Title

Investigation of Neurophobia amongst North American Veterinary Students and Development of a Veterinary Neurophobia Scoring Tool (VetNeuroQ)

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TITLE

Investigation of neurophobia amongst North American veterinary students and development of a veterinary neurophobia scoring tool (VetNeuroQ).

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KEY WORDS

Neurophobia, veterinary neurology teaching, barriers to learning, veterinary medical education, survey research

ABSTRACT

“Neurophobia” is a phenomenon in human medical education where students develop negative attitudes towards neurology, impeding student learning and future clinical practice. While suspected to exist in veterinary medical education, it remains unstudied. The main objectives of this study were to examine North American veterinary student attitudes towards neurology and neurology education and explore elements that might contribute to neurophobia. Additional objectives were to evaluate veterinary educators’ perceptions of student neurophobia and to develop and validate a scoring tool (VetNeuroQ) to quantify veterinary neurophobia. Veterinary students and faculty at North American veterinary schools were surveyed. A scoring tool was developed from a subset of questions and validated using confirmatory factor analysis. 606 anonymous responses were collected from students at all stages of veterinary education. Neurology training was reported as insufficient by 35.9% and most respondents perceived neurology to not be easy to learn. Neuroanatomy/physiology and neurolocalization were considered difficult concepts. Students rated low confidence in neurology (vs. other topics), and low interest in the Neurology/Neurosurgery specialty. 61.7% of educators reported neurophobia amongst their students. The proposed VetNeuroQ scale showed high reliability (Cronbach’s alpha >0.7) and validity ($p<0.05$; CFI >0.9, RMSEA <0.08). VetNeuroQ scores were low but improved over the course of veterinary education. These findings demonstrate low self-efficacy, interest, and confidence, along with perceptions of difficulty, amongst veterinary students, consistent with neurophobia. Contributing elements are discussed. The VetNeuroQ scale allows quantification of veterinary student neurophobia and may be useful for screening students and assessing the impact of educational interventions.

INTRODUCTION

The term “Neurophobia” was coined in 1994 by Dr. R.F. Jozefowicz and was defined as “a fear of the neural sciences and clinical neurology that is due to the students' inability to apply their knowledge of basic sciences to clinical situations”.[1] This complex phenomenon goes beyond just fear, and involves elements of interest, perceived difficulty, knowledge and confidence.[2–11] These perceptions, and resultant negative attitudes towards neurology as a subject have been well documented since the 1950s, amongst human medical general practitioners, medical students, dentistry students and occupational therapy students worldwide.[2,4,8–10,12–20] This complex multifactorial phenomenon has been shown to affect about approximately 30%-66% of students across various studies, arising during pre-clinical training and worsening over time.[4,9,18,21] This leads to low clinical confidence and impaired learning, may result in medical errors, contribute to stress and burnout, and has been linked to a relative decline in medical students seeking neurological residencies.[4,10,11,14] This is a known, well-established barrier to learning in human medical education and has been anecdotally suspected to also exist in veterinary education but is yet to be methodically studied.[22]

In comparison with human neurology, veterinary neurology poses additional challenges unique to the field, including a wider range of treated species, breeds and patient sizes, non-verbal patients, limited owner finances, and scarcity of easily accessible referral resources. Such challenges are likely to compound the effects of neurophobia within our field and create strong perceptions that may be harder to overcome post-graduation. Interventions for neurophobia are most effective when administered early.[3] However, we do not yet know whether neurophobia exists amongst veterinary students, where in veterinary education neurophobia first arises or what contributes to neurophobia amongst our students. Further, we have no means of identifying neurophobic students that might benefit from targeted interventions or teaching strategies. This limits our ability to improve neurology education. Additionally, student perceptions of neurology and their own abilities can be vague and subjective, making it harder to study. The development of an objective measure of neurophobia would help screen for neurophobia and provide an objective outcome measure when evaluating the success of educational interventions between and across learners.

We hypothesized that veterinary students experience neurophobia, reflected by perceptions of low interest, knowledge, confidence, and ease of learning veterinary neurology, similar to their counterparts in human healthcare fields.[2–4,7–11] As such, our aim was to conduct the first large-scale study to examine veterinary students' perceptions of neurology. The first goal of our study was to survey veterinary students across North American veterinary programs at all stages of training, evaluating student perceptions of neurology directly and relative to other topics, as well as perceptions of pre-clinical and clinical neurology education, including perceived sources of difficulty. A second goal was to survey veterinary neurology educators to understand their perceptions of their students' neurology learning, and to identify measures taken to mitigate potential neurophobia. The final goal was to develop and validate a neurophobia scoring tool for use in pre-clinical and clinical veterinary students. By improving our understanding of student perceptions of neurology education, we may be able to create interventions that change negative perceptions, support student learning, and foster self-efficacy, confidence, and interest in neurology- which might, in turn, improve both student satisfaction as well as future veterinary care.

METHODS

The study protocol was reviewed and deemed exempt by the Washington State University Institutional Review Board.

Student and teacher surveys

A survey tool was created, drawing on previous surveys and reviews of neurophobia in human medical education.[2–6,9–11,21] This was further refined through focus group discussions with veterinary students and discussion of the authors with input from psychometricians at the Washington State University Social and Economic Science Research Center Survey Design Clinic. The survey was designed to evaluate student perceptions of neurology and neurology education, on its own, as well as in relation to other topics. Students were also asked questions relating to potential barriers to learning and interventions they felt would improve their learning. Peer review of all survey items wording, flow and instructions were provided by ten student volunteers and three faculty volunteers, who were not involved in the survey design to evaluate face and content validity.[23,24] All survey items were further refined through discussion to reach consensus, incorporating input from psychometricians at the Washington State University Social and Economic Science Research Center Survey Design Clinic.

Terminology commonly used in veterinary medicine was used in the survey, and included words such as neurolocalization, referring to the neuroanatomical localization of a lesion resulting in specific neurological deficits. Additionally, neuroanatomy and neurophysiology were combined in most items on the survey as it was deemed that these topics were highly interrelated and thought to be typically taught concurrently in veterinary curricula.[22]

The final survey instrument (Supplementary material 1) was hosted digitally on an online survey platform[a] and was distributed in the form of a web-link to veterinary students across veterinary schools in the United States and Canada. This was done by contacting the deans of education at North American veterinary schools through the American Association of Veterinary Medical Colleges listserv as well as the American College of Veterinary Internal Medicine- Neurology specialist listservs and requesting that the survey be distributed to veterinary students at each participating school. Upon completion of the survey, participants were given the option of separately entering a random prize-draw for $50 online gift cards as a participation incentive. Responses collected for the random drawing were not linked to survey responses. Data identifying the institutions whose students participated was not collected in an effort to maintain anonymity of survey responses.

A separate survey (Supplementary material 2) was created to gauge teachers' perspectives of their students' attitudes towards neurology and interventions they had tried, to improve student learning. This survey was also evaluated for face validity and content validity by faculty volunteers not involved in survey design. It was administered through an online survey platform[a] and distributed to educators at veterinary schools in the United States of America and Canada, through the deans of education and the Neurology specialist listservs. No incentives to participation were provided.

