 %	11.8 %	6.3 %	6.9 %	5.8 %	1.2 %	25.2 %
Dried leaves	651	75.4 %	9.7 %	4.3 %	3.7 %	1.7 %	2.3 %	0.8 %	0.2 %	2.0 %
Obstacle course	651	43.9 %	11.4 %	3.8 %	10.3 %	5.2 %	7.5 %	7.2 %	1.5 %	9.1 %
Cotton nests for hamsters	649	94.9 %	1.8 %	0.9 %	0.3 %	0.5 %	0.0 %	0.2 %	0.3 %	1.1 %
Digging box	652	24.8 %	10.7 %	9.2 %	12.9 %	4.9 %	6.1 %	7.5 %	1.1 %	22.7 %
Food tree	648	67.6 %	7.9 %	3.2 %	7.1 %	2.6 %	6.2 %	2.3 %	0.2 %	2.9 %
Rodent grass	651	61.6 %	17.7 %	8.4 %	5.4 %	2.3 %	1.7 %	0.8 %	0.2 %	2.0 %
Tissues	652	37.1 %	8.4 %	5.5 %	12.4 %	4.3 %	15.3 %	3.8 %	1.5 %	11.5 %
Swimming pool	645	8.2 %	28.7 %	13.2 %	24.3 %	6.2 %	9.6 %	2.9 %	0.5 %	6.4 %
Human-rat interactions		**never**	**< 1x / month**	**1x / month**	**Multiple times / month**	**1x / week**	**Multiple times / week**	**1x/day**	**Multiple times / day**	
Stroking	669	0.7 %	0.7 %	0.1 %	0.0 %	0.3 %	5.2 %	10.5 %	82.4 %	
Talking	667	0.1 %	0.0 %	0.0 %	0.0 %	0.0 %	1.3 %	3.6 %	94.9 %	
Feeding out of hand	669	1.0 %	0.1 %	0.1 %	0.9 %	0.3 %	8.4 %	18.2 %	70.9 %	
Carrying the rat around	665	8.7 %	2.7 %	1.2 %	2.7 %	3.2 %	19.1 %	21.1 %	41.4 %	
Walks with a leash	666	98.9 %	0.5 %	0.0 %	0.2 %	0.2 %	0.0 %	0.0 %	0.3 %	
Walks without a leash	665	92.3 %	1.4 %	0.6 %	1.4 %	0.6 %	1.5 %	0.6 %	1.7 %	
Roaming on green spaces	668	96.6 %	1.2 %	0.3 %	0.6 %	0.6 %	0.1 %	0.3 %	0.3 %	
Agility / teaching tricks	668	51.3 %	10.5 %	4.0 %	9.1 %	6.7 %	12.1 %	5.2 %	0.9 %	

was significant (Chi square = 2625.10, $P < 0.001$) and the Kaiser-Meyer-Olkin criterion of sampling adequacy was 0.814. The first component comprised six items (frequency of nose, eye, paws, anal, ear checks, palpation for masses) and was labeled "Frequency health checks". The second component comprised the two items fur maintenance and claw clipping and thus was labeled "Frequency fur and claw care". The components had Cronbach α coefficients of 0.84 and 0.37, respectively. For further details, see Table S2.

Behavior of focus rats

Behavior in the housing system and during roaming

Behaviors argued to be indicators of good welfare according to scientific literature were often observed several times per day in the past month before participating in the survey by the percentage of participants written in brackets: self-grooming (89.6%), rearing (46.7%), teeth chattering (28.9%) and eye-boggling (11.6%). The

Table 4
Frequency of feeding different products. The higher the percentage, the darker the shade of orange.

Products	n	never	< 1x / week	1x / week	multiple times / week	1x / day	multiple times / day	ad libitum
Vegetables	651	0.2 %	0.8 %	4.9 %	30.3 %	44.7 %	5.5 %	13.7 %
Fruit	651	0.8 %	16.9 %	22.6 %	28.3 %	21.4 %	2.8 %	7.4 %
Herbage	652	9.4 %	17.8 %	16.3 %	26.2 %	13.0 %	1.8 %	15.5 %
Fresh plants	651	24.4 %	33.5 %	14.6 %	18.4 %	4.6 %	1.2 %	3.2 %
Cookies	651	71.7 %	14.4 %	4.9 %	6.5 %	1.4 %	0.8 %	0.3 %
Chocolate	652	94.5 %	4.8 %	0.5 %	0.2 %	0.2 %	0.0 %	0.0 %
Snacks	651	90.0 %	7.5 %	1.1 %	1.1 %	0.3 %	0.0 %	0.0 %
Dairy products	651	20.1 %	39.0 %	24.6 %	12.6 %	2.8 %	0.5 %	0.5 %
Cooked egg	651	9.7 %	58.2 %	27.3 %	4.3 %	0.5 %	0.0 %	0.0 %
Cooked meat	652	60.7 %	30.2 %	6.0 %	2.9 %	0.2 %	0.0 %	0.0 %
Nuts	649	5.4 %	37.1 %	22.2 %	22.5 %	5.2 %	0.9 %	6.6 %
Seeds	651	2.0 %	10.6 %	9.1 %	26.6 %	17.4 %	4.1 %	30.3 %
Leaves	650	42.3 %	22.3 %	9.7 %	9.8 %	4.2 %	0.9 %	10.8 %
Insects	652	11.8 %	16.7 %	21.3 %	26.7 %	10.7 %	2.6 %	10.1 %
Commercial rat food	641	31.8 %	3.4 %	1.4 %	4.5 %	15.4 %	2.8 %	40.6 %
Pellets	636	79.6 %	5.3 %	1.3 %	2.2 %	3.5 %	1.3 %	6.9 %
Dry cat food	640	90.3 %	6.7 %	1.4 %	0.9 %	0.5 %	0.0 %	0.2 %
Canned cat foot	639	86.2 %	11.3 %	1.6 %	0.9 %	0.0 %	0.0 %	0.0 %
Dry dog food	637	91.5 %	6.0 %	0.9 %	0.9 %	0.3 %	0.0 %	0.3 %
Canned dog food	639	96.4 %	2.8 %	0.6 %	0.2 %	0.0 %	0.0 %	0.0 %
Yogurt drops	639	63.1 %	23.0 %	5.8 %	5.0 %	1.9 %	0.9 %	0.3 %
Bread	640	68.9 %	22.2 %	5.5 %	2.3 %	0.5 %	0.0 %	0.6 %
Side dishes (e.g., pasta, rice, potatoes)	643	7.0 %	46.5 %	24.1 %	19.3 %	2.2 %	0.2 %	0.8 %

following repetitive behaviors were observed at least once in the past month before participating in the survey by the percentage of participants written in brackets: a rat chewing on cage bars (18.5%), pacing back and forth (10.8%), running in circles (4.0%), tail-chasing (4.0%), plucking out its fur (0.9%) and engaging in self-harm (0.2%). A detailed breakdown of welfare-related behaviors is presented in Table 6.

Behavior towards conspecifics

The following socio-positive behaviors towards conspecifics were observed by participants multiple times per day, i.e. very frequently, by the percentage written in brackets: sleeping in the same house inside the enclosure (86.3%), huddling together (85.6%), eating together peacefully (83.8%) playing (61.9%), and allogrooming (51.1%). The following agonistic behaviors were observed at least one time in the past month: hitting a conspecific with front paws/scratching (29.1%), driving away a conspecific from food (28.6%), biting (14.5%), avoiding contact (14.1%), and plucking out fur (8.5%). A detailed breakdown of conspecific related behavior is available in Table 7.

Behavior towards the caretaker

The following positive interactions between the rat and the caretaker were reported to occur frequently, i.e., several times per day, by the percentage of participants written in brackets: approaching the caretaker (80.9%), approaching the caretaker after encouragement (i.e. after calling its name) (75.6%), eating food out of the caretaker's hand (75.6%), climbing on the caretaker (57.9%), and resting next to the caretaker (23.0%). Aggressive behavior towards the caretaker was by far less common. The following aggressive behaviors towards the caretaker reportedly occurred at least once in the month before taking part in the survey by the percentage of participants written in brackets: pinching (26.1%), biting with the result of the caretaker bleeding (7.2%), and scratching with the result of the caretaker bleeding (4.6%). Rat behaviors directed at caretakers are broken down in Table 7.

Caretaker attachment and attitudes

Attachment was assessed using the *Comfort from Companion Animal Scale (CCAS)* with 11 items. The score can range from a minimum of eleven and a maximum of 44. Higher scores reflect greater attachment. The mean CCAS score in the current study was 37.8 ± 5.3 and ranged from 15 to 44 (median: 38). For details, see Table S3. The principal component analysis (PCA) of the attachment items with single-component solution explained 50.6% of the total variance. Bartlett's test for sphericity was significant (Chi square = 3197.32, $P < 0.001$) and the Kaiser-Meyer-Olkin criterion of sampling adequacy was 0.911. Components loadings ranged from 0.50 to 0.78

Table 5
Overview of the frequency of cleaning different spaces/supplies and the frequency of health checks and care measures performed by the caretaker. The higher the percentage, the darker the shade of orange.

