Epidemiology of behavioural problems in pet rabbits: an owners´ survey

A. González-Martínez[a, *], S. Castro[b], F. Camino[c], B. Rosado[d], I. Luño[d], F.J. Diéguez[b].

[a]Veterinary Teaching Hospital Rof Codina. Veterinary Faculty of Lugo, Santiago de Compostela University, Campus Universitario, 27002 Lugo, Spain

[b]Anatomy, Animal Production and Clinical Veterinary Sciences Department, Veterinary Faculty of Lugo, Santiago de Compostela University, Campus Universitario, 27002 Lugo, Spain

[c]IES Valle del Oja, Carretera Gallinero, s/n, Santo Domingo de la Calzada, 26250, La Rioja, Spain

[d]Animal Pathology Department. Veterinary Faculty. Zaragoza Univeristy. Miguel Servet, 177, 50013, Zaragoza, Spain

***Corresponding author**. Tel.: +34982822738. E-mail: angela.gonzalez@usc.es (A. González-Martínez)

Abstract

The present paper was designated to assess the perceived frequency of problematic rabbit behavior in a sample of pet rabbit owners and to characterize this behavior. For this purpose, a questionnaire was administered to 423 rabbit owners from Spain and Latin America. The collected data was processed descriptively and using multiple correspondence analysis (MCA). Results indicated that, among the studied population, the most common behavior problems according to owners´ perception were inappropriate elimination followed by non-social fear, destructive behavior and compulsive disorders. Rabbits generally showed more than just one behavioural problem; there seemed to be an association between non-social fear and destructive behaviour as well as between owner-directed aggression and owner-directed fear. MCA indicated that the studied behavior problems were more frequent in entire females. Rabbits acquired before weaning and, to a lesser extent, between weaning and puberty were more likely to show compulsive disorders and inappropriate urine elimination. These two behavior problems seemed to be also more common in rabbits from breeders and pet stores. Such data support previous findings and provide new information in the field of epidemiology of behavioural problems in pet rabbits.

Key words: exotic companion mammals, behavior disorders, multiple correspondence analysis, animal welfare

1. Introduction

The domestic rabbit is the descendant of the European rabbit, *Oryctolagus cuniculus*, which comes from Western Europe and Northwestern Africa, and it has been kept as a pet since the early sixteenth century (Brooks, 1986; Bradley, 2006; Carpenter, 2003). The popularity of domestic rabbits as domestic pets has been steadily increasing over the last few years (Crowell-Davis, 2007; d'Ovidio et al, 2016).

Assisting rabbit owners in understanding their pet's behavior to prevent and treat behavior problems is an important part of veterinary practice (Crowell-Davis, 2007). The relevance of considering the study of behavioural problems in rabbits stems from the connection between undesirable behavioural patterns and lower satisfaction level (Normando and Gelli, 2011). Thereby, behavior problems are risk factors for relinquishment of rabbits to an animal shelter (Ledger, 2010; Cook and McCobb, 2012). Nevertheless, very little attention has been paid to the behavior and welfare of domestic rabbits kept as pets in the literature (Mullan and Main, 2006; Mullan and Main, 2007; Schepers et al., 2009; Edgar and Mullan, 2011; Normando and Gelli, 2011; Rooney et al., 2014; d´Ovidio et al., 2016).

There are several major categories of behavior issues in rabbits: urine spraying; difficulties in initial litter box training and loss of litter box training; fear of humans, with or without aggressiveness; hostility toward other rabbits, especially unfamiliar ones; destructiveness; and infanticide (Crowell-Davis, 2007). A previous study carried out in Italy indicated that the most frequent complaints made by rabbits' owners included inappropriate elimination and destructiveness, and lack of sociability and/or fondness and affection toward their owners. Complaints related to undesirable behaviour, such as house soiling, biting of electric wires, or digging, amounted to 29.3%. In addition, aggressiveness toward people was reported in 13.0% and stereotypical behavioral patterns were reported by owners in 28.3% of the cases (Normando and Gelli, 2011).

According to owners' reports, neutered male rabbits were more prone to house soiling than entire males (Normando and Gelli, 2011). Bucks were reported to display contact-seeking behavior significantly more often than does did. Also, bucks had a much higher prevalence of sexual behavior compared with does (d´Ovidio et al, 2016).

Does had a much higher prevalence of owner-directed aggressiveness, stranger-directed aggressiveness and fear of strangers compared with bucks. The majority of does showed owner-directed aggressiveness only when being held or manipulated, rather than in the proximity of food or after being approached in their cage. A positive association was

found between females living as single-housed rabbits and owner-directed aggressiveness. Does' aggressiveness toward strangers was frequent, especially in response to being approached in their cages, according to owners' reports. (d´Ovidio et al, 2016).