The surveys were set to allow only one response per computer, and responses were collected in an anonymous manner by masking IP addresses and not asking any identifying information of the participants. Both surveys were distributed in October 2021, with reminders sent at 3 and 6 weeks following the initial request. Respondents were allowed to skip questions if they chose, in an effort to maximize participation. Results were collected 10 weeks from the date of initial distribution.

Scoring tool

A subset of items in the student survey was designed as a scoring tool. These items adapted questions used in a previously validated neurophobia scale with additional items adapted to veterinary neurology education, encompassing the four most commonly reported elements of neurophobia based on medical education literature (interest, perceived difficulty, confidence and knowledge). [2–4,7–10] The scoring tool (Table 1) included a total of 14 items for clinical students and a total of 10 items for pre-clinical students, by omitting items unsuitable for pre-clinical students that had not yet completed a clinical rotation involving neurological patients. Students were asked how much they agree with a series of statements and asked to respond using a 5-point Likert scale (1: strongly disagree, 2: somewhat disagree 3: neither agree nor disagree, 4: somewhat agree, 5: strongly agree). Face and content validity were assessed as previously outlined. Criterion validity could not be assessed due to the lack of a gold standard, as is common in social science research. Construct validity was examined by confirmatory factor analysis as outlined below, and reliability was assessed.[23]

Responses to individual items were used to generate scores for each dimension of neurophobia (interest, perceived ease, confidence, and knowledge), ranging from 1-5. The score for Item 1 represented the Interest score. Items 2 and 3 were reverse-scored and averaged to generate a Perceived Ease score. While the items enquired about perceived difficulty, perceived ease was chosen for the purposes of scoring. Scores for items 4-7 were taken and averaged to generate a Confidence score. For pre-clinical students, scores for items 8-10 were taken and averaged to obtain the Knowledge score, while scores for items 8-14 were taken and averaged to obtain the knowledge score for clinical students. Finally, each of the scores ranging from 1-5 for Interest, Perceived Ease, Confidence and Knowledge were added to generate an overall VetNeuroQ score (or neurophobia score), ranging from 4-20, where a lower score was indicative of more severe neurophobia. The VetNeuroQ tool is provided in Table 1 with instructions for score calculation. For ease of use, a digital calculator of VetNeuroQ scores is also provided, where the user simply needs to provide individual item responses and corresponding scores will be automatically generated (reverse scoring for perceived ease is built-in) (Supplemental material 4).

Statistical analysis

Survey responses were checked for consistency of coding, and all responses, including partial responses were collected. Data were analyzed using commercial statistical software, with consultation with a statistician at the Washington State University Social and Economic Science Research Center Survey Design Clinic [b,c]. The data were found to meet the assumptions of all tests applied below. The data were tested for normality using the Kolmogorov-Smirnov test. Descriptive statistics were reported as percentages, mean (+/- s.d.) or median (95% confidence interval (CI); range) as appropriate. Confidence in learning neurology and interest in specialization in neurology relative to other topics/specialties were compared across stages of training through ANOVA. Next, to assess whether stage of training impacted students' views on how challenging certain types of neurolocalization were, a relative importance index was calculated from the Likert-type responses and used to generate rankings of perceived difficulty. Chi-squared (χ^2) tests were used to compare perceived level of challenge for each neurolocalization between stages of training.

To compare responses from students and teachers on how much they thought each barrier to learning contributed to students' perception of neurology being difficult, response options of minor factor (contributing barrier) and not a factor (contributing barrier) were combined to create a binary variable of major vs non-major factor (contributing barrier). A relative importance index was calculated for each barrier to learning. The proportion of teachers stating a particular barrier was a major one was compared to the proportion of students stating that barrier was a major one using Z-tests. Lastly, χ^2 testing was used to assess the impact of demographic variables (age, gender, and ethnicity) on students' perception of an inability to access hands-on experiences or neurology rotations being a barrier to learning and cause of finding neurology difficult. For the purposes of this analysis, age was recoded into categories of

20-24 year, 25-29 years and >30 years due to low numbers for ages 30-34 years and >34 years. Similarly, due to low numbers in the non-White racial/ethnic categories, these categories were combined into a single category of 'all other groups' for this analysis. Additionally, non-binary gender responses were excluded from this analysis due to low numbers. Responses of prefer not to say were treated as missing data. For all analyses, $p<0.05$ was considered significant.

For evaluation of the VetNeuroQ scale, construct validity was examined by confirmatory factor analysis, using commercial statistical software[d] with significance set at $P<0.05$.[25] Partial or incomplete responses were censored from validation by pairwise removal but included for other statistical comparisons. The effect of friends or family working in neurology, experience with neurological patients prior to veterinary school and prior neuroscience training, on VetNeuroQ scores and scores of individual dimensions of neurophobia were also compared across stages of veterinary neurology training through ANOVA. Stages of training evaluated included no neurology training, completion of neuroanatomy/neurophysiology, completion of neuropathology, completion of clinical neurology theory and completion of a neurology clinical rotation. The VetNeuroQ scale was also tested for reliability by calculating Cronbach's alpha (α) and McDonald's omega (ω) (≤0.5 low; 0.5-0.7 moderate; 0.7-0.9 high; ≥0.9 excellent).[24,26,27]

RESULTS

Results of student survey:

Student demographics:

A total of 612 veterinary students completed the survey, however response rates for each question varied as questions were not mandatory. General demographic results are presented in Table 2. Due to differences in curricular styles and timing of neurology content delivery between institutions, students' stage of training was considered to be different from year of training and it was possible students may have completed stages non-sequentially. Thus, students were also asked how much of their neurology curriculum they had completed at the time of the survey and allowed to select multiple responses. Only 75/612 (12.3%) reported no neurology training yet, while 497 (81.2%) had completed neuroanatomy or neurophysiology, 266 (43.5%) had completed neuropathology, 119 (19.4%) had completed clinical neurology theory, and 63 (10.3%) had completed their neurology clinical rotation.

Student perceptions of neurology training:

Students were generally satisfied with the amount of neurology training they had received, with 325/532 (61.1%) stating it was sufficient; 191 (35.9%) stated their training was insufficient, and only 16 (3.0%) stated it was excessive. When students were asked about their background and prior exposure to neurology, 26/601 (4.3%) reported having family or friends working in human neurology, 58 (9.7%) reported having family or friends working in veterinary neurology, 8 (1.3%) reported having friends and family in both human and veterinary neurology, while the remainder (509; 84.7%) reported neither. When students were asked about their own personal experiences with neurological patients in either a professional or non-professional setting, 89/593 (15.0%) reported caring for a human with neurological disorders, 127 (21.4%) reported caring for a veterinary patient with a neurological disorder, 55 (9.3%) reported caring for both a human and veterinary neurological patient, and the rest (322; 54.3%) reported experience with neither. When asked about their training prior to veterinary school, only 107/594 (18.0%) reported receiving neuroscience education. When asked if they expected to see neurological cases in their future careers, 522/563 (92.7%) of students stated that they did expect to see neurological cases, while 15 (2.7%) said no, and 26 (4.6%) were unsure.