Cleaning measures and health checks	n	never	< 1x / month	1x / month	1x / week	multiple times / week	1x / day
Cleaning…							
...the entire enclosure	642	0.2 %	-	-	58.6 %	38.9 %	2.3 %
…the entire roaming area	631	1.3 %	-	-	36.8 %	47.2 %	14.7 %
Change of litter and underlay	631	3.6 %	-	-	23.8 %	51.8 %	20.8 %
…of blankets	611	4.1 %	-	-	48.1 %	44.8 %	2.9 %
…of the feeding dish	642	0.2 %	-	-	15.7 %	32.1 %	52.0 %
…of water bowl	627	2.4 %	-	-	10.2 %	24.9 %	62.5 %
Health checks							
Ear check	636	7.9 %	6.1 %	6.4 %	32.1 %	20.1 %	27.4 %
Eye check	636	1.6 %	1.4 %	1.3 %	12.6 %	22.2 %	61.0 %
Nose check	634	1.7 %	1.4 %	0.9 %	12.3 %	22.7 %	60.9 %
Paw check	635	3.6 %	3.3 %	3.1 %	24.3 %	29.1 %	36.5 %
Anterior teeth check	632	6.6 %	6.6 %	7.4 %	38.3 %	23.9 %	17.1 %
Fur/coat maintenance	635	61.1 %	11.5 %	3.1 %	13.2 %	4.7 %	6.3 %
Clipping claws	634	80.3 %	12.9 %	3.9 %	2.4 %	0.2 %	0.3 %
Anal check	636	11.6 %	7.5 %	4.9 %	28.6 %	21.4 %	25.9 %
Palpation for masses	636	10.4 %	4.4 %	6.4 %	31.9 %	22.8 %	24.1 %

and the Cronbach α coefficient reached 0.90. For further details, see Table S4.

Overall, participants rated high on positive general attitudes. For instance, the majority strongly agreed that rats are friendly, lovable, cute, and fun. Many respondents also strongly agreed that rats are intelligent, curious, quick to learn, and able to distinguish and recognize people. Ratings on negative general attitudes were rather low. Thus, there was no to little agreement regarding rats being aggressive, or dirty. There was a large degree of opposing views regarding rats being fearful and nervous. Table 8 provides an overview of the general attitudes of owners towards rats. Utilizing a principal component analysis, general attitudes towards rats were summarized into four components explaining 46.2% of the total variance. Bartlett's test for sphericity was significant (Chi square = 1487.76, $P < 0.001$) and the Kaiser-Meyer-Olkin criterion of sampling adequacy was 0.727. The first component comprised six questionnaire items (nervous, fearful, prone to stress, demanding, sensitive, and aggressive) and was labeled "Nervous". The second component which also comprised six items (lovable, fun, cute, affectionate, intelligent, and can distinguish and recognize people) was labeled "Positive". The third component comprised two items and was labeled "Dirty" (dirty, negative loading on cleanly). The fourth component, comprising three items, was labeled "Demanding and expensive" (expensive, and negative loadings on "easy to care for", and "feel little pain"). Cronbach α coefficients ranged from 0.46 ("Demanding and expensive") to 0.67 "Nervous". For further details, see Table S5.

Affective attitudes are depicted in Table 9. Most participants stated that they felt a high degree of comfort during care in general, feeding and providing for the animals, as well as when engaging in observing, stroking the animals, talking to the animals and playing with them. They felt less comfortable when cleaning the enclosure or treating the animals in case of sickness. Almost 60% felt or would feel "rather" to "very uncomfortable" when verbally reprimanding the animals and almost 70% felt or would feel "rather" to "very uncomfortable" when physically disciplining the animals (e.g., pushing them away).

Principal component analysis of affective attitudes revealed three components and explained 53.6% of the total variance. Bartlett's test for sphericity was significant (Chi square = 907.16, $P < 0.001$) and the Kaiser-Meyer-Olkin criterion of sampling adequacy was 0.668. The first component comprised four questionnaire items (degree of comfort during playing with, observing, scratching/stroking, and talking to the animals) and was labeled "Comfort Positive interaction". The second component summarized also four questionnaire items (feeding/providing for, cleaning the enclosure/housing system, care in general, and treating the animals when sick) and was labeled "Comfort Care". The third component was labeled 'Comfort Negative interaction' and comprised two questionnaire items (verbal reprimand, and physical disciplining). Cronbach α coefficients ranged from 0.56 ("Comfort Care") to 0.66 "Comfort Negative interaction". For further details, see Table S6.

Associations between attitudes, attachment, and caretaker behavior

Caretaker attitudes and attachment consistently correlated with human-animal interactions and husbandry practices (Table 10). Apart from one moderate correlation (between attachment and the frequency of carrying around the rat), these correlations were weak. Most significant correlations were found for the affective attitude components "Comfort Positive interaction" and "Comfort Care". Respondents who felt more comfortable during positive interactions with their rats tended to devote more time to them. They reported

Table 6
Frequencies of various behaviors within the month before taking part in the questionnaire. The higher the percentage, the darker the shade of orange.

Behavior	n	never	1x in the past month	Multiple times in the past month	1x per week	Multiple times per week	1x per day	Multiple times per day
Teeth chattering ('bruxing')	630	17.0 %	3.8 %	10.2 %	3.7 %	24.9 %	11.6 %	28.9 %
Self-grooming	635	0.3 %	0.0 %	0.8 %	0.0 %	2.8 %	6.5 %	89.6 %
Plucking out own fur	634	99.1 %	0.9 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Biting own fur	624	60.3 %	2.6 %	3.0 %	3.5 %	12.3 %	6.1 %	12.2 %
Self-harm	634	99.8 %	0.2 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Eye-boggling (eyes popping in and out)	632	47.8 %	8.1 %	8.7 %	3.6 %	12.8 %	7.4 %	11.6 %
Chewing on cage bars	631	81.5 %	8.7 %	3.2 %	1.4 %	2.2 %	1.4 %	1.6 %
Pacing back and forth	632	89.2 %	1.9 %	2.5 %	0.3 %	1.9 %	1.9 %	2.2 %
Scraping at one spot	627	80.5 %	4.0 %	5.1 %	0.8 %	5.3 %	2.1 %	2.2 %
Shaking of body/tail	631	81.6 %	9.8 %	3.3 %	1.6 %	2.5 %	0.6 %	0.5 %
Head sway	631	84.9 %	1.4 %	1.7 %	1.0 %	1.4 %	1.1 %	8.4 %
Rearing	627	7.0 %	1.6 %	7.3 %	1.9 %	23.9 %	11.5 %	46.7 %
Somersaults	627	96.0 %	1.1 %	0.5 %	0.3 %	1.0 %	0.6 %	0.5 %
Tail-whipping	627	84.1 %	7.0 %	4.1 %	1.3 %	1.8 %	1.1 %	0.6 %
Jumping into the air	619	51.2 %	7.9 %	9.7 %	4.0 %	14.4 %	5.2 %	7.6 %
Running in circles/trying to catch its tail	628	96.0 %	1.6 %	1.3 %	0.8 %	0.2 %	0.2 %	0.0 %
Eating own feces	621	81.6 %	8.9 %	3.5 %	1.8 %	2.9 %	0.6 %	0.6 %
Yawning	629	1.9 %	2.5 %	7.0 %	3.2 %	20.8 %	15.3 %	49.3 %
Hiding during roaming	614	19.4 %	5.7 %	10.9 %	5.4 %	20.5 %	11.9 %	26.2 %
Making turns during roaming	610	45.7 %	4.4 %	7.7 %	4.1 %	14.6 %	7.9 %	15.6 %
Attempting to go back into the enclosure during roaming	605	35.0 %	4.6 %	9.8 %	2.6 %	15.5 %	12.6 %	19.8 %

engaging in positive human-animal interactions, such as stroking, talking to the animals, and feeding them by hand more frequently. Additionally, they checked their rat's health more often, performed grooming tasks like fur and claw care more frequently, and provided presumably rat-friendly enrichment, such as litter, paper, and toys typically used for cats and dogs, more regularly and for longer periods. For "Comfort Care", a similar pattern of correlations was found. Also, for "Attachment" and generally positive attitudes ("Positive") similar patterns were found, but with fewer significant correlations. An opposite pattern of correlations was observed for the general attitude component "Dirty". Higher agreement to rats being "Dirty" related to spending less time with and for the rats, less frequent health checks, and less frequent positive human-animal interactions like stroking, talking to the animals, and feeding them out of the hand. Higher agreement on rats being not easy to care for and expensive ("Demanding and expensive") related positively to more frequent health checks and offering longer periods of free-roaming, while it related negatively to taking rats on walks (without a leash), roaming on green spaces and offering running wheels/plates.

Discussion

In this study, we provided an extensive overview of how pet rats are kept and cared for in German-speaking households. The average rat was 1.4 years old, female (intact), weighed 419 g, lived in a group of five individuals, and received 1.6 h of daily interaction with their main caretaker (e.g., activities such as hand-feeding, stroking, playing, training, and observation, excluding the time dedicated to rat care). We further outline a comprehensive insight into the health and behavior of pet rats as well as the human-animal relationship based on caretaker attitudes, attachment, and behavior directed at the caretaker or the rat.

Husbandry of focus rats

The fundamental requirements for rat husbandry include ensuring freedom from thirst, hunger, and malnutrition, freedom from discomfort, freedom from pain, injury, or disease, freedom to express normal behavior, and freedom from fear and distress, as outlined in the five freedoms of animal welfare (Farm Animal Welfare Council, 1993). These basic requirements were met by the vast majority of rat caretakers. Moreover, it is considered crucial for animal welfare that the animal experience positive emotional states, which can be induced by exploration, play behavior and positive social interactions (Rault et al., 2020). Also this was possible for many of the focus rats since various enrichment was provided, there was space to perform play behavior and many rats were housed with conspecifics. The average group size in the current study (5.1) was appropriate for pet-rat well-being concerning the findings of previously published scientific literature. In a study by Talling et al. (2002), rats showed a preference for a group size of three to five animals. Patterson-Kane et al. (2004) observed a preference for a group of six rats in female rat groups (compared to group sizes with 1, 2, 4, and 12 rats). Single housing of a social species such as the rat should be the exception

Table 7
Frequencies of various behaviors towards a conspecific (CS) and the caretaker within the last month before taking part in the questionnaire. The higher the percentage, the darker the shade of orange.