The prevalence of stereotypies was influenced by housing conditions. Pets which were allowed to roam for < 7 hours a day were significantly more often said to show stereotypies than other pets. In particular, both stereotypic pacing and stereotypic gnawing were reported as being more frequent (Normando and Gelli, 2011).

A large number of studies in other species are based upon a questionnaire that tests owner's perceptions in order to examine behavioural problems. Such studies are considered critically important as owner's perception will usually determine the pet's ultimate fate. Similarly, it could be interesting for the veterinarian community to know the prevalence of behavioral complaints in less common pet species in order to be able to counsel prospective owners toward a responsible and informed adoption (Normando and Gelli, 2011).

Despite the scarcity of studies, there are still discrepancies about the most common behavioural problems in pet rabbits and the effect of some risk factors on those problems. Therefore, the aims of the present paper are (1) to assess the perceived frequency of problematic rabbit behavior in a sample of pet rabbit owners and (2) to characterize this behavior using multiple correspondence analysis.

2. Materials and methods

2.1. Questionnaire and animals surveyed

Using the form function in Google Docs, an owner-directed questionnaire (available in Spanish on request from the authors) was designed to collect data regarding a range of rabbit behavioral problems. During the second half of 2017 the questionnaire was posted online, published in the media (related to exotic pets) and emailed to veterinary practitioners (that provided service for exotic pets), so that they could subsequently distribute it among those clients who owned one or more pet rabbits. The questionnaire was distributed across several Spanish-speaking countries, since most of the media groups where the questionnaire was posted are integrated only by Spanish and Latin American members.

The questionnaire, consisted of closed questions, gathered information about the participants' perception of behavior problems, including a brief explanation of the essential components of each behavior pattern (Supplementary Table 1). In addition, data about gender, neuter status of the rabbit, origin (shelter or rescue group, pet shop, direct arrival from breeders, or transfer from another person) and age at the time of acquisition (below 42 d, between 42 d and 120 d or above 120 d) were also included (among other general aspects). Descriptive statistics of the studied rabbit population (both collectively and independently for Spain and Latin America) are presented in Table 1.

2.2. Data processing

Data on respondents was downloaded from the form function in Google Docs into Microsoft® Office Excel. Subsequently, data was rewritten in SPSS 15.0 syntax for statistical analysis. All the behavioral variables were binary and coded as 1 (indicating the presence of the behavior problem) or 0 (absence) except for the case of inappropriate elimination, in which absence was codified as 0, only urine as 1, only feces as 2 and both (urine and feces) as 3.

2.3. Statistical analysis

Initially, a descriptive analysis was conducted to investigate the frequency of the different behavior problems according to owners' perception.

In a second step, and given the nature of the variables included in the analysis (mostly nominal), a multiple correspondence analysis (MCA) was performed. The goal of MCA is to reduce a set of possibly correlated variables (including all the mentioned behavior disorders, sex, neuter status, origin and age at the time of acquisition of the rabbit and geographical area) to a smaller group of linearly uncorrelated ones (dimensions). This study, the number of dimensions was set to two (to allow for a two-dimensional graphical representation). The position of the full set of categories for each investigated variable (category-points) in the MCA graph is the basis for revealing relationships among them: variable categories with a similar profile tend to be grouped together whereas those with no correlation are positioned on opposite sides of the graph.

From the MCA, the correlation matrix of the resulting variables (once optimal scaling had been performed) was also completed in the analysis.

3. Results

A total of 423 owners completed the questionnaire online (234 from Spain, 129 from Chile, 26 from México, 22 from Argentina, 3 each from Colombia and Costa Rica, 2 from both Guatemala and Peru and 1 from both Paraguay and Ecuador).

In the studied population, the most common behavior problems according to owners´ perception were inappropriate elimination followed by non-social fear, destructive behavior and compulsive disorders. On the contrary, owner-directed fear and family-rabbit directed fear were the least frequent complaints. The prevalence estimation of the behavior problems considered in the study is shown in Table 2. Reported prevalence of most recurrent behavioural problems was generally higher for Latin American owners than for Spanish owners, except for the case of stranger-directed fear, family rabbit-directed fear and compulsive disorders) (Table 2). However, significant differences were only observed between the two geographical areas with regard to stranger-directed aggression, destructive behaviour and inappropriate elimination (Table 2).