When asked about cranial nerve and brain neurolocalization, 453/523 (86.6%) reported it to be somewhat or very challenging. Spinal cord neurolocalization was reported to be somewhat or very challenging by 428/526 (81.4%) students. Neuromuscular neurolocalization was reported to be somewhat or very challenging by 456/515 (88.5%) students. Many students also provided free text comments on what they felt was challenging about neurolocalization, which included remembering neural pathways and tracts, the complexity of brainstem and intracranial neurolocalization, distinguishing upper and lower motor neuron signs, and interpreting the results of their neurological exam as normal or abnormal.

Comparison of neurology to other topics:

Students were next asked about their confidence in their ability to apply their learning in cardiology ($N=465$), gastroenterology ($N=452$), renal/urinary ($N=461$), ophthalmology ($N=438$) and neurology ($N=481$). Comparative results are displayed in Figure 1A, where ophthalmology ($P< 0.01$ vs all other topics) and neurology ($P< 0.01$ vs all other topics) rated the lowest. Confidence in cardiology was not different from the beginning to end of training ($P= 0.06$; $df=4$; $F=2.279$), however confidence in gastroenterology ($P< 0.001$; $df=4$; $F=10.768$), renal/urinary (P<

0.001; df=4; F=6.145), ophthalmology (P= 0.001; df=4; F=4.642) and neurology (P< 0.001; df=4; F=16.640) increased significantly from the beginning to end of training (Figure 1B).
Next, students were asked to imagine that they were going to specialize and were asked how likely they would be to choose each of the following specialties: cardiology (N= 525), oncology (N= 518), internal medicine (N= 527), ophthalmology (N= 521), neurology/neurosurgery (N= 530) and surgery (soft tissue/orthopedic) (N= 528). Comparative results are displayed in Figure 2A, with neurology being rated significantly lower than other specialties (P=0.001; df=4; F=4.450). Interest in specialization in neurology was significantly higher at the end of training and increased significantly amongst students who had completed a neurology rotation, compared to students at each other stage of training (P= 0.001; df=4; F=4.500). Interest in specialization in other specialties was not different across stages of training (Figure 2B).

Perceptions of self-efficacy:

When asked about how easy or difficult they found learning neurological concepts and diseases themselves, 128/512 (25.0%) reported it to be somewhat or very easy, while 273 (53.3%) reported it to be somewhat or very difficult and 111 (21.7%) reported it to be neither easy nor difficult. In contrast, when asked to compare their own ability to learn relative to other students, 137/528 (25.9%) felt neurology was easier for them than others, 144 (27.3%) felt neurology was harder for them than others, while 247 (46.8%) were unsure.

Changes in opinions of neurology:

While 331/521 (63.5%) of students reported no change in their opinion of neurology over the course of their training, 137 (26.3%) reported a change from a negative opinion of neurology to a positive one. Some elements that contributed to this change in opinion from negative to positive, as reported by students through free text responses included having repeated hands-on practice, being taught with a clinical context, being taught how to manage neurological cases in a non-referral setting, the enjoyment of the puzzle-like challenge and the satisfaction of correct neurolocalization. The most commonly cited contributing elements in the free text responses were having impactful, enthusiastic teachers (faculty or residents), and having experienced a hands-on neurology rotation.

On the other hand, 53 (10.2%) reported a change from a positive opinion of neurology to a negative one. Some elements that contributed to this change in opinion from positive to negative, as reported by students through free text responses included perceptions of the coursework being hard and disorganized, underlying conceptual complexity, an inability to apply theoretical knowledge to clinical cases, the large volume of material and insufficient time to learn, the high cost of referral level care, unapproachable teachers, and long work hours with heavy patientcare. The most commonly cited contributing elements in the free text responses were a lack of access to rotations, and a lack of clinical context when being taught in the pre-clinical years.

Barriers to learning:

The top barriers ranked by students as contributing to their feelings of neurology being a difficult topic included the large volume of content, conceptual difficulty, insufficient hands-on labs, inability to access hands-on experiences, (complexity of) neurolocalization, as well as neuroanatomy and neurophysiology, and knowledge of neurological diseases. A comparison of student and teacher responses is presented in Table 3. Other contributing barriers were sought through free text responses. One recurring comment was that of perceived differences in teaching quality between clinical veterinarians and non-clinical or non-veterinarian instructors. Students perceived more effective, clinically relevant teaching from clinical veterinarians over other instructors. This was commonly reported in the context of neuroanatomy and neurophysiology courses, with students also commenting on a resultant poor foundation for future learning. Other reported contributing barriers included a lack of access to clinical experiences and neurological patients, lack of exposure to neuroscience in pre-veterinary coursework, inconsistent terminology, insufficient time in the curriculum, lack of repetition and reinforcement, and being unable to visualize concepts. Students also commented on the subjectivity of the neurological examination, and fears of coming to an incorrect diagnosis or not being able to diagnose or treat patients in a general practice setting. Additionally, the COVID19 pandemic was cited as a contributing barrier, with quality of distance-learning, technological challenges, and reduced hands-on opportunities being the main hinderances. Many students also commented on a lack of resources to supplement their learning.

Additional resources

Students were asked to rate how helpful various additional resources or learning interventions might be for their neurology education. When asked about online reading materials such as textbook chapters or summarized notes, only 159/495 (32.1%) reported these would be helpful. In comparison, 355/507 (70.0%) reported online viewing materials such as individual animations and videos would be helpful, while 377/496 (76.0%) reported structured virtual practice cases would helpful. When asked about the number of lectures, 179/478 (37.5%) reported that more lectures would be helpful while only 37/449 (8.2%) felt that less lectures would be beneficial. The majority of students (449/502; 89.4%) reported that additional hands-on live animal labs, clinical cases or cage-side rounds would be helpful. When asked about discussions with neurology clinicians, 405/499 (81.2%) reported this would be a helpful intervention, while 257/504 (51.0%) stated that peer-to-peer discussions with other students on neurological cases would be useful. Lastly, 261/482 (54.1%) reported that edutainment interventions such as games, music, comics, etc. would be useful. Student rankings of interventions were similar to those of teachers.

Students were asked to comment at what stages in their training they would want learning interventions and resources. The most common response (259/442; 58.6%) was for interventions at all stages of the training program. Students often expressed interest in having control over when they accessed resources, often due to limitations of time. Some students expressed interest in accessing resources during their clinical neurology theory education (63; 14.3%), or during neuroanatomy training (57; 12.9%). The rest requested access during other times, including all pre-clinical years, during clinical rotations, or in lieu of rotations if they could not access hands-on clinical experiences.

A total of 314/612 (51.3%) students responded to the free text question asking if their veterinary school offered resources or unique teaching tools outside of standard lectures and rotations. 100/314 (31.8%) students were aware of resources offered through their school. These included virtual rounds organized by student clubs, student led group study, neurology electives, neurology games (Jeopardy!®, charades, etc.), coloring pages, 3D models, diagrams and animations, online videos of neurological examinations and patients, virtual case simulation, text-based practice cases, and access to 3rd party resources purchased by the school.