Behavior	n	never	Once in the past month	Multiple times in the past month	Once per week	Multiple times per week	Once per day	Multiple times per day
Behavior towards conspecific (CS)								
Avoiding contact with a CS	616	85.9%	3.9%	3.9%	1.5%	1.9%	1.1%	1.8%
Playing with a CS	616	5.0%	1.1%	5.8%	1.3%	16.6%	8.3%	61.9%
Plucking out fur	615	91.5%	5.5%	2.0%	0.5%	0.3%	0.2%	0.0%
Biting a CS	614	85.5%	10.1%	2.4%	0.8%	0.7%	0.3%	0.2%
Chasing a CS	613	40.0%	10.6%	17.0%	6.2%	16.6%	4.4%	5.2%
Driving a CS away from food	617	71.3%	8.1%	8.1%	1.6%	5.8%	2.4%	2.6%
Grooming a CS	615	2.9%	2.3%	7.5%	2.3%	22.8%	11.2%	51.1%
Mounting a CS	606	59.2%	9.4%	13.0%	4.6%	10.4%	1.3%	2.0%
Chattering with teeth	604	79.1%	6.0%	6.8%	1.3%	3.3%	1.3%	2.2%
Huddling with a CS	613	0.2%	0.2%	1.5%	0.7%	6.7%	5.2%	85.6%
Sleeping in the same house with a CS	613	0.7%	0.2%	1.0%	0.5%	6.9%	4.6%	86.3%
Eating peacefully with a CS	612	1.1%	0.2%	1.0%	0.2%	5.9%	7.8%	83.8%
Spattering a CS with urine	592	64.0%	3.5%	9.5%	2.9%	8.6%	3.0%	8.4%
Hitting with front paws/scratching a CS	608	70.9%	10.7%	8.1%	3.1%	4.6%	1.0%	1.6%
Raising fur towards a CS	607	72.8%	11.2%	9.9%	1.8%	3.0%	0.8%	0.5%
Pushing a CS away with its rear end	604	51.7%	14.1%	16.4%	3.6%	9.3%	2.5%	2.5%
Behavior towards caretaker								
Pinched me	618	73.9 %	11.8 %	0.0 %	8.3 %	4.0 %	1.0 %	1.0 %
Scratched me, so that I felt bothered	619	88.5 %	3.2 %	0.0 %	6.1 %	1.6 %	0.5 %	0.0 %
Scratched me, so that I bled	619	95.5 %	2.9 %	0.0 %	1.3 %	0.2 %	0.2 %	0.0 %
Bit me, so that I felt bothered	618	94.0 %	3.6 %	0.0 %	2.3 %	0.2 %	0.0 %	0.0 %
Bit me, so that I bled	618	92.9 %	5.5 %	0.0 %	1.5 %	0.2 %	0.0 %	0.0 %
Approached me	619	0.3 %	0.5 %	0.0 %	1.9 %	8.7 %	7.6 %	80.9 %
Approached me after encouragement	620	2.6 %	0.5 %	0.0 %	3.5 %	10.2 %	7.6 %	75.6 %
Approached me for food	620	0.5 %	0.3 %	0.0 %	1.1 %	4.0 %	16.9 %	77.1 %
Allowed me to pick it up	618	7.8 %	2.1 %	0.0 %	6.8 %	10.2 %	12.8 %	60.4 %
Rested next to me	618	31.6 %	5.7 %	0.0 %	13.8 %	14.2 %	11.8 %	23.0 %
Ate food out of my hand	619	1.1 %	0.6 %	0.0 %	1.5 %	7.3 %	13.9 %	75.6 %
Groomed me	618	22.3 %	5.3 %	0.0 %	12.5 %	16.7 %	13.8 %	29.4 %
Sniffed me	620	0.6 %	0.8 %	0.0 %	3.1 %	8.2 %	13.4 %	73.9 %
Climbed on me	618	8.3 %	2.6 %	0.0 %	5.5 %	11.3 %	14.4 %	57.9 %

(Castelhano-Carlos and Baumans, 2009), as was the case in the current study (4.1%). Erhard (2017) and Neville et al. (2021) found a similarly low percentage of rats in solitary housing, with 1.6% and 2.4% respectively. Whether the most common explanation provided by caretakers for doing so in the current study ("due to social incompatibility") presents animal welfare issues, is subject to further investigation. The most common reason for single housing in the study conducted by Neville et al. (2021) was the death of the conspecific with which the rat had previously been housed. In future studies, reasons for social incompatibility should be investigated, as this may be sex-biased (Castelhano-Carlos and Baumans, 2009) or a result of traumatic experiences. Solitary housing due to a "lack of space" certainly presents an animal welfare issue. Regarding the social composition, the vast majority of rats in the current study were kept in same-sex groups and groups with mixed ages (81.6% and 97.5% respectively), which is considered beneficial for rat welfare. The most advantageous group constellation is a same-sex group with mixed ages according to scientific literature (Proops et al. 2021). The finding that 19.8% of the participants kept seven or more rats in the same enclosure could potentially suggest that many rats are housed in excessively large groups and/or that some rats had currently offspring.

The current study found that rat caretakers rarely allow predator species access to the room in which pet rats are kept. These findings disagree with the study by Neville et al. (2021), which found that of the 47.7% of caretakers who reported owning a predator species, 68.4% allowed predator species (i.e. cat, ferret, or snake) access to the same room in which the rats were housed. This raises a welfare

Table 8
The heat map shows the results of Likert scale questions targeting general attitudes towards rats. The table demonstrates the percentage of respondents indicating their answer to a seven-point Likert scale ranging from 'fully disagree' to 'fully agree'. The higher the percentage, the darker the shade of orange.

General attitudes	n	response categories						
In general, rats are…		fully disagree	disagree	rather disagree	partly/partly	rather agree	agree	fully agree
Friendly	615	0.0%	0.0%	0.0%	6.5%	6.7%	31.7%	55.1%
Fearful	614	2.8%	5.9%	11.7%	57.7%	11.2%	8.8%	2.0%
feel little pain	615	68.1%	17.6%	4.9%	5.7%	1.6%	0.8%	1.3%
enjoy being stroked	616	0.2%	0.5%	3.4%	42.0%	18.0%	19.5%	16.4%
Can distinguish and recognize people	615	0.2%	0.2%	0.5%	2.4%	5.2%	23.4%	68.1%
learn quickly	616	0.0%	0.0%	0.2%	3.4%	4.7%	32.8%	58.9%
aggressive	614	31.1%	33.6%	19.7%	15.0%	0.2%	0.3%	0.2%
affectionate	616	0.2%	0.0%	2.1%	29.4%	16.6%	26.8%	25.0%
peaceful	616	0.0%	0.0%	0.3%	16.2%	17.2%	34.4%	31.8%
intelligent	616	0.0%	0.0%	0.2%	1.5%	1.8%	15.9%	80.7%
Cleanly	616	0.0%	0.3%	1.1%	9.7%	13.3%	27.3%	48.2%
very individual	616	0.0%	0.2%	0.0%	0.6%	1.9%	12.5%	84.7%
Loveable	616	0.0%	0.0%	0.0%	0.3%	0.8%	10.2%	88.6%
demanding	614	11.2%	17.9%	18.1%	37.1%	8.5%	4.4%	2.8%
brave/courageous	616	0.2%	1.9%	5.2%	40.4%	16.1%	18.2%	18.0%
prone to stress	614	0.8%	2.4%	8.5%	28.8%	23.5%	25.2%	10.7%
Curious	616	0.0%	0.0%	0.0%	2.9%	5.2%	24.0%	67.9%
Nervous	614	4.6%	11.4%	22.1%	48.0%	8.3%	4.1%	1.5%
sensitive	615	1.1%	3.6%	10.1%	36.9%	21.0%	17.6%	9.8%
Fun	615	0.0%	0.0%	0.0%	4.2%	10.6%	28.1%	57.1%
expensive	616	8.6%	7.8%	13.0%	28.6%	14.8%	16.1%	11.2%
easy to care for	615	4.6%	12.0%	20.8%	31.7%	17.1%	8.0%	5.9%
Dirty	616	49.0%	31.5%	12.3%	5.8%	0.5%	0.3%	0.5%
Cute	616	0.0%	0.0%	0.2%	0.3%	0.5%	7.8%	91.2%

issue, given that the odor of predator species is known to induce fear in rats (Burn, 2008). This may suggest that some caretakers are not informed well enough about the stress induced by predator species.

The size of an enclosure for two rats should be at least 80 x 40 x 50 cm (length x width x height) according to Austrian animal protection laws and 100 x 50 x 70 cm (length x width x height) according to German animal protection laws. This means that the area of the floor space needs to be at least 0.5 m^2. Almost 10.6% of participants did not provide the minimum floor space area. Nevertheless, participants in this present study provided more space compared to participants taking part in the study by Erhard (2017), where 42.8% of participants did not meet the criterion for species-appropriate space dimensions for rats.