The MCA biplot (Figure 1), where the data have been standardized, explained 35.1% of the variance of the data on behavior, sex/neuter status, origin and age of acquisition obtained from 423 pet rabbit owners. The percentage of variance explained by the first dimension was 20.9% and, for the second dimension, it was 14.2%.

The main results of the MCA are presented using a graphical display (Figure 1). Upon visual inspection a certain pattern in the data is noticeable. The categories associated with the presence of aggressions and fear (except family-rabbit directed fear) are clustered on the lower right quadrant of the chart, as are destructive behavior patterns and inappropriate elimination of both urine and feces. This indicated that rabbits show generally more than one behavior problem. Accordingly, there seems to be an association between non-social fear and destructive behavior or between owner-directed aggression and owner-directed fear, as the category points indicating the presence of these problems are very close in the chart.

According to the MCA, behavior problems are more likely to occur in entire females, as the corresponding category point lies in the direction of the category points of most behavioral problems. This also occurs with the category point corresponding to owners from Latin American.

Category points corresponding to the presence of compulsive disorders and inappropriate urine elimination are located in the lower left quadrant of the chart. Categories indicating acquisitions before weaning and between weaning and puberty are also found in this

quadrant. The MCA biplot seems to indicate that, especially those animals acquired before weaning tend to be more susceptible to behavior problems. Acquisitions before weaning are also closer to the category corresponding to Latin America.

According to the second dimension, most behavior disorders could also tend to be more frequent in rabbits acquired at pet stores or from breeders (mainly non-social fear, compulsive disorders, destructive behavior and inadequate urine elimination). Rabbits transferred from another person seem to be the healthiest from a behavioral point of view. Rabbits adopted from shelters are the ones that are neutered most often (especially males). In addition, they are frequently acquired after puberty and they are less prone to show family rabbit-directed aggressiveness (when applicable).

The correlation matrix of the transformed variables considered in the study (after optimal scaling) is presented in Supplementary Table 2.

4. Discussion

The primary aim of this study was to determine the prevalence of behavior problems according to owners´ perception and to explore some related factors. It is interesting to say that only a few studies about behavior problems in pet rabbits had previously been published (Schepers et al., 2009; Normando and Gelli, 2011; d´Ovidio et al, 2016). Nevertheless, differences among studies could be due to several aspects including the sample number, design of the questionnaire, statistical methods or even differences in breeding conditions (depending on the country from which the information is obtained), as well as different nomenclatures for the same behavioral problems (González- Martínez et al., 2011).

A possible limitation of the current study, which should not be underestimated, was the potential role that other factors may have played in the present design (especially the habitat of the rabbit). In addition, the survey was distributed on-line. Thereby, rabbits were not diagnosed by a veterinary behaviorist and medical problems couldn´t be ruled out. However, owner's perception of their pet's behavior is an important determinant of the pet's fate; thus, it is of paramount relevance when dealing with behavioral problems. Moreover, the people who are in contact with the pet for a long time on a daily basis (owners, caretakers, trainers, breeders) are the people who are most likely to see and note how the animal behaves in the varied circumstances of its everyday life (Normando, et al., 2011). In addition, it is important to keep in mind that participants enrolled voluntarily

213 in the study, and therefore our results cannot be extrapolated directly due to possible
214 selection bias. Contributing countries also had different levels of participation.
215 The most frequent behavior problem declared by owners was inappropriate elimination.
216 This behaviour is also seen in domesticated rabbits, which show a tendency towards
217 depositing urine and feces at the same place in their enclosures, making it possible to
218 litter-box train them (Bradley, 2006). Wild rabbits create a latrine area within their
219 warrens for urination and defecation. Previously, Normando and Gelli (2011) had found
220 similar results. In the case of dogs, Herron et al. (2007), suggested that brief preadoption
221 counseling for owners enhances successful house-training of adopted animals from
222 shelters. Counseling owners at the time of rabbit acquisition may thus have beneficial
223 effects on the prevention of inappropriate elimination behavior. Veterinarians and animal
224 care staff should be encouraged to devote time to counsel new rabbit owners on successful
225 house-training, as well as other healthcare and behavioral needs.
226 The second most common behavioural problem was non-social fear, followed by
227 destructive behaviour and compulsive disorder. Interestingly, this result differs from that
228 found by Normando and Gelli (2011), in which the second most common undesirable
229 type of behaviour was destructiveness.
230 Since rabbits have evolved as prey animals, they are particularly susceptible to stressors
231 associated with actual or perceived threats (Bradley, 2012). Perceived threats might
232 include non-social stimuli such as loud sounds, new objects or new environments.
233 Therefore, the high prevalence of non-social fear in rabbits can be expected. No previous
234 studies on this field were found, so new studies seem necessary in order to establish an
235 adequate diagnosis that could differentiate normal from pathological fear.
236 As mentioned, a high prevalence of compulsive disorders was also perceived in the
237 studied population. Compulsive disorders have also been referred to as obsessive-
238 compulsive disorders and stereotypies (Landsberg et al., 2013). Stereotypies have been
239 described as forms of invariant repetitive behaviour patterns induced by frustration,
240 inability to cope, or central nervous system dysfunction (Mason, 2006). Nevertheless,
241 compulsive behaviors are abnormal and repetitive behaviors that may be variable in form
242 and fixated on a goal (Luescher, 2009). In this paper the authors would rather use the term
243 *compulsive disorders*, because excessive grooming, for example, may be present in
244 variable forms and is fixated in a goal. However, other studies opted for the term
245 *stereotypies* to describe similar behavioral problems such as excessive grooming or bar
246 biting.

