Critical Thinking of Scientific Journal Articles in Neuroscience Course

By Dr. Heidi Day

This portfolio describes an upper division neuroscience class focused on critically thinking about data presented in journal articles.

Background

NRSC 4062 Neurobiology of Stress is an upper division elective in neuroscience. The course is a traditional lecture class that covers the fundamental responses of the body and brain to stress; how various systems of the body are impacted by stress, and how individuals may be vulnerable versus resilient to stressful experiences. As part of the class, students are required to read research articles. Over several semesters of teaching this class, it became clear that students were primarily reading the text of the articles, and mostly ignoring the data. I was surprised to learn that many students have significant difficulty interpreting graphical data, and significant gaps in comprehension of experimental design. Thus I modified the course to include the following course goal: Develop critical thinking skills specifically as they pertain to assessment and interpretation of primary scientific research literature.

Implementation

When reading primary scientific literature, ideally, students will be able to:

1. Assess and interpret data in a primary research article without relying on the author's interpretation of that data.
2. Evaluate the limitations of the data.
3. Formulate additional research questions.
4. Construct a simple experimental design to answer one of those research questions.

Assessment of students in these areas was ongoing, and culminated with a "Journal Article exam", where students were provided with an original primary scientific research article, without title, abstract or discussion. They were required to provide a title and abstract for the article, answer various questions about the data presented in the article, and provide follow-up research questions and an experimental design to answer one of those questions.

To prepare for this assessment, published experiments with their accompanying graphs were chosen to illustrate specific points in regular lectures. These experiments and graphs were completely deconstructed during class discussions, including explanations of the experimental design and group by group interpretation of the data. Clicker questions were asked in class, and "low stakes" homework assignments included multiple choice questions based on interpretation of graphical data explained in lecture, and aspects of experimental design. Journal article assignments were reduced to just four, but more class time was devoted to discussion of the data, including student presentations of the data. Interim assessments included free response exam questions to describe and interpret graphical data previously seen in lecture, and to design experiments based on a hypothesis related to concepts learned in class.

Student Work

Questions based on either interpretation of graphical data or experimental design (with or without showing hypothetical data) were asked in 3 consecutive exams. The grading of these questions revealed good student growth in both of these areas over the course of the semester, especially for students initially scoring in the lower tertile. The mean grades for the Journal Article exam were consistent across semesters: 77% (fall 2016), 77% (spring 2017) and 78% (summer 2017). Survey results showed that students recognize the importance of understanding how to interpret graphical data, and felt their ability to do so had improved. Similarly, they reported their ability to think critically about journal articles had improved. Students generally reported they were more likely to think of additional scientific questions and would be better able to design an experiment to answer those questions. Finally, students felt better equipped to critically assess scientific claims made by the media.

Reflections

Overall I was very pleased with the growth shown by students in the area of graphical interpretation and experimental design. I was also happy the survey data were largely very positive, with students generally feeling they had improved in these specific areas. The journal exam grades were lower than I would prefer, and individual answers revealed specific areas of weakness that will be addressed more specifically in future semesters. I would like to provide additional real-world relevance by expanding this critical thinking exercise to include assessment of a stress-related claim made by the media.

Background

The Neurobiology of Stress (NRSC 4062 – see syllabus at end) is an upper division course, usually with about 35-40 students, offered as an elective primarily for neuroscience majors. But there are also other majors represented, especially psychology, integrative physiology and molecular biology, since the only prerequisite is either Introduction to Neuroscience (NRSC 2100) or Biological Psychology (PSYC 2012). This means that students come from relatively diverse backgrounds, although it is stressed from the start of class that students should have a strong interest in neuroscience and physiology. This class is not a prerequisite for any other classes, and as such does not need to cover specific content or skills in preparation for other classes. I am the only instructor to teach this class and essentially have autonomy over the learning goals, as long as they are appropriate for the neuroscience degree.

In general, the class provides an introduction to the concept of stress and the physiological systems involved. After studying specific stress response systems, we go on to explore the interactions of stress with other physiological systems with health relevance, such as the effects of stress on pain and immune responses. The final cluster of topics focuses on factors modulating stress vulnerability versus resilience, such as having behavioral control or exercising regularly. There is no textbook for the class. Instead, emphasis is placed on current research. This takes the form of lecture material based on multiple research papers that I have summarized to form specific topics for study. Claims made in each topic are supported in the lecture material by data from these papers, presented primarily in graphical form. In addition, students are expected to read primary research literature.