A small proportion of caretakers (1.5%) reported never offering either a drinking bowl or a nipple drinker. If these responses are plausible, they suggest a welfare problem that aligns with the clinical observations made by Tamura (2010) that an insufficient water supply is a common problem with pet rodents. Another explanation might be that some caretakers offered water differently but did not elaborate on this. Otherwise, the majority of rat caretakers stated that they consistently provided furnishings required for good rat husbandry (such as small houses located inside of the enclosure, nesting material, hammocks, a toilet, stairs, tunnels or tubes, caves, and other supplies which can be used by rats as hiding spaces). This suggests that the majority of rat caretakers taking part in this study were informed about appropriate housing and enrichment supplies for pet rats. This was the case in the study conducted by Neville et al. (2021) as well, with over 65.0% of participants providing suspension areas, climbing structures, hide-aways, tubes, and foraging toys respectively. The importance of complex environments through housing supplements for rat welfare has been demonstrated in studies involving laboratory rats (Kobayashi et al., 2002; Simpson and Kelly, 2011; Vitalo et al., 2012) and pet rats (Brandão and Mayer, 2011). Furthermore, studies concluding that rats prefer cages with nesting materials (Manser et al., 1998) suggest its importance in meeting a rat's behavioral needs. In the current study, the most common nesting material was newspaper (49.1%). So far, only scientific research is available on rats' preferences regarding nesting material, but there is a lack of corresponding research regarding the potential health implications associated with these materials.

Table 9
The heat map shows the results of Likert scale questions targeting affective attitudes and assessing the degree of comfort felt during certain situations. The table demonstrates the percentage of respondents indicating their answer to a seven-point Likert scale ranging from 'feel very uncomfortable' to 'feel very comfortable'. The darker the color, the higher the percentage of respondents.

Affective attitudes Degree of comfort felt during…	n	Response categories very uncomfortable	uncomfortable	rather uncomfortable	partly/ partly	rather comfortable	comfortable	very comfortable
care in general.	617	0.2%	0.0%	0.0%	0.8%	1.6%	19.0%	78.4%
feeding/providing for the animals.	617	0.3%	0.0%	0.0%	1.0%	3.6%	23.5%	71.6%
verbal reprimand (e.g., scolding) the animals.	609	17.2%	13.6%	26.9%	30.7%	5.1%	3.8%	2.6%
cleaning the enclosure/ housing system.	618	1.1%	4.4%	12.5%	38.8%	15.2%	20.4%	7.6%
Petting/stroking.	618	0.0%	0.0%	0.0%	0.3%	1.3%	5.7%	92.7%
observing the animals.	618	0.0%	0.0%	0.0%	0.2%	0.3%	9.9%	89.6%
treating the animals when sick (e.g., giving medication).	613	2.1%	4.6%	13.1%	39.5%	14.0%	15.2%	11.6%
talking to the animals.	615	0.0%	0.0%	0.0%	1.3%	1.5%	12.0%	85.2%
physical disciplining (e.g. pushing away) of the animals.	610	27.2%	17.9%	23.8%	24.4%	3.0%	1.8%	2.0%
playing with the animals.	617	0.0%	0.0%	0.0%	0.8%	1.1%	16.4%	81.7%

Neville et al. (2021) stated being uncertain whether rats had adequate nesting substrate as well, which suggests that this topic warrants further scientific investigation. It is important to determine not only the frequency of access but also the number of items per rat. However, we did not collect this information to avoid increasing the dropout rate. In future studies, particularly those involving on-site assessments, gathering this data would be essential.

Supplies that may impair rat welfare were rarely provided by the participants of the current study ("at least once per week" by less than 7%). Running wheels or running plates, for example, can potentially cause rats to move in an unphysiological, posture, limbs or the tail might become trapped in the wheel or animals might fall off the plate, which exposes them to the risk of injury (Döring, 2017). However, the questionnaire did not include specifics about the running wheels provided to the rats, particularly in relation to the rear wall and running surface being closed, or the diameter of the wheel in relation to body size. Consequently, this survey cannot draw major conclusions on this enrichment item. If adequate running wheels are chosen and they are anchored appropriately, they can provide additional enrichment. Activities that may put pet rats at risk of injury or expose them to predatory species, such as walking them on a leash, taking them for walks without a leash, and allowing them to roam freely in public green spaces (Weiß-Geißler, 2004) were only carried out at least once a week by 0.5%, 4.4%, and 1.4%. Leashes are inappropriate to use on rats, as being taken for a walk in an unfamiliar area is very stressful. Furthermore, leashes impair the rat's ability to hide. A leash's pressure on the thorax when pulled or when the rat begins to run can be relevant to rat welfare as well. However, roaming opportunities are necessary to satisfy the natural exploratory behavior of rats and should be provided for at least one hour every day (Saunders, 2020). According to Austrian regulation (Animal Husbandry Regulation Appendix 1), rats, like other rodents, must have the opportunity for exercise outside the cage several times a week. Our current study found that the average amount of space and time provided for roaming (13.9 m^2 and 2.5 h per day in case rats did not have permanent access to roam outside of the housing system and were not housed in a rat room or lived in the apartment) is positive in terms of rat welfare, especially in comparison to the results found by Neville et al. (2021). In this study, only 2.4% of rat caretakers allowed their rat time to run freely outside of their cage, and merely 0.6% had a separate playpen for their rats. There is currently no scientific research on minimum dimensions for roaming spaces or the amount of time appropriate for pet rats. However, studying the home ranges of wild rats suggests that rats roam large areas (Pryde et al., 2005). This may suggest that most pet rat housing conditions cannot satisfy the natural roaming needs of a rat.

Participants who claimed to "never" clean the supplies in the enclosure (including litter, underlay, blanket, feeding dish, and water bowl), or the enclosure itself, raise concerns about welfare. This is because maintaining good hygiene is essential for the health and welfare of the animals. However, this was only the case with less than 5.0% of participants. Moreover, it is plausible that respondents who indicated they "never" cleaned the enclosure utilized bioactive setups coupled with scatter feeding techniques. In such instances, potential welfare concerns may not arise; however, it is premature to definitively conclude this without further investigation. The findings of the current study agree with cleaning routines among caretakers reported by Neville et al (2021). Neville et al. (2021) found that the most common cleaning frequency was between weekly and fortnightly (44.0%), and that cleaning frequency does not predict the likelihood of respiratory issues. However, the current study provides a more detailed overview of cleaning practice in terms of cleaning the feeding dish, water bowl, roaming area, and changing the litter of the underlay.

The current study found that a relatively large fraction of caretakers provided ad libitum access to commercial rat food (40.6%) and seeds (30.3%). A species-appropriate diet consists of daily grain feed, supplemented fresh feed, and animal protein (Ardente, 2023). In the study by Erhardt, 80% met the conditions for a species-appropriate diet for the rat. The results of the current survey and the study conducted by Erhardt can only be compared to a limited extent since

Table 10
Spearman rank correlations between caretaker attachment (Comfort from Companion Animal Scale Score, following Zasloff, 1996) and attitudes and caretaker behavior represented by husbandry practices and human-animal interactions. Significant correlation coefficients (r_s) are depicted in bold. Darker color indicates a stronger relationship. n = 541–618.

Caretaker behavior (husbandry practices, human-animal interactions)	Caretaker attachment and attitudes							
	Attachment	Comfort Positive interaction [a]	Comfort Care [a]	Comfort Negative interaction [a]	Nervous [a]	Positive [a]	Dirty [a]	Demanding & expensive [a]
Time spent on care and activities for/with rat(s)	**0.21*****	**0.17*****	**0.15*****	-0.03	0.06	**0.14****	**-0.10***	**0.08***
Frequency health checks [a]	**0.16*****	**0.19*****	**0.11****	-0.06	-0.04	**0.16*****	**-0.11****	**0.12****
Frequency fur & claw care [a]	**0.15*****	**0.10***	**0.13*****	0.00	**-0.10***	**0.09***	-0.07	-0.06
Time spent directly with focus animal	**0.18*****	**0.19*****	**0.19*****	-0.01	-0.01	**0.16****	**-0.13****	**-0.09***
Frequency agility / teaching tricks [a]	0.03	**0.12****	0.08	0.04	**0.09***	0.03	0.00	0.06
Frequency of stroking	**0.26*****	**0.22*****	**0.10***	-0.05	-0.07	**0.18*****	**-0.14*****	0.01
Frequency of talking to focus rat	**0.23*****	**0.21*****	**0.11****	-0.04	-0.01	**0.10***	**-0.10***	-0.01
Frequency of feeding out of hand	**0.28*****	**0.20*****	**0.11****	-0.01	-0.03	**0.16*****	**-0.11****	0.04
Frequency of carrying the rat around	**0.31*****	**0.15*****	**0.17*****	0.00	-0.03	**0.20*****	**-0.11****	**-0.09***
Frequency of walks with a leash	-0.02	**-0.08***	-0.02	0.06	0.00	0.01	0.03	-0.05
Frequency of walks without a leash	0.07	0.03	**0.08***	0.03	**-0.10***	0.08	-0.04	**-0.16*****
Frequency of roaming on green spaces	0.02	-0.01	0.00	0.00	**-0.10***	0.06	-0.03	**-0.15*****
Frequency of providing litter [a]	0.00	**0.11****	**0.15*****	0.00	-0.01	0.02	-0.03	0.00
Frequency of providing paper [a]	0.03	**0.12****	**0.14*****	-0.05	0.06	**0.09***	**-0.09***	0.06
Frequency of providing cat & dog toys [a]	0.02	**0.13****	**0.09***	0.01	0.03	0.02	**-0.08***	0.04
Frequency of providing a food tree [a]	-0.02	0.01	**0.09***	0.03	0.01	0.03	0.03	0.04
Frequency of providing labyrinth / parkour [a]	0.01	**0.11****	0.04	-0.01	0.04	**0.08***	0.00	0.04
Frequency of providing running wheels/plates [a]	-0.01	0.05	0.01	0.06	-0.03	0.02	-0.01	**-0.11****
Size of main living area	0.01	0.07	**0.11****	-0.08	-0.05	0.08	-0.02	-0.02
Frequency of roaming outside main living area	**0.15*****	0.08	**0.09***	**-0.09***	**-0.10***	**0.10***	-0.05	-0.07
Duration of roaming bouts	0.07	**0.12****	0.05	-0.05	0.06	0.05	0.02	**0.11****

[a] Attitude and behavior subscales were calculated following principal component analyses.
* $P > 0.01 \leq 0.05$;
** $P < 0.01$;
*** $P < 0.001$.

the current study investigated how often different foods were fed, which was not the case with the study conducted by Erhardt. In the current study, 13.9% of caretakers said they fed their rats cookies at least once per week, and 2.5% of people even fed their rat biscuits at least once a day, which may put pet rats at risk of obesity. Chocolate was fed extremely rarely (0.9% at least once a week, 0.2% at least once a day). Overall, in the present study as well as in the study conducted by Erhardt, many but not all pet caretakers met the conditions for a species-appropriate diet.