According to Normando and Gelli. (2011), stereotypic behavioural patterns were reported by owners in 28.3% of the cases. Some authors suggest that high levels of stereotypic behavior can indicate that animals may be suffering from frustration and stress (Podbersheck et al., 1991; Gunn and Morton, 1995). In addition, it has been shown that the conditions in which pet rabbits are kept often have a negative impact on their welfare (Lidfors, 1997; Hansen et al., 1999; Chu et al., 2004; Schepers et al., 2004). Lack of positive welfare could also explain why those rabbits show generally more than one behavior problem.

The different prevalence of behavioural problems between geographical areas may be partly explained by the comparatively greater proportion of entire females in Latin America as well as the relatively higher frequency of acquisition previous to weaning, as showed in both the descriptive analysis and the multivariate MCA.

Interestingly, the present paper found an association between owner-directed aggression and owner directed fear. As other authors indicated, when human-directed aggression is not caused by a medical problem, this is primarily due to fear (Crowell-Davis, 2010; Normando and Gelli, 2011).

In addition, there seems to be an association between non-social fear and destructive behavior. In spite of the fact that no previous studies that considered this relationship in rabbits were found, in other species, such as dogs, destructive behavior may be due to flight attempts as a result of fears and phobias (Landsberg et al., 2013).

In our study, behavioral problems were more frequent among entire females according to owners´ perception. Sex differences in the brain occur at many levels, either morphological, physiological, molecular, or genetic (Lenz et al., 2012), leading to differences in behavior, with regard to learning and memory, fear, anxiety, and nociception (McCarthy et al., 2012; Prendergast et al., 2014; d´Ovidio et al., 2016).

Female pet rabbits have long been thought of as more temperamental, owing to their hormonal cycling without ovulation. This perception stems from the fact that female rabbits have been significantly more likely to be described by using terms that characterize ‘antisocial or negative personality traits’ and less likely to be described as ‘quiet and placid’ (Mullan and Main, 2007; d´Ovidio et al., 2016). Some studies also suggested that female rabbits could be more aggressive than males because they tend to acquire and defend the exclusive access to warrens and this is one of the several reasons why does kept as pets should be neutered (Lockley, 1964; Mykytowycz, 1968, Crowell-Davis, 2007, Crowell-Davis, 2010). Nevertheless, D´Ovidio et al. (2016) found no

281 significant differences in the probability of displaying aggressive behavior between intact
282 and neutered does and Normando and Gelli (2011) found no correlation between reports
283 of aggressive behaviour by owners and pet gender. Because rabbits are social animals,
284 they live in big social groups that number up to 300-400 rabbits where there are typically
285 multiple subgroups each consisting of 2-8 individuals. Females within the same social
286 group are usually related, as occurs with other social species such as wolves. Many of the
287 early studies were of captive wolves' packs, often artificially assembled from unrelated
288 individuals, and aggression may be sometimes observed more frequently than might be
289 expected in the wild (Zimen, 1975).
290 Neutered animals showed more frequently inappropriate fecal elimination, according to
291 owners´ perception. Similar results were found by Normando and Gelli (2011) in a study
292 in which they established a direct correlation between neutering and house soiling.
293 Unsuccessful attempts to solve that behavioural problem by neutering the animals that
294 presented inadequate behaviour might partly explain that correlation (Normando and
295 Gelli 2011).
296 Also, occasional dropping of the small firm fecal balls outside of the box is normal,
297 especially if the box is not cleaned frequently enough or the rabbit is startled. Stress,
298 changes in schedule, changes in household can all cause house soiling in rabbits.
299 (Crowell-Davis, 2010).
300 Animals acquired at a younger age (especially before 42 d) tend to be more susceptible
301 to behavior problems. Some studies have suggested the existence of a sensitive period in
302 rabbits (Bilkó and Altbäcker, 1999). It is shown that the presence of the mother affects
303 the ratio of types of activity in offspring and the mother can demonstrate behavioral
304 patterns to suppress aggressive behavior in offspring. It was found that rabbits in the
305 prepubertal period continue having active contact with their mother and make successful
306 attempts at sucking. There were significant differences in the frequency of the socially
307 oriented behavior and the duration of feeding behavior in young rabbits, who grew up
308 with their mother and without her (Fedosov et al., 2015). Maternal deprivation has also
309 been found to contribute to aggressiveness, heightened fearfulness, anxiety, social
310 abnormalities, and the development of stereotypic behaviors in other species (Latham and
311 Mason, 2010).
312 Rabbits transferred from another person seem to be the healthiest from a behavioral point
313 of view. Since the age at which the rabbits were separated from their mothers is unknown,
314 it is possible that they had not reached 42 days of age when they were first acquired by