Initially, (this course was first offered spring 2013), students chose a research article to present individually. Because of the relatively large number of students, and to allow more time for discussion, in later semesters students chose an article to present as a group. The choice of article was not always optimal, and there was a wide variety in each presenter's comprehension of the paper. The presentation ability affected the attention and engagement of the student audience. In addition, because, there was no assessment for the students listening to the presentation, there was no external motivation to be an engaged participant. In subsequent semesters I chose 7 or 8 relevant and good quality articles myself, and had students present in groups. I set homework to try to ensure students had read and understood the papers, and participation in the class discussion was part of the grade. While this was an improvement, it was clear that there were significant gaps in most students' ability to interpret data presented in these primary research articles.

Over time, I came to realize how difficult it is for most undergraduate students to read and fully comprehend primary research literature. More fundamentally, they often struggle with assessing and interpreting graphical data, and often have deficits in understanding the experimental designs. This was a surprise to me, because students are frequently assigned research articles to read in other classes, and also need to search them out and read them when writing papers assigned in other classes. However, it became apparent that students will, more often than not, take the author's interpretation at face-value, rather than assessing the data for themselves. One reason for this, that I had not fully appreciated until recently, is that students often have difficulty understanding the experimental design and evaluating graphical data.

While this class has more than one learning goal, this portfolio is focused on just one:

- Develop critical thinking skills specifically as they pertain to assessment and interpretation of primary scientific research literature.

Ideally, by the end of the semester, students should be able to:

1. Assess and interpret data in a primary research article without relying on the author's interpretation of that data.
2. Evaluate the limitations of the data.
3. Formulate additional research questions.
4. Construct a simple experimental design to answer one of those research questions.

While the papers read during the semester focus on subject matter specific to this class, the ability to critically read and evaluate primary research literature is a vital skill for students going on to graduate school (either for research or in the medical field). More generally, the ability of a consumer to assess data critically, independently of another person's interpretation, and to formulate questions that remain to be answered, is an invaluable life skill.

Implementation

The overarching learning goal addressed in this portfolio is to:

- Develop critical thinking skills specifically as they pertain to assessment and interpretation of primary scientific research literature.

Experience has shown me that 1) students tend to appraise scientific research literature primarily through the words of the authors who wrote the paper, rather than through the data presented in the paper and 2) this issue likely arises because most students have significant difficulty in understanding the experimental design and evaluating data. Ideally, at the end of this course, I would like students to be able to:

1. Assess and interpret data in a primary research article without relying on the author's interpretation of that data.
2. Evaluate the limitations of the data.
3. Formulate additional research questions.
4. Construct a simple experimental design to answer one of those research questions.

To assess these aspects of the course learning goal, a final "Journal Article exam" was designed for the end of the semester. Students were provided with an original primary scientific research article, without title, abstract or discussion. They were required to provide a title and abstract for the article, answer various questions about the data presented in the article, and provide follow-up questions and an experimental design to answer one of those questions.

To prepare for this exam, and the reading of journal articles in general, as early as the second topic of the twelve topics covered in the course, a portion of the lecture material was presented in the form of experimental data. As early as topics 2 and 3, for which most of the material can be found in a textbook, I provided examples illustrating how the information was derived. For example, in topic 2, I showed subregions of a hypothalamic nucleus that are important for higher levels of control over autonomic brainstem responses. Most students studiously write notes, but won't question how we would ever determine which brain regions could control brainstem autonomic responses. And so, we started slowly, with some fundamentals, such as how to determine which brain regions project to the brainstem and thus are in a physical position to potentially alter responses. As the semester continued, we started to address how to determine if a brain region (or a particular neurotransmitter receptor) is necessary or sufficient for a particular response. By topic 4, 18 of the 40 slides included graphical data and by the end of the course with topics 11 and 12, a little over half the slides were data slides. This gave ample opportunity for students to view graphical data over the course of the semester.