Weight, health status, health checks, and subjection to passive smoking

The normal weight of adult male rats is between 450 and 520 g according to Wolfensohn and Lloyd (2003). A normal weight for adult female rats is between 250 and 300 g, according to Ågmo and Snoeren (2015). However, according to Döring (2017), a weight of up to 600 g is acceptable, and even more for rams. If we base our information on Döring's proposition, approximately 14% of the rats in this study were overweight. However, this assessment can only be made very tentatively. The provision of unhealthy snacks regularly, as was the case in 14.6% of feeding cookies in our study, may explain the increased body weight of some rats. Feeding rats ad libitum may pose challenges for their long-term physical well-being, unless it is "healthy" low-calorie feed. However, ad libitum feeding of seeds and other low-caloric foods may not impair a rat's health or welfare. Further studies looking into feeding regimes to ensure a rat's optimal weight are necessary. Kaliste (2007) described that, generally, ad libitum feeding has significant negative effects on health compared to restrictive feeding. Apart from obesity, it is associated with a shorter lifespan, and a higher susceptibility to degenerative kidney diseases, neoplasms, and cardiovascular diseases (Bordone and Guarente, 2005; Moraal et al., 2012). However, appropriate feeding depends on age and reproductive status. Additionally, the diet of the rat must be adapted in case of certain diseases.

The most commonly diagnosed diseases in the present study were respiratory diseases. Respiratory infections are often described as the most common disease in pet rats (Donnelly, 2015). Neville et al. (2021) found that the majority of participants (60.4%) reported

respiratory issues in their rats, which is double the amount of the rats reported to suffer from respiratory disease in the current study.

The results of our current study agree with the results of previous studies on the high incidence of tumors among pet rats (Everaars, 2011; Neville et al., 2021). For females, mammary tumors are common in rats (Russo, 2015) and were also common in the present study. Other tumors that are common in rats (such as lipoma, lymphoma, pituitary adenoma, and cymbal gland tumor (Saunders, 2020) were not mentioned by any participants. Most participants reported "never" smoking in the room where the housing system of the rat is kept, which is positive in terms of passive smoking not being a likely contributor to the development of neoplasia in most cases. Until now, the impact of passive smoking on rat health has only been studied in the laboratory context. Ajiro et al. (2010) discovered detrimental effects of cigarette smoke exposure on the bone development of juvenile rats. For guinea pigs, negative effects on the lungs were shown after chronic exposure (histologically and functionally). Alterations were compared to pathological findings in humans suffering from chronic obstructive pulmonary disease (Vasconcelos et al., 2019).

The few cases of abscesses reported in the current study could indicate problems in housing or management in individual cases, since subcutaneous abscesses in rats often occur after trauma or a bite wound (Hoppmann and Barron, 2007).

Most caretakers reported to perform health checks several times per week. In general, to our knowledge, there is no scientific literature available on how frequently health checks should be carried out by caretakers. As for laboratory rats, score sheets often determine how often health checks must be carried out, which largely depends on the type of experiment which the animals are being used for. Future studies could develop a score-sheet for pet rats, which could help caretakers notice inappropriate weight gain and other symptoms indicative of poor health and welfare. The majority of participants stated that they only consult a vet if the A rat has a health problem (85.5%) and 4.6% of the rat keepers stated that they "never" visit a veterinarian, which may present a welfare issue. Neville et al. (2021) found that over a fifth of caretakers had never taken their rats to the vet, and reported that respondents had raised the issue of many veterinarians lacking knowledge of rat health and welfare. There are no recommended or mandatory vaccinations for rats, which may explain the low percentage of regular vet visits. However, with advancing age, diseases occur more frequently, for which the care of a veterinarian with rat experience would be advantageous. Almost 19.7% of participants state that they trim their focus rat's claws at least once a month and 0.5% even state that they cut the rats' claws either several times a week or even daily. Husbandry guidelines written by experienced caretakers (such as Weiß-Geißler, 2004) state that clipping the claws of rats is usually not necessary and should only be carried out if a claw has been torn.

Behavior of focus rats

The current survey allowed insight into the frequency of 51 rat behaviors reported by caretakers. The questionnaire provides information on behaviors in the past month to reflect current behavior and not, for example, behavior expressed by the animals when they were young. In the current study, there were mostly indications of good well-being. These include self-grooming and socio-positive behaviors (such as huddling with a conspecific, sleeping in the same house, eating together peacefully, playing, and allogrooming), which were observed frequently. Self-grooming several times per day is a natural behavior for rats, which also serves thermoregulation, social communication, and relaxation (Kalueff et al., 2016). However, what is understood by individual participants as "self-grooming" is partly subject to a subjective assessment. Thus, it is possible that also "biting own fur" was interpreted as physiological grooming behavior. Perhaps caretakers either did not evaluate or overlooked typical signs of excessive grooming, such as hairless patches and skin lesions (Khoo et al., 2020).

To our knowledge, the only other extensive study on the frequency of various behaviors concerning pet rats reporting 16 behaviors is a study on pet rats in the United Kingdom (Neville et al., 2022). Neville et al. (2022) reported that pet rats were most likely to climb and sleep communally daily. Huddling with a conspecific and sleeping in the same house inside the enclosure were also reported very frequently by most of the participants in the current study. We further assumed that eating together peacefully, playing and allogrooming were part of the rats' socio-positive behavior. Socio-positive behaviors towards conspecifics can be interpreted as signs of well-being (Hawkins et al., 2011; Held and Špinka., 2011). Nevertheless, the perception of the difference between play and agonistic interactions in the current study was subjected to the interpretation of the caretaker. In future studies, this difficulty could be remedied by carrying out studies using "citizen science", in which video recordings from home can be evaluated to promote objectivity.

Comparable to Neville et al. (2022) there was a large variation in reports of teeth chattering ("bruxing") and eye-boggling behavior (ranging from "never" to "multiple times per day"), but it was overall commonly reported. Neville et al. (2022) suggested these might be potential indicators of "contentment-like state". In the current study, evidence of reduced well-being was present in only a few rats. Presumably repetitive behavior (chewing on cage bars, pacing back and forth, running in circles/trying to catch its tail, somersaults, whipping of the tail, trembling of the body and/or tail) occurred only occasionally. "Biting own fur" was reported for approximately 30% of Focus rats. This is abnormal and potentially harmful behavior according to Döring (2017), but it is possible that some of the participants may have interpreted normal self-grooming as biting own fur, and vice versa. In the study conducted by Normando and Gelli (2011), stereotypic behavior (defined as repetitive cage pacing and/or bar-gnawing) among the three rats which participants had reported on, was described as well in one of the rats. However, due to the small sample size, it is difficult to compare the prevalence. The results in the present study can only be compared to the findings by Neville et al. (2021) to a limited extent as well, because different behaviors were asked in the survey. While the current study assessed the frequency of reports of chewing on cage bars expressly, Neville et al. (2022) assessed observing gnawing non-food items (e.g., chewing on cage bars), thus covering more items. This behavior varied between "never" and "several times per day" in Neville et al.'s study. Chewing cage bars reflects an attempt to escape the cage, and can thus be used as a behavioral measure for welfare according to Lewis and Hurst (2004). This behavior could perhaps be addressed by providing more space and/or enrichment. However, the causes and necessary management implications may be more complex.

Automutilation, which can be allocated to stereotypic behavior too, was rarely reported in the current study. According to Vergneau-Grosset and Ruel (2021a), the main causes of auto-mutilation are medical and/or environmental. In the case of repetitive behavior, the subjectivity of the caretaker must be pointed out as a limitation again. It cannot be ruled out that caretakers report repetitive behavior too often or not often enough. We use the term repetitive for our data because we cannot assume to diagnose stereotypies based on our questionnaire alone. Stereotypic behaviors often substitute for normal behavior and may reduce frustration. For example, stereotypes cannot necessarily be used to quantify well-being in the current housing system (Mason and Latham, 2004; Vergneau-Grosset and Ruel, 2021b), because stereotypic behaviors induced by a different husbandry system can persist despite improvements in husbandry. Therefore, stereotypies should always be taken seriously as a warning sign of potential suffering, but not taken as an index of well-being without considering other parameters. In addition,

Mason and Latham (2004) provide examples that show that stereotypies are not always positively correlated with other signs of poor well-being. For example, in farmed mink, stereotypies correlate negatively with corticosteroid levels, a common physiological parameter to assess stress (Malmkvist et al., 2011). It is possible that animals that display stereotypy can cope better with stressors than those animals in the same group that do not. Addressing stereotypic behaviors is important for both animal welfare and caretaker satisfaction with the animal, as they are often unwanted behaviors and may lead to the relinquishment of an animal (Hou and Protopopova, 2022).