315 their owners. Nevertheless, several behavior disorders could have a tendency to be more
316 frequent in rabbits acquired in pet stores or from breeders. Similar results were shown in
317 puppies. Puppies obtained from pet stores versus non-commercial breeders represented a
318 significant risk factor for the development of a wide range of undesirable behavioral
319 characteristics (McMillan et al., 2017).
320
321 **5. Conclusions**
322 The findings of the present paper support previous findings and suggest some new
323 information to the epidemiology of behavioral problems in pet rabbits.
324 In summary, inappropriate elimination, non-social fear, destructive behavior and
325 compulsive disorders are the most common behavioural problems in the studied rabbit
326 population. Entire females acquired before weaning from pet stores or breeders would be
327 the profile with the highest tendency to show behavioral problems.
328 Despite the inherent limitations of this study we believe it to have provided a
329 comprehensive overview of the main behaviour problems in this species. Such data
330 should be useful to focus training, management and prevention strategies.
331
332 **Acknowledgments**
333 The authors thank Oscar Beceiro for his invaluable help in the research.
334
335 **Conflict of interest**
336 The authors declare no conflicts of interest
337
338 **Ethical statement**
339 Animals were treated according to European and Spanish legislation on animal protection
340 (Directive 86/609/EEC, Real Decreto1201/2005)

341 **References**

342 Bradley, B.T., 2006. Rabbit behaviour. In: Bradley, B.T., Lighfoot, T, Mayer, J. (Eds.),
343 Exotic Pet Behavior: Birds, Reptiles, and Small Mammals, 1st ed. Elsevier Health
344 Sciences. St. Louis, MO, pp. 1-50.

345 Brooks, D.L., 1986. Rabbits, hares, and pikas (lagomorpha). In: Fowler, M.E. (Ed.), Zoo
346 and wild animal medicine, 2nd edition. Saunders, Philadelphia, PA, pp 712-725.

347 Carpenter, J.W., 2003. Lagomorpha (pikas, rabbits, and hares). In Fowler, M.E., Miller,
348 R.E. (Eds.): Zoo and wild animal medicine, 5th edition. Saunders. Philadelphia, PA, pp
349 410-419.

350 Cook, A. J., McCobb, E., 2012. Quantifying the shelter rabbit population: An analysis of
351 Massachusetts and Rhode Island animal shelters. Appl. Anim. Behav. Sci. 15, 297-312.

352 Crowell-Davis, S. L., 2007. Behavior problems in pet rabbits. J. Exot. Pet. Med. 16, 38-
353 44.

354 Crowell-Davis, S.L., 2010. Rabbits. In: Tynes, V.V. (Ed.), Behavior of exotic pets, 1st ed.
355 Wiley- Blackwell, Oxford, UK, pp. 69-77

356 Chu, L. R., Garner, J. P., Mench, J. A., 2004. A behavioral comparison of New Zealand
357 White rabbits (Oryctolagus cuniculus) housed individually or in pairs in conventional
358 laboratory cages. Appl. Anim. Behav. Sci. 85, 121-139.

359 Csatadi, K., Kustos, K., Eiben, C., Bilkó, Á., Altbäcker, V., 2005. Even minimal human
360 contact linked to nursing reduces fear responses toward humans in rabbits. Appl. Anim.
361 Behav. Sci. 95, 123-128.

362 Davis, H., Gibson, J. A., 2000. Can rabbits tell humans apart? discrimination of individual
363 humans and its implications for animal research. Comp. Med. 50, 483-485.