Simply viewing data is not sufficient to learn how to interpret it. When teaching in class, especially with the earliest graphical examples, I tried to guide students through the data slowly, by asking them questions about different aspects of the graph and engaging in discussion. Points of emphasis (described in more detail in Points of Emphasis, at end) included:

1. Determination of an appropriate control group for each variable
2. Recognizing and differentiating between different graphical symbols.
3. The importance of statistical significance versus a visual difference.
4. The importance of groups that show no significant difference
5. The difference between inhibiting a response and preventing an increase.
6. Experiments that show something is necessary for a response
7. Experiments that show something is sufficient for a response
8. Overall interpretation of the data

To provide practice for students thinking in this way, I had in-class clicker questions and online homework quizzes after most lectures, which consisted of multiple choice and true/false questions based on experimental design and graphical interpretation. For the last three of the four exams, students were required to describe and interpret graphs they had seen previously in class. In these exams I also asked students to describe how they would design an experiment to test a particular hypothesis based on concepts covered in the class, and to show a graph of hypothetical data supporting that hypothesis. All this was in preparation for reading and critically assessing data presented in journal articles.

Over the course of the semester students were assigned only four journal articles, but I covered these in greater depth than previously. I also cut out one of the lecture topics I used to cover to allow more class time for journal article discussion. Assigning so few articles at first seemed ridiculous for an upper division course. However, my previous experience with covering more articles in less depth was frustrating; answers to homework questions on the journal article tended to be superficial or vaguely worded, and in-class discussions lacked depth. Each journal article was picked to be relevant to the course material studied, to cover both human and animal research, and to cover a variety of methodological techniques. A list of the articles and the rationale for including them can be found in Journal Article Selection (at end of document). Prior to the in-class discussion, students had a homework assignment including short answer questions to assess their understanding of some of the key points of each paper. In addition to a homework grade, students were graded on their participation in the class discussion. For two of the four papers, which are particularly “data dense”, students were divided into groups, and assigned a graph from the paper to present. They were additionally given key questions to discuss, such as the rationale for using a particular technique. After a brief discussion within their group, we discussed the data from the paper as a class, with each group presenting the data from their assigned graph. The final article was presented without title or abstract, which students had to provide, similar to the final exam. Guidance for this writing was provided. During the in-class discussion of the paper we discussed the data and critically assessed aspects of various titles and abstracts from the actual paper or from previous student examples.

The goal was for students to be better equipped to critically evaluate scientific data, whether as a research scientist or a general consumer, after taking this course.

Student Work

The above plan was first implemented in fall 2016 and I taught the course in a similar way both spring and summer 2017. To determine if there was improvement over the course of each of these semesters, scores from specific questions on successive exams were compared. It should be noted that these data are not from a controlled experiment. There is no true baseline data, as students had some practice interpreting graphs and with experimental design before the exam, through in class discussion, clicker questions and homework quizzes. Determining improvement assumes the questions are reasonably equivalent between successive exams. (The one exception was the first experimental design question, which was deliberately less detailed than subsequent ones, and did not ask students to provide a graph to show hypothetical data supporting the hypothesis). No statistical analysis was performed because of the above, and additional limitations.

With these caveats in mind, for all semesters, for both graphical interpretation and experimental design, there was improvement in the scores for each type of question over the three exams. When broken down into tertiles, students initially scoring in the lowest tertile showed the most growth over the course of each semester for both questions types. For the full dataset, see Grade Summary, at end of document.

I had not previously given a journal article exam, and so it is not possible to tell if there was improvement over semesters where there was less focus on experimental design and data interpretation. Grades for the journal article exam were very consistent across the 3 semesters: 77% (fall 2016), 77% (spring 2017) and 78% (summer 2017).

A student survey conducted using clickers after the last in-class journal article discussion revealed students recognize the importance of understanding how to interpret graphical data, and felt their ability to do so had improved after taking this class. Similarly, they reported they their ability to think critically about both journal articles and scientific claims made by the media had improved. Finally, students generally reported they were more likely to think of additional scientific questions and would be better able to design an experiment to answer those questions. For the full dataset, see Survey Summary at the end of this document.

Reflections

Overall I was very pleased with the growth shown by students in the area of graphical interpretation and experimental design. I was also happy the survey data were largely very positive, with students generally feeling they had improved in these specific areas.

The journal exam grades were lower than I would prefer, and individual answers revealed specific areas of weakness that remain that will be addressed more specifically in future semesters. For example, students frequently made a claim that a variable caused a response, when it only prevented the potentiation of that response caused by a second variable. Students also showed growth in experimental design when specific hypotheses were presented (for example in an exam), but showed a lack of sophistication and even logical reasoning in the type of experimental questions they thought of as follow ups to the experiments described in the Journal Article exam. Additional emphasis will be placed on follow up questions when reading other journal articles to bridge that gap.