Positive interactions between the rat and the caretaker (such as the rat approaching the caretaker with or without encouragement, eating food out of the caretaker's hand, climbing on the caretaker, and resting next to the caretaker) were very common overall (although there was high variation) and indicate a positive human-animal relationship. A positive, trusting human-animal relationship is very important for pet well-being (Rault et al., 2020). Fear of humans, i.e., a negative emotion, can cause stress in animals (Rushen et al., 1999). This can lead to avoidance of or aggression towards humans. In the current study, biting and scratching caretakers so that they felt bothered or bled were infrequently reported. Also, Neville et al. (2022) reported that incidents of rats biting humans were rare. In the study conducted by Normando and Gelli (2011), one of the three rats had bitten more than 5 times and was reported to be aggressive towards the owner. However, the sample size is too small to draw meaningful conclusions. According to Neville et al. (2022), owners that reported greater interaction with their rats less frequently reported biting of humans, underlining the importance of regular interactions with rats to promote a good human-animal relationship. Avoidance of or aggression towards caretakers can seriously deteriorate the human-animal relationship and even lead to relinquishment.

Hou and Protopopova (2022) found that unwanted animal behavior accounted for 1.4% of relinquishment and that 20.8% of euthanized rats were euthanized due to behavioral issues (e.g., not being social to people or animals, 17.2%; being aggressive to humans, 3.6%). Future studies could look into the efficacy of various refinements of housing and behavioral modification methods to treat behavioral problems.

Human-animal relationship including caretaker attachment and attitudes

To our knowledge, this study presents the first systematic investigation of attitudes towards and attachment to pet rats. Overall, participants had a close attachment to their rats, rated high on positive general attitudes and felt a high degree of comfort during e.g., care in general, providing for the animals, as well as when stroking the animals, talking to the animals and playing with them. This suggests a positive human-animal relationship was present in most cases. To our knowledge, this was the first study to explore attachment and attitudes towards rats systematically. The likes and dislikes regarding rats reported by caretakers in the study by Neville et al. (2021) partly also reflect attitudes, for instance general attitudes such as "rats are intelligent" or "malodourous". In Neville's survey, caretakers mentioned several terms we used for our set of general attitudes. Caretakers often described pet rats as "intelligent". This is in line with our finding that caretakers agree with the statement that "Rats are intelligent". The *Comfort from Companion Animal Scale* was used with rat caretakers for the first time in this study. The scale was originally developed and used in dogs and cats by Zasloff and Kidd (1994) and Zasloff (1996) to measure the perceived level of emotional comfort that caretakers receive from their pets. Although the scores of rat caretakers (mean score 37.8 ± 5.3) remained below the scores of cat and dog caretakers (cat scale mean score: 39.6 ± 4.8, dog scale mean score: 40.1 ± 4.8 according to Zasloff (1996) an overall high score could be reached (maximum 44). The time caretakers spend with their rats (1.6 h) is close to the recommended time of two hours (TVT, 2014), yet still leaves some room for improvement. Regarding positive human-animal interactions, talking to the rats, stroking them and feeding them out of the hand were reported very often, which indicates a positive human-animal relationship.

From the animals perspective the findings regarding the behavior towards caretakers suggest a positive human-animal relationship was present in most cases in our sample. Neutral or friendly interactions with the caretakers such as sniffing the caretaker, climbing on the caretaker, approaching the caretaker after encouragement were reported very frequently. As stated earlier, aggressive behavior towards the caretaker including biting occurred seldom. These findings agree with the study conducted by Neville et al. (2021), who reported that biting the caretaker was rare as well. A good human-animal relationship can trigger positive emotional states (Waiblinger et al., 2006) which was also beneficial in terms of welfare for the rats in the current study.

Associations between attitude, attachment, and caretaker behavior

Several attitude variables and attachment weakly, but consistently correlated with caretaker behavior (husbandry practices, human-animal interactions). More favorable attitude towards the animals and a closer attachment was weakly but significantly linked with positive human-animal interactions and husbandry practices that promote good animal welfare. This is in line with earlier studies showing associations between caretaker attitudes, attachment, and behavior toward the animals and husbandry practices (e.g., dairy cattle: Waiblinger et al., 2002, pigs: Coleman et al., 2000; cats: Windschnurer et al., 2022).

In the current study, no strong correlations were found. In contrast, the associations (though highly significant) were partly very weak. We expect that the associations would have been stronger if we had included attitudes towards the actual behavior such as behavioral beliefs (e.g., included an assessment of the degree of agreement to the importance of allowing free roaming to correlate it with the frequency or duration of free-roaming) instead of general and affective attitudes only. In general, attitudes and beliefs that are more closely related to the actual behavior of the rat relate more strongly to caretaker behavior, as shown in previous studies (e.g., Waiblinger et al., 2002; Windschnurer et al., 2022). Future studies on pet rats should also address attitudes toward the actual behaviors directed at rats.

Apart from positive effects on an animal's affective states during positive human-animal interactions (Rault et al., 2020), a strong human-animal bond can have a positive impact on animal welfare if the caretaker is willing to spend time and money on necessary veterinary treatment (Wensley, 2008), is better informed and provides more welfare friendly housing conditions. For instance, in cats, study results suggest that the knowledge about species-specific needs has an impact on the provision of enrichment (Gazzano et al., 2015). On the other hand, it should not be overlooked that in certain circumstances a strong bond can also be the cause of compromised welfare. For example, caretakers may be reluctant to allow euthanasia for welfare reasons, or they may promote obesity (Wensley, 2008).

Limitations and outlook

Since participation in the study was voluntary, the results of the study are likely to reflect the efforts of motivated, committed caretakers who are willing to complete a long questionnaire. Offering rat care items as an incentive might have increased participation from individuals interested in rat care, but it would not have motivated

those who are not engaged in rat care. Therefore, less motivated caretakers may not have been represented by this study. Certain descriptive statistics indicate a possible bias in the population. For instance, the number of rats were kept in the households was relatively large. Also, many respondents were animal foster carers or other non-traditional pet owners, and the rats were relatively old (1.4 years). Participants were mainly recruited through social media (80%). Furthermore, the majority of participants were female (91.7%) and 25–34 years old (44.1%). Thus, the participants in this study are not representative across the demographic spectrum. However, similar sex and age distributions have been described in other online surveys (Smith, 2008) and surveys regarding pets that were not conducted online (Kendall and Ley, 2008; Rooney et al., 2014). As is the case with any survey, the accuracy of the answers provided could not be validated. Pet caretakers may over-report or underreport the frequency of behaviors. It is also unclear whether rats were observed at more inactive times of the day or precisely at their most active times. Rats are active at night and twilight and may not have been observed at these times (Döring, 2017).

Reports on caretakers' descriptions of their own behavior may be biased for several reasons. In a meta-analysis carried out by Kormos and Gifford (2014), which aimed to quantify the relationship between self-reports and objective behavior, 79% of the variance remained unexplained. One possible explanation for this is that respondents might forget things. Everyday behaviors are poorly recorded by memory, and sometimes deliberately or unconsciously exaggerated or understated (Kormos and Gifford, 2014). Respondents may also be able to give preferential responses that they believe are more likely to meet with social approval due to the well-studied "social desirability bias" (Miller, 2011). One participant reported keeping 140 rats. The validity of this is questionable.

This study highlights the importance of informing caretakers about the nutritional and housing needs of pet rats. It provides a basis that can aid husbandry recommendations in veterinary practice and behavioral consultations for veterinarians, as some caretakers may not be aware of the basic needs of pet rats. Although some participants exceeded the expectations for rat housing in many ways (i.e. providing a "rat room" as opposed to an enclosure with the minimum dimensions), some rats were not provided with the legally required minimum floor space, suffered from disease, and are overweight. Although weakly, attachment and attitudes significantly correlated with human behavior reflected in husbandry decisions such as the frequency of providing certain enrichments or possibilities for free-roaming and human-animal interactions. Human behavior can be both explained and predicted by attitudes (Ajzen and Fishbein, 1980). Attitudes are learned and may thus be altered by the provision of information as well as new experiences (Ajzen, 1988). By targeting the attitudes of rat caretakers, also handling practices and husbandry might be improved and in consequence animal welfare. For instance, cognitive behavioral intervention programs have been successfully applied to people working with cattle and pigs (Coleman et al., 2000; Hemsworth et al., 1994, 2002). Moreover, these results can be used as a foundation for further studies that aim to improve rat welfare by, for example, validating reported data with video recordings provided by pet rat caretakers and home visits.

Conclusion

In conclusion, this study provides a descriptive overview of welfare-related aspects regarding petrats, including potentially problematic husbandry practices and behaviors. Caretaker-reported data suggest that most pet rats in the German-speaking households of the current study have adequate housing systems, good health, and living conditions enriched by adequate toys/supplies for housing. The vast majority of rats enjoyed the company of conspecifics under the group composition recommended by scientific literature. Many rats exhibited behaviors that indicate good welfare (socio-positive behavior, signs of well-being such as grooming and teeth chattering) and little fear of humans. However, problematic husbandry practices were identified in a few cases (e.g., insufficient minimum floor space, in addition to supplies and activities that do not comply with animal welfare). Our findings contribute to a better understanding of pet rat living conditions and behavior, which provides a foundation for future studies on the rat-human relationship, welfare assessment tools, and the provisioning of new pet rat care guides. The identified relationships between caretaker attitudes and behaviors can help design interventions to promote caretaker behavior that is beneficial for rat welfare.