364 d'Ovidio, D., Pierantoni, L., Noviello, E., Pirrone, F., 2016. Sex differences in human-
365 directed social behavior in pet rabbits. J. Vet. Behav. Clin. Appl. Res. 15, 37-42.

366 Edgar, J.L., Mullan, S.M., 2011. Knowledge and attitudes of 52 UK pet rabbit owners at
367 the point of sale. Vet. Rec. 168, 353.

368 Fedosov, E. V., Ambaryan, A. V., Maltsev, A. N., Karaman, N. K., Kotenkova, E. V.,
369 2015. Influence of the Mother on the Behavior of Young Rabbits during the Prepubertal
370 Period. Biol. Bull. 42, 531-539.

371 Martínez, Á. G., Pernas, G. S., Diéguez, F. J., Rey, M. L. S., de la Cruz Palomino, L. F.,
372 2011. Risk factors associated with behavioral problems in dogs. J. Vet. Behav. Clin.
373 Appl. Res. 6, 225-231.

374 Gunn, D., Morton, D.B., 1995. Inventory of the behavior of New Zealand white rabbits
375 in laboratory cages. Appl. Anim. Behav. Sci. 45, 277-292.

376 Hansen, L. T., Berthelsen, H., 2000. The effect of environmental enrichment on the
377 behaviour of caged rabbits (Oryctolagus cuniculus). Appl. Anim. Behav. Sci. 68, 163-
378 178.

379 Herron, M. E., Lord, L. K., Hill, L. N., Reisner, I. R., 2007. Effects of preadoption
380 counseling for owners on house-training success among dogs acquired from shelters. J.
381 Am. Vet. Med. Assoc. 231, 558-562.

382 Hsu, Y., Serpell, J.A., 2003. Development and validation of a questionnaire for measuring
383 behavior and temperament traits in pet dogs. J. Am. Vet. Med. Assoc. 223, 1293–1300.

384 Landsberg, G., Hunthausen, W., Ackerman, L., 2013. Handbook of behavior problems of
385 the dog and cat, 3rd ed. Saunders, London, UK.

386 Latham, N.R., Mason, G.J., 2010. Maternal deprivation and the development of
387 stereotypic behaviour. Appl. Anim. Behav. Sci. 110, 84–108.

388 Ledger, R. A., 2010. The relinquishment of rabbits to rescue shelters in Canada. J. Vet.
389 Behav. Clin. Appl. Res. 5, 36-37.

390 Lenz, K.M., Nugent, B.M., McCarthy, M.M., 2012. Sexual differentiation of the rodent
391 brain: dogma and beyond. Front. Neurosci. 6, 26.

392 Lidfors, L., 1997. Behavioural effects of environmental enrichment for individually
393 caged rabbits. Appl. Anim. Behav. Sci. 52, 157-169.

394 Lockley, R. M., 1964. The private life of the rabbit: An account of the life history and
395 social behaviour of the wild rabbit. 1st ed. Corgi, London, UK.

396 Luescher, A.U. 2009. Repetitive and compulsive behaviour in dogs. In: Horwitz, D.F.,
397 Mills, D.S., BSAVA manual of canine and feline behavioural medicine. 2nd ed. 236-244.
398 BSAVA Publications. Gloucester. UK.

399 Mason, G.J. 2006. Stereotypic Animal Behaviour: Fundamentals and Application to
400 Welfare. CAB International. Wallingford.

401 McCarthy, M.M., Arnold, A.P., Ball, G.F., Blaustein, J.D., De Vries, G.J., 2012. Sex
402 differences in the brain: the not so inconvenient truth. J. Neurosci. 32, 2241-2247

403 McMillan, F. D., 2017. Behavioral and psychological outcomes for dogs sold as puppies
404 through pet stores and/or born in commercial breeding establishments: Current
405 knowledge and putative causes. J. Vet. Behav. 19, 14-26.

406 Mullan, S.M., Main, D.C.J., 2006. Survey of the husbandry, health and welfare of 102
407 pet rabbits. Vet. Rec. 159, 103-109.

408 Mullan, S.M., Main, D.C.J., 2007. Behaviour and personality of pet rabbits and their
409 interactions with their owners. Vet. Rec. 160, 516-520.

410 Mykytowycz, R., 1968. Territorial marking by rabbits. Sci. Am. 218, 116-129.

411 Normando, S., Gelli, D., 2011. Behavioral complaints and owners' satisfaction in rabbits,
412 mustelids, and rodents kept as pets. J. Vet. Behav. Clin. Appl. Res. 6, 337-342.

413 Podbersheck, A.L., Blackshaw, J.K., Beattie, A.W., 1991. The behavior of group penned
414 and individually caged laboratory rabbits. Appl. Anim. Behav. Sci. 28, 365-373.