A total of 296/612 (48.4%) students responded to the free text question asking if they were aware of or had used 3rd party resources outside those provided by their veterinary school. 101/296 (34.1%) students were aware of resources offered outside their school. These included unspecified videos and animations, YouTube videos (cited primarily for basic neuroscience and neuroanatomy), Veterinary Information Network 3D anatomy, University of Minnesota Veterinary Neuroanatomy website, Colorado State University Virtual Animal Anatomy program, Merck Veterinary Manual online, as well as online case videos from Cornell University, University of Minnesota, the Neuro Pet Vet website, and social media (Instagram accounts of veterinary neurologists). A compiled list of educational resources used by students and teachers to supplement neurology education is provided (Supplementary material 3).

Differences in perceived ease of neurolocalization

After completing neuroanatomy, spinal cord neurolocalization was considered somewhat challenging while cranial nerve/brain (intracranial) neurolocalization and neuromuscular neurolocalization were considered least challenging. After completing neuropathology training, all neurolocalization were considered equally challenging. Following completion of clinical neurology theory, intracranial neurolocalization was identified to be the most challenging, followed by neuromuscular and lastly spinal cord neurolocalization. For the students who had completed a neurology rotation, neuromuscular neurolocalization was the most challenging localization, while intracranial and spinal cord neurolocalization were ranked similar to one another. A graphical representation of the sum rank of ease of neurolocalization is provided in Figure 3.

Ease of spinal cord neurolocalization and neuromuscular neurolocalization were found to be significantly different between different stages of training ($P<0.001$; df=6; $\chi^2=37.285$; N=491 and $P=0.009$; df=6; $\chi^2=17.186$; N=482 respectively). Intracranial neurolocalization was found to be challenging at all stages but not different between stages of training ($P= 0.322$; df=6; $\chi^2=6.985$; N=487).

Impact of demographics on experiential access

There was no effect of age ($P=0.744$; df=4; $\chi^2=1.955$), gender ($P=0.776$; df=2; $\chi^2=0.508$) or race/ethnicity ($P=0.841$; df=2; $\chi^2=0.347$) on how much students thought access to hands-on experiences or rotations contributed to them finding neurology difficult.

Results of teacher survey

Descriptive results

Teachers' demographics:

A total of 53 teachers completed the survey, however response rates for each question varied as questions were not mandatory. Teachers aged 30-39 years of age accounted for 10/45 (22.2%), while 12 (26.7%) were between 40-49 years of age. There were 15 (33.3%) aged 50-59 years of age, while 8 (17.8%) were greater than 59 years of age. Of the 44 respondents that reported their gender, 22 (41.5%) identified as female, 19 (35.8%) identified as male, 1 (1.9%) identified as non-binary while 2 (3.8%) preferred not to say. When asked about their racial or ethnic identity, the majority of respondents (37/45; 82.2%) identified as Caucasian or White, while only 1 (2.2%) identified as Hispanic or Latinx, 1 (2.2%) identified as African American or Black, and 2 (4.4%) identified as other (multiracial or other race), with 4 (7.5%) preferring not to answer.

Teachers varied in training background, with 20/43 (46.5%) respondents identifying as board-certified veterinary neurologists, 14 (32.6%) as clinicians board-certified in a different specialty, and 5 (11.6%) as basic neuroscience researchers. An additional 4 (9.3%) listed different backgrounds (other). The majority of teachers (25/44; 56.8%) had over 9 years of experience teaching veterinary neurology, while 5 (11.4%) had 5-9 years of experience, 10 (22.7%) had 1-4 years of experience and 4 (9.1%) had less than one year of experience teaching veterinary neurology.

Teachers’ perceptions of neurophobia

When provided a definition of neurophobia, 29/47 (61.7%) of educators reported witnessing neurophobia amongst their students. 10 (21.3%) reported not seeing neurophobia and 8 (17.0%) were unsure. No teachers reported their students found neurology quite easy or very easy, 9/47 (19.1%) said their students found neurology neither easy nor difficult, 27 (57.4%) reported students their students found neurology quite difficult, while 11 (23.4%) reported their students found neurology very difficult. Teachers were generally optimistic in outlook, with 15/47 (31.9%) feeling it was quite easy to change students’ perceptions around veterinary neurology. 21 (44.7%) were neutral on the ease or difficulty of changing student perceptions, while 8 (17.0%) reported it was quite difficult to change perceptions and 1 (2.1%) reported it was very difficult. An additional 2 (4.3%) reported they were unsure.

Teachers’ perceptions of barriers to student learning

The top teacher-perceived barriers to learning contributing to students’ feelings of neurology being a difficult topic, included conceptual difficulty, complexity of neuroanatomy and neurophysiology, volume of content, neurolocalization, reputation of the course or rotation, level of teachers’ enthusiasm and approachability of the teacher. A full comparison of student and teacher responses is presented in Table 3. Other contributing barriers reported by teachers through free text responses included neuroanatomy teaching by non-veterinarians, non-tangible concepts, lack of faculty engagement, difficult vocabulary, and a lack of exposure prior to veterinary school.

Teachers’ perceptions of additional resources

Teachers were asked to rate how helpful various additional resources or learning interventions might be for their students’ education. When asked about online reading materials such as textbook chapters or summarized notes, only 10/45 (22.2%) reported these would be helpful. In comparison, 35/45 (77.8%) reported online viewing materials such as individual animations and videos would be helpful, and 36/45 (80.0%) reported structured virtual practice cases would helpful. 10/45 (22.2%) reported that more lectures would be helpful while 4/44 (9.1%) felt that less lectures would be beneficial. A majority of teachers (34/45; 75.6%) reported that additional hands-on live animal labs, clinical cases or cage-side rounds would be helpful. When asked about discussions with neurology clinicians, 37/45 (82.2%) reported this would be a helpful intervention, while 19/45 (42.2%) stated that peer-to-peer discussions with other students would be helpful. Lastly, 17/45 (37.8%) reported that edutainment interventions such as games, music, comics, etc. would be useful. Teacher rankings of interventions were similar to rankings by students.

Teachers’ use of novel resources and interventions

20/53 (37.7%) teachers had attempted novel interventions in their teaching to combat neurophobia. Of these, 18/20 (90.0%) reported success to some degree, while 2 (10.0%) reported a perceived lack of learning despite student engagement. Based on analysis of free text responses, the interventions used were grouped as follows: instructor led case-based learning, self-directed case-based learning (low fidelity paper cases to high fidelity virtual cases), use of anonymous polling in lectures, near-peer learning, clinical shadowing, games (board games, Jeopardy!® -style, and other competitive quizzes), concept maps, hands on models and props, virtual anatomy atlases and models, and social media. Teachers commented about being unable to get student participation in self-directed learning opportunities, as well as uncertainty as to the benefits of game-based teaching. Other resources recommended by teachers outside their curricula included the virtual anatomy tools such as Veterinary Information Network 3D Anatomy, the Neuro Pet Vet website, the Cornell University case videos, the University of Minnesota Veterinary Neuroanatomy website, the Neuroanatomy of the Dog website, as well as miscellaneous video resources from YouTube, Colorado State University and University of Georgia. A compiled list of educational resources used by teachers and students to supplement neurology education is provided (Supplementary Material 3).