The last question of the student survey revealed that students generally thought more critically about the scientific claims they saw in the media. I did not address this specifically, but would like to provide additional real-world relevance by expanding this critical thinking exercise to include assessment of a stress-related claim made by the media. This would likely be driven by students to find the claim and articles supporting and refuting that claim. It may be possible, depending on the claim, to have an in-class debate with students representing each side of the argument, or some similar active learning exercise.

Like most teachers I will continue to adjust this course in an effort to improve the learning experience and outcome for the students taking it. Writing this portfolio has been a very valuable experience. It has helped me to focus on the learning goal I value most, and to identify gaps in my teaching and assessment of that goal.

NRSC 4062 - THE NEUROBIOLOGY OF STRESS - SYLLABUS SPRING 2017

LECTURE SCHEDULE & GENERAL INFORMATION

Meets MWF 12:00 – 12:50 p.m. in HLMS 141

Course Instructor - Dr. Heidi Day
Email: heidi.day@colorado.edu
Office: Muenzinger E242
Phone (with voice mail): 303-735-3815

Office Hours (MUEN E242)
Tuesday 3:00 – 4:00 p.m.
Wednesday 1:00 - 2:00 p.m.
Thursday 2:00 p.m. - 3:00 p.m.
By appointment

COURSE REQUIREMENTS
I will be using the Desire2Learn (D2L) online system extensively. Please make sure you check in regularly for homework assignments and other course information. Material for each lecture is available on the site. I will update your grades on a regular basis, so please check in and make sure you're on the track you want!

There is no required textbook for this course. In lieu of this, I will post various reading material on D2L on a regular basis.

I will be asking clicker questions in class, and your answers to questions can earn you extra credit. **Please bring your i-clicker to class if you want to earn extra credit!** There is no penalty for forgetting your i-clicker, but you will not earn any extra credit for that class.

COURSE OUTLINE AND GOALS
This course is designed to familiarize students with the principles of the neurobiology of stress. It provides an introduction to the concept of stress and the physiological systems involved. Stress interactions with physiological systems relevant to physical and mental health will be studied. Factors modulating stress vulnerability versus resilience will also be explored. Emphasis will be placed on current research, including reading of journal articles. Training in critical thinking, from a research scientist viewpoint will be emphasized.

***** A strong foundation and interest in neuroscience and physiology is highly recommended *****

LECTURE & EXAM SCHEDULE

UNIT 1 – WEEKS 1-4 (JAN 18 – FEB 8)
Topic 1: Stress: History & Concepts
Topic 2: Stress & the Autonomic Nervous System
Topic 3: Stress & the HPA axis
UNIT 1 EXAM (TOPICS 1-3) FRI FEB 10

UNIT 2 – WEEKS 5-7 (FEB 13 – MAR 3)
Topic 4: The HPA axis & Depression
Topic 5: Central Control of Stress
Topic 6: Stress Interactions: Pain
UNIT 2 EXAM (TOPICS 4-6) MON MAR 6

UNIT 3 – WEEKS 8 - 13 (MAR 8 – APR 12)
Topic 7: Stress Interactions: Immune System
Topic 8: Stress Interactions: Gut
Topic 9: Stress Vulnerability vs. Resilience: Development
UNIT 3 EXAM (TOPICS 7-9) FRI APR 14

UNIT 4 – WEEKS 14-16 (APR 17 – MAY 5)
Topic 10: Stress Resilience: Habituation
Topic 11: Stress Resilience: Control
Topic 12: Stress Resilience: Exercise
UNIT 4 EXAM (TOPICS 10-12) FINALS WEEK (TIME TBD)

EXAM SCHEDULE

Unit 1 Exam (Topics 1-3)	Friday February 10
Unit 2 Exam (Topics 4-6)	Monday March 6
Unit 3 Exam (Topics 7-9)	Friday April 14
Unit 4 Exam/Final (Topics 10-12)	Finals Week; TBD

JOURNAL ARTICLE SCHEDULE:

Journal Article 1	Monday February 27
Journal Article 2	Wednesday AND Friday March 15 & 17
Journal Article 3	Monday AND Wednesday April 10 & 12
Journal Article 4	Friday April 28 AND Monday May 1

GRADING

Your final grade will be computed from the following point breakdown:

Exam - Unit 1	15%
Exam - Unit 2	15%
Exam - Unit 3	15%
Exam - Unit 4 (1^{st} part of Final Exam)	15%
Homework (based on lectures)	15%
Journal Article participation & homework	20%
Journal Article Exam (2^{nd} part of Final Exam)	5%
Extra Credit – Clickers	3%

UNIT EXAMS - 15% X 4

Ignorance of exam dates is not a legitimate excuse for missing an exam. If you have a University-sponsored conflict on the day of an exam (for example, if you are a member of a Univ. of Colorado sports team that will be competing out-of-town that day), you can take the exam on an alternate date with a letter of verification from your coach. You will receive a grade of ZERO for any exam not taken. Exams will consist of multiple choice, true/false and short answer questions. Exams are based on lecture material only, and you will not be tested on content of the research articles discussed in class. The final is NOT cumulative. I will provide practice material for the exams on D2L, before each test.