415 Prendergast, B.J., Onishi, K.G., Zucker, I., 2014. Female mice liberated for inclusion in
416 neuroscience and biomedical research. Neurosci. Biobehav. Rev. 40, 1-5.

417 Rooney, N.J., Blackwell, E.J., Mullan, S.M., Saunders, R., Baker, P.E., Hill, J.M., Sealey,
418 C.E., Turner, M.J., DE Held, S., 2014. The current state of welfare, housing and
419 husbandry of the English pet rabbit population. BMC Res. Notes 7, 942.

420 Schepers, F., Koene, P., Beerda, B., 2009. Welfare assessment in pet rabbits. Anim. Welf.
421 18, 477-485.

422 Zimen, E., 1975. Social dynamics of the wolf pack. In: Fox, M.W. (Ed.), The Wild
423 Canids: Their Systematics, Behavioral Ecology and Evolution, 1st ed. Van Nostrand
424 Reinhold, New York, NY, pp. 336-362.

Tables

Table 1 Descriptive analysis of the studied rabbit population

Variable	Frequency (percentage)	Frequency (percentage) Spain	Frequency (percentage) Latin America
Sex/neuter status			
Female entire	100 (23.6%)	44 (18.7%)	55 (29.3%)
Female neutered	77 (18.2%)	53 (22.8%)	24 (12.6%)
Male entire	138 (32.6%)	73 (31.1%)	37 (19.7%)
Male neutered	108 (25.6)	64 (27.4%)	73 (38.4%)
Origin of the rabbit			
Pet shop	206 (48.8%)	127 (54.3%)	79 (41.8%)
Private individual	114 (26.9%)	54 (23.3%)	60 (31.5%)
Shelter/rescued group	87 (20.5%)	46 (19.5%)	41 (21.8%)
Breeder	16 (3.8%)	7 (2.9%)	9 (4.8%)
Age of acquisition			
Before 42 d	129 (30.5%)	65 (27.8%)	63 (33.3%)
From 42 to 120 d	235 (55.6%)	128 (54.7%)	107 (56.6%)
After 120 d	59 (13.9%)	41 (17.5%)	19 (10.1%)

442

443 **Table 2** Prevalence estimations for behavioral problems in dogs according to owners'
444 perception

Behavioral problems (n)	Percent of prevalence (95% CI)[a]	Percent of prevalence Spain (95% CI)[a]	Percent of prevalence Latin America (95% CI)[a]
Owner-directed aggression (423)	15.1 (12.0-18.9)	13.2 (8.9-17.5)	17.2 (11.7-22.7)
Stranger-directed aggression (401)[b]	**16.0 (12.7-19.9)**	**9.5 (5.6-13.4)**	**21.2 (15.6-26.8)**
Family rabbit-directed aggression (127)	21.3 (15.0-29.2)	13.2 (4.1-22.3)	27.0 (16.9-37.1)
Owner-directed fear (421)	3.8 (2.3-6.1)	2.7 (0.6-4.8)	5.0 (2.0-8.0)
Stranger-directed fear (401)	25.7 (21.7-30.2)	26.5 (20.7-32.3)	24.4 (18.5-30.3)
Family rabbit-directed fear (127)	1.6 (0.4-5.5)	1.9 (0-5.6)	1.4 (4.1)
Non-social fear (423)	59.8 (55.1-64.4)	56.8 (50.3-63.3)	63.1 (56.5-69.7)
Destructive behavior (407)[b]	**56.8 (51.9-61.5)**	**45.6 (39.0-52.2)**	**69.5 (63.0-76.0)**
Compulsive disorder (311)	49.2 (43.7-54.7)	52.8 (45.5-60.1)	44.4 (36.0-52.8)
Excessive grooming (395)	25.6 (21.5-30.1)	22.2 (16.5-27.9)	29.3 (22.8-35.8)
Inappropriate elimination (411)			
Only urine[b]	**3.9 (2.4-6.2)**	**1.4 (0-3.0)**	**6.7 (3.2-10.2)**
Only feces	26.5 (22.5-31.0)	23.9 (18.2-29.6)	29.5 (23.1-35.9)
Both[b]	**30.2 (25.9-34.8)**	**23.4 (17.8-29)**	**37.8 (31-44.6)**
Total	60.6 (55.8-65.2)	48.7 (42.1-55.3)	74 (67.8-80.2)

445 [a]95% confidence interval

446 [b]Significant differences when comparing prevalences (Spain and Latin America)

447

448

449 **Figure captions**

450 **Figure 1** Joint plot of category points included in the study (behavior disorders, sex,
451 neuter status, origin and age at the time of acquisition of the rabbit and area) resulted from
452 the multiple correspondence analysis. Category points with a similar profile tend to be
453 grouped together whereas those negatively correlated are positioned on opposite sides of
454 the graph.