VetNeuroQ scale

Validation and reliability

A total of 531 complete responses were collected from students that completed all items of the proposed scale as part of the student survey. Results of confirmatory factor analysis are shown in Table 4 and Figure 4. Table 4 shows that all items in the model were significant ($P<0.001$). Test for model fit revealed the factor loading model to be a good fit ($\chi^2=249.49$, df=62; $P<0.001$; CFI=0.916; RMSEA=0.07). All standardized regression weights were above 0.7, except for items 6 and 7 (0.64 and 0.56 respectively), which were >0.5 suggesting good construct validity. [28–30] Reliability was high (>0.7) for Knowledge ($\alpha=0.873$; $\omega=0.873$), Confidence ($\alpha=0.771$; $\omega=0.777$) and Perceived ease ($\alpha=0.827$; $\omega=0.775$). [24,26,27]

Descriptive results

VetNeuroQ scores were normally distributed. The mean Interest score was 3.2 (+/- 1.2), with a range of 1.0 to 5.0. The mean Perceived Ease score was 2.3 (+/- 1.0) with a range of 1.0 to 5.0. The mean Confidence score was 3.1 (+/- 0.8) with a range of 1.0 to 5.0. The mean Knowledge score was 3.1 (+/- 1.0) with a range of 1.0 to 5.0. The mean overall VetNeuroQ score (neurophobia score) was 11.8 (+/- 2.9), with a range of 4.0 to 20.0. The frequency distribution of all student VetNeuroQ scores is shown in Figure 5.

Proposed cutoffs

Based on a median score of 3.0 corresponding to neutral phrasing in the Likert scale for each item, a neutral VetNeuroQ score of 12.0 was calculated. As such this is proposed as the neurophobia cutoff score. Per these criteria, a total of 274/531 (51.6%) respondents were characterized as neurophobic (VetNeuroQ score of <12) in the current survey. Proposed sub-cutoffs include: scores of 10.0 to <12.0 = mild neurophobia, scores of 7.0 to <10.0 = moderate neurophobia, and scores of 4.0 to <7.0 = severe neurophobia. Per these criteria, the rates of mild, moderate and severe neurophobia in the surveyed population was 23.9%, 23.2% and 4.5% respectively.

Impact of stage of training and student background characteristics

Respondents' stage of neurology training in the veterinary curriculum significantly impacted VetNeuroQ scores as well (P=0.017; df=4; F=3.054). Scores for Perceived ease (P<0.001; df=4;

$F=5.991$), Confidence ($P<0.001$; $df=4$; $F=7.796$) and Knowledge ($P<0.001$; $df=4$; $F=40.344$) and overall VetNeuroQ scores ($P<0.001$; $df=4$; $F=14.906$) were different between stages of training, while Interest scores were not significantly different ($P= 0.088$; $df=4$; $F=2.033$). Results of post-hoc multiple comparisons follows.

For Perceived ease scores, students that had completed a neurology rotation scored significantly higher scores than those with no training ($P<0.001$), those that had completed neuroanatomy ($P<0.001$), those that had completed neuropathology ($P<0.001$), but not those that had completed clinical neurology theory ($P=0.051$). Other comparisons of stages of training were not significantly different. For Confidence scores, students who had completed neuroanatomy ($P=0.045$), neuropathology ($P=0.001$), clinical neurology theory ($P=0.001$) and a neurology clinical rotation ($P<0.001$) each had higher scores than those with no training in neurology. Those that had completed a neurology clinical rotation had higher confidence scores than those that had completed neuroanatomy training ($P=0.007$). Other comparisons of stages of training were not significantly different. For Knowledge scores, each subsequent stage of training scored significantly higher than the prior stage of training ($P<0.001$), except for clinical neurology theory, which was no different in Knowledge scores than neuroanatomy ($P=0.055$) and neuropathology ($P=1.0$). Mean plots of scores for each dimension of Interest, Perceived ease, Confidence and Knowledge, broken down by stage of training are displayed in Figure 6A.

For overall VetNeuroQ scores, scores were significantly higher at each stage of training compared to no training ($P<0.001$), and scores of students that had completed a neurology rotation were significantly higher than scores at all previous levels ($P<0.001$). However, scores for students that had completed neuroanatomy, neuropathology, and clinical neurology theory were not significantly different (P=1.000). Mean plots of scores for overall VetNeuroQ scores broken down by stage of training are displayed in Figure 6B.

Having family members or friends working in human or veterinary neurology was significantly associated with higher VetNeuroQ scores (P=0.027; df=3; F=3.080), while experience with neurological patients prior to veterinary school was not (P=0.173; df=3; F=1.667). A history of neuroscience training prior to veterinary school was also associated with higher VetNeuroQ scores (P=0.017; df=1; F=5.689).

DISCUSSION

While neurophobia has been documented across various medical fields, and has been suspected to exist in veterinary medicine, this is the first published study demonstrating features of neurophobia amongst veterinary students.[2,4,9,10,12–21,31] The majority of students reported finding neurology to be difficult to learn and reported low perceptions of self-efficacy, similar to medical students.[2,3,10] Students also reported low confidence in neurology as compared to other topics, as well a low interest in neurology as a specialty compared to other specialties, akin to findings from medical students.[2,6,10] These findings of high perceptions of difficulty, and low interest and confidence, are some of the hallmark features of neurophobia as described in medical students, and demonstrate neurophobia amongst veterinary students.[2,3,10] These findings likely have significant ramifications for veterinary education. The impact of neurophobia on students likely has long lasting consequences, impacting how veterinarians practice, as well as their future patients and clients. By better understanding this phenomenon in veterinary education, we can better design interventions and implement strategies to improve learning, while also shifting the paradigm from simply building knowledge to also countering perceptions of difficulty, improving student confidence, and sparking interest in neurology.

Early development of veterinary neurophobia:

Similar to neurophobia in human medical training, veterinary students appear to experience neurophobia in both clinical and pre-clinical stages of training.[4,9,11,21] While veterinary students were generally satisfied with their training, approximately one third of respondents felt their training was insufficient. This highlights a potential perceived lack of knowledge, another feature of neurophobia. As curricula are expanded to cover a growing breadth of material, the quality of teaching and learning of topics such as neurology may be diluted as contact hours are decreased.[32,33] Specifically, shrinkage of contact time and reduced cadaver access have impacted neuroanatomy training in medical schools and have been identified as contributors to neurophobia.[2,4,5,32,33]

Barriers to learning neuroanatomy and neurolocalization:

Difficulty of learning neuroanatomy/neurophysiology was identified by veterinary students as a barrier to learning. A strong foundation of neuroanatomy is especially important in veterinary medicine, as it lays the foundation for neurolocalization, which was also identified as being a challenging concept in this study. Neurolocalization plays a key role in the diagnosis, management, and prognostication of a neurological patient, and has been identified as an important day one skill for veterinary students.[22] Training appeared to impact students' perceptions of the difficulty of neurolocalization over the course of their education and further study is warranted to help develop targeted interventions. While curricular design varies across institutions, often neurology is taught in a relatively linear manner, starting with neuroanatomy, then neuropathology, then specific diseases and finally clinical exposure. Following completion of basic neuroanatomy, where emphasis is typically placed on learning the cranial nerves, intracranial neurolocalization is considered less challenging. Spinal cord anatomy might receive relatively less focus or may not lend itself to memorization, making spinal neurolocalization relatively challenging at this stage despite being conceptually simpler. Next, while students learn pathology, it is possible that there is less reinforcement of neurolocalization, which might contribute to all neurolocalization being perceived as very challenging. Next, while learning about specific diseases, when faced by a variety of case presentations, students appear to be overwhelmed by the depth of complexity of intracranial localization. Finally, following hands-on exposure to clinical cases, performing, and interpreting the neurological examination and practicing neurolocalization appears to help reduce perceptions of difficulty around neurolocalization. Neuromuscular localization was often ranked as the most challenging, likely due to the rarity of case exposure and the inherent challenges of neurolocalization in such cases. The overall trend of perceived difficulty of neurolocalization follows a curve similar to the Dunning-Kruger effect and may reflect a similar phenomenon here as well, where students with low neurology experience may overestimate their abilities with neurolocalization.[34] Thus, improvement of neuroanatomy teaching and neurolocalization education should be goals of future teaching interventions, and care must be taken to ensure adequate contact time in the curriculum for these foundational topics, including sufficient vertical and horizontal integration and regular reinforcement of these essential skills. Reducing time gaps between basic neuroscience and clinical teaching may also prove useful, and comparative study of different curricular designs may prove valuable.

Another barrier reported by students was a perceived difference in teaching quality in neuroanatomy and neurophysiology between clinical veterinarians and non-clinical or non-veterinarian instructors, with students perceiving better teaching from clinical veterinarians. While there are no data to confirm or refute this perception, this finding, combined with the high demand for clinical cases, likely highlights the importance of effective teachers and of providing a clinical context to foundational pre-clinical material. As neuroanatomy can be conceptually complex and hard to visualize, incorporating the use of advanced imaging modalities and clinical patient videos can help show students the clinical context of these topics, and aid in sparking interest early on. Since many students reported challenges in accessing hands-on experiential learning opportunities, the use of digital media to supplement learning could be better leveraged. Many disparate interventions providing supplementary clinical case materials are reported to be in use across North American veterinary schools. The development of free, open source, media-rich resources under a creative commons license that could be shared across institutions may help supplement pre-clinical teaching in a more efficient, equitable and standardized manner.

Bridging the student-teacher divide:

Comparison of calculated rankings of barriers to learning (Table 3) showed that students and teachers were aligned on certain perceived barriers to learning such as the volume and complexity of content and the difficulty of neuroanatomy and neurolocalization. However, there were discrepancies that reflect a disconnect between expectations and beliefs of students and teachers around the need for more lectures, the difficulty of the neurological examination, impact of teacher enthusiasm and impact of reputation among others. Educators should consider the opinions of our self-aware student body when thinking about content delivery, curricular design, and educational interventions. Not doing so may perpetuate biased beliefs that are not aligned with student concerns and reduce educational impact. However, students are also prone to biased thinking and may not be able to fully identify the elements that shape their learning.[35] Thus, while the opinion of neither teacher nor student should necessarily take priority, it is important to attempt to bridge this gap to improve the educational experience. Interestingly, both students and teachers ranked the suggested additional resources in a similar manner, providing common ground to initiating change.

The VetNeuroQ scale:

To date, there is only one validated neurophobia scale (NeuroQ) developed for use in human medical education for pre-clinical medical students.[3] This scale has not been validated in clinical students. Additionally, differences exist between human and veterinary medicine, and the way each is taught. For example, veterinary students need to learn veterinary neurology in multiple species, rely more heavily on history and neurological examination findings (over self-reported symptoms), and are expected to diagnose and treat neurology cases as general practitioners after usually a single clinical year, unlike their human medical counterparts who more commonly undergo additional clinical training. Thus, the NeuroQ scale is not an ideal for use in veterinary medical education. In the present study, the VetNeuroQ scale was designed with these differences in mind and specifically for use in both pre-clinical and clinical veterinary students. The VetNeuroQ scale may fill multiple roles. Currently, identifying students experiencing neurophobia is challenging. By drawing from multiple known dimensions of neurophobia, the VetNeuroQ scale developed in this study acts as a validated, quantitative, objective means to screen both pre-clinical and clinical students for neurophobia of varying severity. This could help educators provide specific, targeted interventions to the students that need them the most. The scale could help track student neurophobia over time and act as an outcome measure for research into the impact of different educational interventions. Ideally, in the future, when applied to a new population of students, confirmatory factor analysis should be repeated, to evaluate the reliability of the tool in a novel population. Additionally, there remains no comprehensive study into elements contributing to neurophobia in both human medical education and veterinary medical education. Future qualitative and quantitative studies into neurophobia may help inform the core elements of neurophobia inherent to veterinary medicine, and revision of the scoring tool may be warranted.

Comparison to human medical education:

The results above highlighted the relatively high overall rate (51.6%) of neurophobia amongst veterinary students, comparable to that in human medical education (30%-66% across different populations of students in different studies).[4,9,18,21] Differences in curricular design and timing of neurology content delivery between veterinary schools may have impacted these findings to some extent. Students were grouped by the stage of neurology learning completed instead of year of learning to minimize such effects, but this approach may not account for all variations in curricular design, such as case-based learning models. Further study is required to assess whether certain curricular formats might mitigate neurophobia more than others. Additionally, variation in availability of access to clinical neurology rotations and similar experiential learning opportunities may have also impacted neurophobia rates. Overall neurophobia scores significantly increased (became less neurophobic) following competition of a neurology rotation after a relative plateau during pre-clinical training. This appears to highlight the importance of clinical exposure to neurology cases and the potential value of mentorship by clinical neurologists in helping mitigate neurophobia.

The net improvement in neurophobia seen over the course of veterinary education in the present study is different from reports of worsening neurophobia over the course of human medical education, after which it persists into clinical practice in human healthcare settings.[4,14,18,36] It remains unclear if this is the case in veterinary medicine. In addition to neurophobia carried over from veterinary school, the relatively high stakes and time sensitive nature of certain neurology cases and significant limitations of owner finances that impacts decision-making and diagnostic/treatment capabilities in veterinary medicine might contribute to neurophobia amongst clinical veterinarians. In human healthcare settings, clinician neurophobia has been linked to diagnostic inaccuracies, increased referrals, and poor patient outcomes.[3,14] Further study is required to evaluate neurophobia amongst practicing veterinarians and whether neurophobia worsens following graduation. This may also impact student education because many veterinary students work in emergency and general practice settings prior to and during veterinary school, including on externships and clinical rotations during their clinical curriculum. Witnessing neurophobia amongst their mentors in such settings may subconsciously influence their own perceptions of neurology and perpetuate neurophobia.