CRediT authorship contribution statement

Raffaela Lesch: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Conceptualization. **Stephanie Schneidewind:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ines Windschnurer:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Veronika Heizmann:** Writing – review & editing, Visualization, Validation, Conceptualization.

Acknowledgments

We are very grateful to all caretakers of rats who participated in the survey.

Ethical Considerations

All procedures applied during the course of this study were discussed with the ethics committee of the University of Medicine, Vienna, which has to be contacted if studies involving human participants are carried out at the University of Veterinary Medicine Vienna. This committee confirmed that no ethics vote was necessary, in accordance with guidelines for Good Scientific Practice and with Austrian national legislation. Informed consent was obtained from all subjects involved in the study.

Conflict of Interest

All authors declare that they have no conflict of interest.

Appendix A. Supporting material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jveb.2024.06.009.

References

Ajzen, I., 1988. Attitudes, Personality, and Behaviour. Open University Press, Milton Keyes, UK.
Ajzen, I., Fishbein, M., 1980. Understanding Attitudes and Predicting Social Behaviour. Prentice-Hall, Inc, Upper Saddle River, NJ.
Abou-Ismail, U.A., Burman, O., Nicol, C., Mendl, M., 2010. The effects of enhancing cage complexity on the behaviour and welfare of laboratory rats. Behav. Processes 85 (2), 172–180.
Ågmo, A., Snoeren, E., 2015. Silent or vocalizing rats copulate in a similar manner. PLoS One 10 (12), e0144164.
Ajiro, Y., Tokuhashi, Y., Matsuzaki, H., Nakajima, S., Ogawa, T., 2010. Impact of passive smoking on the bones of rats. Orthopedics 33 (2), 90–95.
Ardente, A., 2023. Exotic Animal Nutrition, An Issue of Veterinary Clinics of North America: Exotic Animal Practice, E-Book: Exotic Animal Nutrition. An Issue of Veterinary Clinics of North America: Exotic Animal Practice, E-Book. Elsevier Health Sciences, Philadelphia, USA.
Arhant, C., Troxler, J., 2014. Approach behaviour of shelter dogs and its relationships with the attitudes of shelter staff to dogs. Appl. Anim. Behav. Sci. 160, 116–126.

Arhant, C., Wogritsch, R., Troxler, J., 2015. Assessment of behavior and physical condition of shelter cats as animal-based indicators of welfare. J. Vet. Behav.: Clin. Appl. Res. 10 (5), 399–406.
Benato, L., 2012. Respiratory diseases in rats. UK Vet. Companion Anim. 17 (4), 47–50.
Bläske, A., 2019. Tierschutzaspekte bei der privaten Haltung von und dem Handel mit (exotischen) Säugetieren in Deutschland. Ludwig-Maximilians-Universität, Munich.
Bordone, L., Guarente, L., 2005. Calorie restriction. SIRT1 and metabolism: Understanding longevity. Nat. Rev. Mol. Cell Biol. 6 (4), 298–305.
Brandão, J., Mayer, J., 2011. Behavior of rodents with an emphasis on enrichment. Journal of Exotic Pet Medicine 20 (4), 256–269.
Burman, O., Owen, D., Aboulsmail, U., Mendl, M., 2008. Removing individual rats affects indicators of welfare in the remaining group members. Physiol. Behav. 93 (1-2), 89–96.
Castelhano-Carlos, M., Baumans, V., 2009. The impact of light. noise. cage cleaning and in-house transport on welfare and stress of laboratory rats. Lab. Anim. 43 (4), 311–327.
Burn, C., 2008. What is it like to be a rat? Rat sensory perception and its implications for experimental design and rat welfare. Appl. Anim. Behav. Sci. 112 (1-2), 1–32.
Cloutier, S., Baker, C., Wahl, K., Panksepp, J., Newberry, R., 2013. Playful handling as social enrichment for individually-and group-housed laboratory rats. Appl. Anim. Behav. Sci. 143 (2-4), 85–95.
Coleman, G.J., Hemsworth, P.H., Hay, M., Cox, M., 2000. Modifying stockperson attitudes and behaviour towards pigs at a large commercial farm. Appl. Anim. Behav. Sci. 66, 11–20.
Donnelly, T., 2004. Disease problems of small rodents. Ferrets Rabbits Rodents 299.
Donnelly, T., 2015. Mice and rats as pets - exotic and laboratory animals. ⟨https://www.merckvetmanual.com/exotic-and-laboratory-animals/rodents/mice-and-rats-as-pets⟩.
Döring, D., 2017. Ratte. In: Schneider, B., Döring, D., Hrsg (Eds.), Verhaltensberatung bei kleinen Heimtieren: Haltung. Normalverhalten und Behandlung von Verhaltensproblemen. Schattauer, Stuttgart, pp. 158–182.
Erhard, M., 2017. Haltung exotischer Tiere und Wildtiere in Privathand: Situationsanalyse. Bewertung und Handlungsbedarf insbesondere unter Tierschutzaspekten. Zweiter Zwischenbericht. LMU München Tierärztliche Fakultät. Veterinärwissenschaftliches Department Lehrstuhl für Tierschutz. Verhaltenskunde. Tierhygiene und Tierhaltung.
Everaars, M., 2011. Research into premature Death of Pet Rats and Ferrets. Faculty of Veterinary Medicine, Utrecht University, Utrecht.
Farm Animal Welfare Council (FAWC), 1993. Second Report on Priorities for Research and Development in Farm Animal Welfare. DEFRA, London, UK.
Gazzano, A., Bianchi, L., Campa, S., Mariti, C., 2015. The prevention of undesirable behaviors in cats: Effectiveness of veterinary behaviorists' advice given to kitten owners. J. Vet. Behav. 10, 535–542.
Graham, J., Schoeb, T., 2011. Mycoplasma pulmonis in rats. J. Exot. Pet Med. 20 (4), 270–276.
Hawkins, P., Morton, D., Burman, O., Dennison, N., Honess, P., Jennings, M., Westwood, K., 2011. A guide to defining and implementing protocols for the welfare assessment of laboratory animals: Eleventh report of the BVAAWF/FRAME/RSPCA/UFAW Joint Working Group on Refinement. Lab. Anim. 45 (1), 1–13.
Held, S., Špinka, M., 2011. Animal play and animal welfare. Anim. Behav. 81 (5), 891–899.
Hemsworth, P.H., Coleman, G.J., Barnett, J., 1994. Improving the attitude and behavior of stockpeople towards pigs and the consequences on the behaviour and reproductive performance of commercial pigs. Appl. Anim. Behav. Sci. 39, 349–362.
Hemsworth, P.H., Coleman, G.J., Barnett, J.L., Borg, S., Dowling, S., 2002. The effects of cognitive behavioral intervention on the attitude and behavior of stockpersons and the behavior and productivity of commercial dairy cows. J. Anim. Sci. 80, 68–78.
Hou, C., Protopopova, A., 2022. Rats as pets: Predictors of adoption and surrender of pet rats (*Rattus norvegicus domestica*) in British Columbia, Canada. Plos One 17 (2), e0264262.
Hurst, J., Barnard, C., Tolladay, U., Nevision, C., West, C., 1999. Housing and welfare in laboratory rats: Effects of cage stocking density and behavioural predictors of welfare. Anim. Behav. 58 (3), 563–586.
Hoppmann, E., Barron, H., 2007. Rodent dermatology. J. Exot. Pet Med. 16 (4), 238–255.
Kaliste, E., 2007. The Welfare of Laboratory Animals. Springer, Dordrecht, pp. 61.
Kalueff, A., Stewart, A., Song, C., Berridge, K., Graybiel, A., Fentress, J., 2016. Neurobiology of rodent self-grooming and its value for translational neuroscience. Nat. Rev. Neurosci. 17 (1), 45–59.
Kendall, K., Ley, J., 2008. Caretaker observations can provide data for constructive behavior analysis in normal pet cats in Australia. J. Vet. Behav.: Clin. Appl. Res. 3 (6), 244–247.
Khoo, S., Correia, V., Uhrig, A., 2020. Nesting material enrichment reduces severity of overgrooming-related self-injury in individually housed rats. Lab. Anim. 54 (6), 546–558.
Krohn, T., Sørensen, D., Ottesen, J., Hansen, A., 2006. The effects of individual housing on mice and rats: A review. Anim. Welf. 15 (4), 343–352.
Kobayashi, S., Ohashi, Y., Ando, S., 2002. Effects of enriched environments with different durations and starting times on learning capacity during aging in rats assessed by a refined procedure of the Hebb-Williams maze task. J. Neurosci. Res. 70 (3), 340–346.
Kormos, C., Gifford, R., 2014. The validity of self-report measures of proenvironmental behavior: A meta-analytic review. J. Environ. Psychol. 40, 359–371.
LaFollette, M.R., 2020. Human-Animal Interactions. Animal-centric Care and Management. Taylor & Fracis Group, Abbingdon, UK, pp. 1–14.
Lewis, R., Hurst, J., 2004. The assessment of bar chewing as an escape behaviour in laboratory mice. Anim. Welf. 13 (1), 19–25.
Malmkvist, J., Jeppesen, L., Palme, R., 2011. Stress and stereotypic behaviour in mink (*Mustela vison*): A focus on adrenocortical activity. Stress 14 (3), 312–323.
Manser, C., Broom, D., Overend, P., Morris, T., 1998. Operant studies to determine the strength of preference in laboratory rats for nest-boxes and nesting materials. Lab. Anim. 32 (1), 36–41.
Mason, G., Latham, N., 2004. Can't stop. won't stop: Is stereotypy a reliable animal welfare indicator? Anim. Welf. 13 (Suppl. 1), 57–69.
Maso, G., Burn, C., Peters, A., 2006. Acute effects of cage cleaning at different frequencies on laboratory rat behavior and welfare. Anim. Welf. 15 (2), 161–171.
McPherson, K., Shields, C., Poudel, B., Fizer, B., Pennington, A., Szabo-Johnson, A., Williams, J., 2019. Impact of obesity as an independent risk factor for the development of renal injury: Implications from rat models of obesity. Am. J. Physiol.-Renal Physiol. 316 (2), F316–F327.
Miller, A., 2011. Investigating social desirability bias in student self-report surveys. Educ. Res. Quart. 36 (1), 30–47.
Miller, K., Garner, J., Mench, J., 2006. Is fearfulness a trait that can be measured with behavioural tests? A validation of four fear tests for Japanese quail. Anim. Behav. 71, 1323–1334.
Moraal, M., Leenaars, P., Arnts, H., Smeets, K., Savenije, B., Surfs, J., Ritskes-Hoitinga, M., 2012. The influence of food restriction versus ad libitum feeding of chow and purified diets on variation in body weight. growth and physiology of female Wistar rats. Lab. Anim. 46 (2), 101–107.
Neville, V., Mounty, J., Benato, L., Hunter, K., Mendl, M., Paul, E., 2021. Pet rat welfare in the United Kingdom: The good, the bad and the ugly. Vet. Rec., e559.
Neville, V., Mounty, J., Benato, L., Hunter, K., Mendl, M., 2022. Thinking outside the lab: Can studies of pet rats inform pet and laboratory rat welfare? Appl. Anim. Behav. Sci. 246, 1–11.
Normando, S., Gelli, D., 2011. Behavioral complaints and owners' satisfaction in rabbits. mustelids. and rodents kept as pets. J. Vet. Behav. 6, 337–342.
Pallant, J., 2013. 'Checking the Reliability of a Scale' in SPSS Survival Manual: A Step by Step Guide to Data Analysis using IBM SPSS, 5th Edition. Open University Press, Berkshire, England.
Pallant, J., 2020. 'Factor Analysis' in SPSS Survival Manual: A Step by Step Guide to Data Analysis using IBM SPSS, 7th Edition. Routledge, Abingdon, OX and New York, NY.
Palmeiro, B.S., Roberts, H., 2013. Clinical approach to dermatologic disease in exotic animals. The veterinary clinics of North America. Exot. Anim. Pract. 16 (3), 523–577.
Patterson-Kane, E., Hunt, M., Harper, D., 2004. Short communication: Rats demand for group size. J. Appl. Anim. Welf. Sci. 7 (4), 267–272.
Proops, L., Troisi, C., Kleinhappel, T., Romero, T., 2021. Non-random associations in group housed rats (*Rattus norvegicus*). Sci. Rep. 11 (1), 1–9.
Pryde, M., Dilks, P., Fraser, I., 2005. The home range of ship rats (*Rattus rattus*) in beech forest in the Eglinton Valley. Fiordland. New Zealand: A pilot study. N.Z. J. Zool. 32 (3), 139–142.
Rault, J., Waiblinger, S., Boivin, X., Hemsworth, P., 2020. The power of a positive human–animal relationship for animal welfare. Front. Vet. Sci. 7, 590867.
Reavill, D., Imai, D., 2020. Pathology of diseases of geriatric exotic mammals. Vet. Clin.: Exot. Anim. Pract. 23 (3), 651–684.
Rooney, N., Blackwell, E., Mullan, S., Saunders, R., Baker, P., Hill, J., Sealey, C., Turner, M., Held, S., 2014. The current state of welfare, housing and husbandry of the English pet rabbit population. BMC Res. Notes 7 (942), 1–13.
Rey, F., Bulliot, C., Bertin, N., Mentré, V., Rey, F., 2015. Morbidity and disease management in pet rats: A study of 375 cases. Vet. Rec. 176 (15). https://doi.org/10.1136/vr.102728
Russo, J., 2015. Significance of rat mammary tumors for human risk assessment. Toxicol. Pathol. 43 (2), 145–170.
Rushen, J., Taylor, A., De Passillé, A., 1999. Domestic animals' fear of humans and its effect on their welfare. Appl. Anim. Behav. Sci. 65 (3), 285–303.
Saunders, R., 2020. Rats. In: Kubiak, M. (Ed.), Handbook of Exotic Pet Medicine. Wiley-Blackwell, Hokoen. New Jersey, pp. 99–119.
Simpson, J., Kelly, J., 2011. The impact of environmental enrichment in laboratory rats–behavioural and neurochemical aspects. Behav. Brain Res. 222 (1), 246–264.
Schoeb, T.R., 2000. Respiratory diseases of rodents. Vet. Clin. North Am.: Exot. Anim. Pract. 3 (2), 481–496.
Sinclair, K.M., 2021. Rats and mice. Exot. Anim. Emerg. Crit. Care Med. 330–348.
Smith, G., 2008. Does gender influence online survey participation? A record-linkage analysis of university faculty online survey response behavior. ERIC Document Reproduction Service No. ED 501717.
Talling, J., Van Driel, K., Inglis, I., 2002. Do laboratory rats choose to spend time together? [Abstract] Proceedings of the 36th International Congress of the ISAE, Egmond aan Zee. Wageningen, The Netherlands. August 6–10. 2002, p. 168.
Tamura, Y., 2010. Current approach to rodents as patients. J. Exot. Pet Med. 19 (1), 36–55.
Turner, P.V., 2014. Rodent and Rabbit Welfare in the Research Environment. In: Laboratory Animal Welfare. Academic Press, pp. 171–196. https://doi.org/10.1053/j.jepm.2010.01.014
Vasconcelos, L., Silva, M., Costa, A., Souza, I., Queiroga, F., Araujo, L., Vieira, G., 2019. A Guinea pig model of airway smooth muscle hyperreactivity induced by chronic allergic lung inflammation: Contribution of epithelium and oxidative stress. Front. Pharmacol. 9, 352148.
Vergneau-Grosset, C., Ruel, H., 2021a. Abnormal repetitive behaviors and self-mutilations in small mammals. Vet. Clin.: Exot. Anim. Pract. 24 (1), 87–102.
Waiblinger, S., Menke, C., Coleman, G., 2002. The relationship between attitudes. personal characteristics and behaviour of stockpeople and subsequent behaviour and production of dairy cows. Appl. Anim. Behav. Sci. 79, 195–219.

Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M.-V., Janczak, A.M., Visser, E.K., Jones, R.B., 2006. Assessing the human–animal relationship in farmed species: A critical review. Appl. Anim. Behav. Sci. 101 (3-4), 185–242.
Waiblinger, S., 2019. Agricultural animals. In: Hosey, G.:, Melfi, V. (Eds.), Anthrozoology: Human–Animal Interactions in Domesticated and Wild Animals. Oxford University Press, Oxford, pp. 32–58.
Weiß-Geißler, E., 2004. Das andere Rattenbuch. Nordersted: Books on Demand GmbH. 173–197.
TVT (Tierärztliche Vereinigung für Tierschutz e.V.), 2014. Merkblatt Nr. 160 - Heimtiere: Ratten (Stand: Apr. 2014). ⟨https://www.tierschutz-tvt.de/alle-merkblaetter-und-stellungnahmen/#c270⟩. Accessed May 25, 2024.
Wensley, S., 2008. Animal welfare and the human–animal bond: Considerations for veterinary faculty, students, and practitioners. J. Vet. Med. Educ. 35 (4), 532–539.
Windschnurer, I., Boivin, X., Waiblinger, S., 2009. Reliability of an avoidance distance test for the assessment of animals' responsiveness to humans and a preliminary investigation of its association with farmers' attitudes on bull fattening farms. Appl. Anim. Behav. Sci. 117 (3–4), 117–127.
Windschnurer, I., Häusler, A., Waiblinger, S., Coleman, G.J., 2022. Relationships between owner and household characteristics and enrichment and cat behaviour. Appl. Anim. Behav. Sci. 247, 105562.
Wolfensohn, S., Lloyd, M., 2003. Handbook of Laboratory Animal - Management and Welfare, 3rd Ed. Blackwell Publishing, Hoboken, New Jersey.
Vergneau-Grosset, C., Ruel, H., 2021b. Abnormal repetitive behaviors and self-mutilations in small mammals. Vet. Clin.: Exot. Anim. Pract. 24 (1), 87–102.
Vitalo, A., Gorantla, S., Fricchione, J., Scichilone, J., Camacho, J., Niemi, S., Levine, J., 2012. Environmental enrichment with nesting material accelerates wound healing in isolation-reared rats. Behav. Brain Res. 226 (2), 606–612.
Zasloff, R.L., 1996. Measuring attachment to companion animals: A dog is not a cat is not a bird. Appl. Anim. Behav. Sci. 47 (1–2), 43–48.
Zasloff, R.L., Kidd, A.H., 1994. Attachment to feline companions. Psychol. Rep. 74 (3), 747–752.

Legislations cited

Animal Husbandry Regulation - Verordnung der Bundesministerin für Gesundheit über die Haltung von Wirbeltieren, die nicht unter die 1. Tierhaltungsverordnung fallen, über Wildtiere, die besondere Anforderungen an die Haltung stellen und über Wildtierarten, deren Haltung aus Gründen des Tierschutzes verboten ist (2. Tierhaltungsverordnung).