455

456

457

458

459

460

461

462

463

464

465

466

467

468

469

470

471

472

473

474

475

476

477

478

479

480

481

482

483

Supplementary Table 1 Explanation of the essential components of each behavior pattern included in a questionnaire designated to assess the perceived frequency of these behaviors in pet rabbits

Owner-directed aggression Stranger-directed aggression Family rabbit-directed aggression	In these cases, the rabbit usually shows a combination of these signs: thumping, hitting the ground with its hind legs, leaning on hind legs showing a position similar to that of a boxer, rigid tail, ears flattened back, open mouth with visible teeth, growling, snorting, biting more or less hard, scratching and kicking using front or hind legs
Owner-directed fear Stranger-directed fear Family rabbit-directed fear Non-social fear	In the case of fear the rabbit may show a combination of several of the following signs: crouching down, licking lips, lying head flat on ground, pulling ears back, mydriasis, wide open eyes, restlessness, dashing away to hide, standing frozen with weight equally on all four legs in a braced stance. Non-social fear involved fearful behavior towards noise, unfamiliar objects, storms, wind, or new situations.
Destructive behavior	Bites or destroys objects (furniture, walls, personal belongings of the owners ...)
Compulsive disorder	Behaviors that are abnormal and repetitive (barbiting, nose sliding or excessive grooming).
Inappropriate elimination	Urinates or defecates outside the tray or in places not indicated for it

Supplementary Table 2

Correlation matrix of the transformed variables (after optimal scaling) included in the study (behavior disorders, sex, neuter status, origin and age at the time of acquisition of the rabbit and geographical area)

	Age of acquisition	Area	Compulsive disorder	Destructive behavior	Family rabbit-directed agression	Family rabbit-directed fear	Inappropriate elimination	Non-social fear	Origin of the rabbit	Owner-directed agression	Owner-directed fear	Sex	Stranger-directed fear	Stranger-directed agression
Age of acquisition	1.000	-0.107	0.072	-0.058	0.029	-0.078	0.025	-0.055	0.428	-0.011	0.047	0.037	0.005	0.006
Area	-0.107	1.000	0.142	0.254	0.136	-0.003	0.228	0.064	0.022	0.057	0.58	0.030	-0.027	0.162
Compulsive disorder	0.072	0.142	1.000	-0.027	-0.025	-0.052	0.022	-0.035	0.002	-0.122	-0.057	0.113	0.014	-0.012
Destructive behavior	-0.058	0.254	-0.027	1.000	0.083	0.012	0.147	0.071	-0.031	0.102	-0.009	0.060	-0.002	0.115
Family rabbit-directed aggression	0.029	0.136	-0.025	0.083	1.000	-0.123	0.209	0.056	0.074	0.160	0.050	0.104	0.010	0.052
Family rabbit-directed fear	-0.078	-0.003	-0.052	0.012	-0.123	1.000	0.074	0.084	-0.049	0.029	0.014	-0.047	0.039	0.029
Inappropriate elimination	0.025	0.228	0.022	0.147	0.209	0.074	1.000	0.103	0.050	0.083	0.103	0.057	0.054	0.062
Non-social fear	-0.055	0.064	-0.035	0.071	0.056	0.084	0.103	1.000	-0.060	0.144	0.036	0.133	0.195	0.064
Origin of the rabbit	0.428	0.022	0.002	-0.031	0.074	-0.049	0.050	-0.060	1.000	0.055	0.034	0.024	-0.029	-0.031
Owner-directed agression	-0.011	0.057	-0.122	0.102	0.160	0.029	0.083	0.144	0.055	1.000	0.124	0.029	0.053	0.172
Owner-directed fear	0.047	0.058	-0.057	-0.009	0.050	0.014	0.103	0.036	0.034	0.124	1.000	-0.072	0.118	0.020
Sex	0.037	0.030	0.113	0.060	0.104	-0.047	0.057	0.133	0.024	0.029	-0.072	1.000	0.029	0.073
Stranger-directed fear	0.005	-0.027	0.014	-0.002	0.010	0.039	0.054	0.195	-0.029	0.053	0.118	0.029	1.000	0.175
Stranger-directed agression	0.006	0.162	-0.012	0.115	0.052	0.029	0.062	0.064	-0.031	0.172	0.020	0.073	0.175	1.000

493

494