Study limitations:

The findings of this study should be weighed in the context of some limitations. Respondents were allowed to skip questions in an effort to maximize participation and ensure all voices were heard. However, this led to variable response rates between questions and not all respondents answered all questions in the survey. Additionally, not all questions allowed for a neutral response. This may have prevented respondents from accurately reflecting their opinions but may have encouraged students to think more and commit to an answer instead. These results are from voluntary survey data collected at a single timepoint, and do not track the same population of students over time, which may impact some of the conclusions made. Additionally, as with many survey-based studies, these findings may be prone to acquiescence bias, where respondents may try to answer what they expect the researchers want to hear, and courtesy bias, where respondents may be reluctant to state their unhappiness.[37,38] Attempts were made to minimize these concerns through the anonymous nature of the survey. The broad range of positive and negative responses suggests minimal effects of these biases on the survey results. Additionally, caution must be taken when interpreting students' responses around self-perceptions of barriers to learning and learning interventions, as students may not be able to fully self-identify the barriers that impact their attitudes or learning. Many students likely carry preconceptions and skewed perceptions influenced by their peers, previous experiences and more, that they may not be aware of, that perhaps their teachers might pick up on. Similarly, not all educators are aware of their own unconscious preconceptions and assumptions in teaching. Additionally, variations in curricular design across institutions likely influenced the study results. In an attempt to minimize these effects, comparisons were made across stages of training instead of year of training. However, even this may not fully account for the spectra of curricula as schools may not cover material in the same order. While students were not restricted to a single response for stage of training, this may have clouded the findings. As such, investigation of neurophobia within specific curricular designs and at specific points in training may prove useful in identifying additional elements that propagate or diminish neurophobia. Identification of the participating veterinary schools or evaluation of responses by institution could have provided additional information to account for the impacts of variations in curricular design, availability of board-certified neurologists, etc. and to evaluate response rates for overrepresentation of certain institutions. However, this was not possible in the present study and should be considered in the future.

Certain choices in phrasing of survey items may have impacted responses as well. For example, neuroanatomy and neurophysiology were thought to be inherently linked and likely to be taught concurrently. Therefore, these were grouped together, but could have posed a challenge for students who had covered one but not the other, with some students interpreting the question as asking for completion of either and others interpreting the question as asking for completion of both. Similarly, when asking students about their interest in specialization, neurology and neurosurgery were combined to reflect the nature of the specialty in veterinary medicine, where both medical and surgical neurology is performed by veterinary neurologists. However, it is possible that students may have had more exposure to medical neurology than neurosurgery, and the inclusion of the combination could have made them hesitant to declare an interest in the specialty. Additionally, this study was conducted during the COVID19 pandemic, when students were dealing with remote teaching and other disruptions to content delivery, which likely influenced students' perceptions of neurology and neurophobia. Lastly, the VetNeuroQ scale was shown to have good validity and reliability. However, we acknowledge that while the current model is still a good fit, there is some room for improvement and iteration in the future.

Proposed curricular changes to reduce neurophobia:

Based on the findings of this study, there are many potential curricular changes that may improve neurology education and minimize neurophobia in veterinary medicine. One consideration is to increase access to neurology rotations or consider creating mandatory neurology rotations. Many students commented that a hands-on neurology rotation contributed to improved opinions of neurology and a lack of access to rotations was commonly reported as a barrier to learning. Students who had completed a neurology rotation also had higher interest in neurology as a specialty. Improved vertical and horizontal integration of neurology within curricula with sufficient repetition and reinforcement of key content could help reduce neurophobia. Additionally, efforts to provide consistency in terminology, at least within institutions could improve comprehension and reduce confusion. Attempts have been made in Europe to create consensus on learning objectives.[22] Similar initiatives in North America could help create more standardized neurology educational experiences across institutions and help reduce neurophobia. Additionally, educators have been trialing various educational interventions to improve neurology teaching. Greater collaboration and objective scales like the VetNeuroQ tool and other outcome measures are needed to help optimize these interventions to counter neurophobia. Lastly, there has been little research into neurophobia amongst post-graduate veterinarians, and neurophobia must be studied in different practice settings.[31] This is especially important for emergency and general veterinary practice, where veterinarians are the first-line care providers for most patients with common neurological conditions, and due to the financial limitations commonly faced in veterinary medicine, are also often the only care providers.

Conclusions:

This report is the first documentation of neurophobia amongst veterinary students and, through the VetNeuroQ tool, offers a validated, objective measure of veterinary pre-clinical and clinical veterinary neurophobia. Early identification and intervention to counter neurophobia is important as neurophobia has been shown to persist into clinical practice amongst general practice doctors, where they may have significant implications for patient care and clinical wellbeing.[2,4,10,11,15] This is likely true in veterinary medicine as well. By providing students with the support and tools to engage with neurology in a fun, encouraging manner we can likely minimize neurophobia, which may help reduce future stress, anxiety, and burnout. Additionally, countering neurophobia may also improve patient outcomes, and reduce referral burdens on veterinary specialists. Further targeted study of veterinary neurophobia and research into interventions to combat neurophobia are required.

NOTES

a. Qualtrics®, Provo, UT, USA
b. IBM SPSS® v.28.0, Armonk, NY: IBM Corp, USA
c. GraphPad Prism v.10.0, Boston, MA, USA
d. IBM SPSS Amos® v.28.0, Armonk, NY: IBM Corp, USA

FIGURE CAPTIONS

Figure 1A. Comparison of overall mean (+/- s.d) of student scores of confidence in neurology compared to other topics. Number of responses: cardiology (N=465), gastroenterology (N=452), renal/urinary (N=461), ophthalmology (N=438) and neurology (N=481). Overall scores of confidence were significantly lower for neurology ($P<0.001$) compared to all topics aside from ophthalmology.

Figure 1B. Change in mean student scores of confidence in neurology and other topics over the course of different stages of training. Confidence in neurology showed significant improvement over all stages of training ($P<0.001$).

Figure 2A. Comparison of mean (+/- s.d) scores of student interest in specialization in neurology/neurosurgery and other specialties. Number of responses: cardiology (N= 525), oncology (N= 518), internal medicine (N= 527), ophthalmology (N= 521), neurology/neurosurgery (N= 530) and surgery (soft tissue/orthopedic) (N= 528). Overall interest in specialization in neurology/neurosurgery was significantly lower than interest in specialization in internal medicine and surgery (P<0.001).

Figure 2B. Change in mean scores of student interest in specialization over the course of different stages of training. Interest in specialization in neurology significantly rose following completion of a neurology clinical rotation (P=0.001).

Figure 3. Sum rank scores of perceived ease of neurolocalization over different stages of training showing a decline in student-reported ease of neurolocalization after learning neuroanatomy, which subsequently improves over the course of training. Number of responses: cranial nerves and brain (N= 556), spinal cord (N=564), Neuromuscular (N=563).

Figure 4. Factor loading (standardized regression weights) of items 2-14 (represented as e1-13) from the VetNeuroQ scale onto factors of perceived ease, confidence, and knowledge. Abbreviations for each item are defined in Table 4. Note that item 1 (interest) was not included as it was the only item mapping to interest.

Figure 5. Frequency histogram of students' overall VetNeuroQ scores showing a normal distribution (N=531).

Figure 6A. Mean scores for each dimension (Interest, Perceived Ease, Confidence and Knowledge) across stages of neurology training, showing a progressive improvement over time. Note the scale ranges from 1 to 5 (N=531).

Figure 6B. Mean VetNeuroQ scores across stages of neurology training showing a progressive improvement over time (N=531). Note the scale ranges from 4 to 20.

TABLES

Table 1. Validated VetNeuroQ veterinary neurophobia scale with instructions for use.

VetNeuroQ: Veterinary Neurophobia Scale

Note:
Questions 1-10 only are intended for pre-clinical veterinary students
Questions 1-14 are intended for clinical veterinary students

Questions:

How much do you agree with the following statements?

1. *I am very interested in veterinary neurology*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

2. *I find neurological concepts difficult to understand*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

3. *Compared to other topics, I find neurology is harder to learn*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

4. *I am confident in my ability to study and learn neurological concepts*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

5. *I do well on tests or quizzes of neurological concepts*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

6. *I have a strong understanding of neuroanatomy (structure and function)*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

7. *I have a strong understanding of neurological diseases (pathophysiology, clinical presentation, etc.)*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

8. *I can apply my theoretical neurology knowledge to perform a complete neurological exam*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

9. *I can accurately identify abnormalities on a neurological exam*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

10. *I can accurately interpret findings on the neurological exam to localize a neurological lesion (This could be a lesion within the brain or within the spinal cord or in the peripheral nerves/neuromuscular unit. Please answer based on your overall confidence in your neurolocalization skills).*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

11. *I can apply theoretical neurology knowledge to generate a thorough list of differential diagnoses for neurological patients (eg: patients with seizures, or vestibular signs, or signs of spinal cord disease, etc.)*
   1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

12. *I can apply theoretical knowledge to recommend diagnostics (including referral) for neurological patients (eg: IVDD, seizures, vestibular disease, etc.)*

1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

13. *I can apply theoretical knowledge to generate a treatment or stabilization plan for neurological patients (eg: IVDD, seizures, vestibular disease, etc.)*
    1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

14. *I can discuss key aspects of a neurological case with a pet owner/client (eg: IVDD, seizures, vestibular disease, etc.)*
    1 = strongly disagree; 2 = somewhat disagree; 3 = neither agree nor disagree; 4 = somewhat agree; 5 = strongly agree.

<u>Scoring instructions:</u>

- The VetNeuroQ tool measures neurophobia amongst veterinary students in 4 dimensions:
    - Interest
    - Perceived Ease
    - Confidence
    - Knowledge

- For Q1 the response is the score. This is the **Interest** score (range 1-5).
- For Q2-3, reverse the scales of the responses to generate corresponding scores.
    - A response of 1 = score of 5
    - A response of 2 = score of 4
    - A response of 3 = score of 3
    - A response of 4 = score of 2
    - A response of 5 = score of 1
- Calculate the average of these two scores. This is the **Perceived Ease** score (range 1- 5).
- For Q4-7, calculate the average of the responses to each question to obtain the **Confidence** score (range 1-5).
- For Q8-10 for pre-clinical students, or Q8-14 for clinical students, calculate the mean of the responses to each question to obtain the **Knowledge** score (range 1-5).

- Next, add the Interest, Perceived Ease, Confidence and Knowledge scores to generate an overall **VetNeuroQ** score (range 4-20). Low VetNeuroQ scores indicate more severe neurophobia.

Table 2: Summary of demographic variables of survey respondents

Demographic Variables	Number of respondents (%)
Age (years)	N=515
20-24	252 (48.9)
25-29	223 (43.3)
30-34	26 (5.0)
>34	14 (2.7)
Gender	N=516
Female	438 (84.9)
Male	68 (13.2)
Non-binary	8 (1.6)
Preferred not to answer	2 (0.4)
Racial/ethnic identity	N=516
Caucasian/White	426 (82.6)
Hispanic/Latinx	27 (5.2)
Asian	27 (5.2)
Native American/Indigenous	4 (0.8)
African American/Black	2 (0.4)
Native Hawaiian/Pacific Islander	1 (0.2)
Multiracial/Other	19 (3.7)
Preferred not to answer	10 (1.9)
Year of training	N=516
Year 1	102 (19.8)
Year 2	137(26.6)
Year 3	147 (28.5)
Year 4	130 (25.2)

Table 3: Comparison of student and teacher rankings of various barriers to neurology learning. Ranks ranged from 1 (highest priority barrier) to 20 (lowest priority barrier). Significance of P <0.05 indicates significant difference between student and teacher ranking.

Barrier to learning	Student ranking	Teacher ranking	Z-score	p-value
Large volume of material/detail taught	1	3	-1.259	0.208
Conceptual complexity	2	1	2.162	0.031
Insufficient number of hands-on labs	3	11	-3.132	0.002

Inability to access neurology rotation/get hands-on experience	4	8	-0.361	0.718
(Difficulty of) Neurolocalization	5	4	0.652	0.515
(Difficulty of) Neuroanatomy/physiology	6	2	4.535	<0.001
Knowledge of neurological diseases	7	10	-2.022	0.043
Need for advanced referral diagnostics/treatment	8	9	-0.543	0.587
Insufficient number of clinical patients	9	15	-0.755	0.450
High stakes nature of cases	10	13	-0.412	0.681
Insufficient learning resources (notes, slides, diagrams, etc)	11	18	-2.087	0.037
Insufficient number of lectures	12	14	-0.632	0.528
Neurological exam	13	12	0.966	0.334
Teachers' level of enthusiasm	14	6	4.491	<0.001
Reputation from other veterinary students	15	5	5.038	<0.001
Teacher being intimidating/unapproachable	16	7	3.518	<0.001
Too many lectures	17	20	-0.507	0.612
Negative outcomes of cases students see/hear about	18	17	1.467	0.142
Large amount of hands-on patient care	19	16	1.220	0.222
Too many clinical patients	20	19	1.432	0.152

Table 4. Unstandardized regression weights per item in the VetNeuroQ scale. Items are labelled with abbreviations corresponding to Figure 4.

			Estimate	S.E.	C.R.	P
Item 1: Interest		-	-			
Item 2: Ease1	<---	Ease	1.000			
Item 3: Ease2	<---	Ease	1.104	0.067	16.517	***
Item 4: Conf1	<---	Confidence	1.000			
Item 5: Conf2	<---	Confidence	0.971	0.062	15.708	***
Item 6: Conf3	<---	Confidence	0.855	0.062	13.786	***
Item 7: Conf4	<---	Confidence	0.720	0.060	12.044	***
Item 8: Know1	<---	Knowledge	1.000			
Item 9: Know2	<---	Knowledge	0.732	0.047	15.574	***
Item 10: Know3	<---	Knowledge	0.906	0.052	17.451	***

			Estimate	S.E.	C.R.	P
Item 11: Know4	<---	Knowledge	0.875	0.073	12.012	***
Item 12: Know5	<---	Knowledge	0.822	0.071	11.624	***
Item 13: Know6	<---	Knowledge	0.823	0.075	10.974	***
Item 14: Know7	<---	Knowledge	0.789	0.079	9.955	***

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