HOMEWORK - 15%

Homework quizzes will be posted on D2L after each lecture and are due 30 minutes before the next lecture. Late submissions will not be accepted. Quizzes will be based on material covered in class that day. Homework is not the same as an exam! Please use any and all resources available to you. This includes using the provided PowerPoint slides, working with other students, and asking me about anything you're not sure about. Your two lowest homework scores will be dropped.

JOURNAL ARTICLES - 20%

20% of your grade will be based on reading and comprehension of four assigned journal articles. The grade will be based on your participation in class discussions of the articles, and homework quizzes/assignments based on the articles. You need to be present and an active participant in class during discussions to earn credit for the participation portion of the grade. Failure to attend class on the days that journal articles are discussed will result in zero attendance & participation points for that session. If you have a legitimate excuse (e.g. a grad school interview or you are sick) you will need to provide documentation for the absence. There are 7 classes when we discuss the journal articles (three of the articles will each take two classes to discuss) and the dates are provided above under the Lecture and Exam Schedule. Note: no journal article grades will be dropped.

JOURNAL ARTICLE EXAM - 5%

The journal article reading assessment will be based on a short journal article (or portion of an article) that will be provided without a title, abstract or discussion. You will be asked to provide a suitable title and abstract for the article, and discuss specific aspects of the article. This will be part of your final exam, combined with the Exam for Unit 4.

EXTRA CREDIT – UP TO 3%

Participation in each clicker question will be awarded 1 point. A correct answer to a clicker question will be awarded another 1 point. Up to 3% extra credit will be awarded, prorated based on the number of questions answered/answered correctly. You must use your i-clicker if you want to earn extra credit points!

UNIVERSITY POLICIES

ADD/DROP POLICIES

The deadlines and policies for adding and dropping classes are clearly indicated on the following calendar: Academic Calendar, and will be strictly adhered to.

ACCOMMODATION FOR DISABILITIES

If you qualify for accommodations because of a disability, please submit to Dr. Day a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary Injuries guidelines under the Quick Links at the Disability Services website and discuss your needs with your professor.

RELIGIOUS HOLIDAYS

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, you should inform Dr. Day of any conflicts at least one week in advance so that appropriate accommodations can be made. See the campus policy regarding religious observances for full details.

CLASSROOM BEHAVIOR

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. For more information, see the policies on classroom behavior and the student code.

SEXUAL MISCONDUCT, DISCRIMINATION, HARASSMENT AND/OR RELATED RETALIATION
The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. CU-Boulder will not tolerate acts of sexual misconduct, discrimination, harassment or related retaliation against or by any employee or student. CU's Sexual Misconduct Policy prohibits sexual assault, sexual exploitation, sexual harassment, intimate partner abuse (dating or domestic violence), stalking or related retaliation. CU-Boulder's Discrimination and Harassment Policy prohibits discrimination, harassment or related retaliation based on race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. Individuals who believe they have been subject to misconduct under either policy should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding sexual misconduct, discrimination, harassment or related retaliation can be found at the OIEC website.

HONOR CODE
All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the academic integrity policy of the institution. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access, clicker fraud, resubmission, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code Council as well as academic sanctions from the faculty member. Additional information regarding the academic integrity policy can be found at honor code.

A FINAL WORD

I hope that you find this course to be stimulating, insightful, and relevant to your life experiences. I'm always happy to talk with you, especially if you are finding any aspects of the class difficult, so please don't be afraid to come and see me! I look forward to working with you throughout this semester and appreciate all feedback.

POINTS OF EMPHASIS

1. DETERMINATION OF AN APPROPRIATE CONTROL GROUP FOR EACH VARIABLE

For example, the control for a group that gets a lesion of a brain area isn't, "not getting a lesion", but a sham operation. What does it mean to have a sham operation? The control for a group that gets a drug injection isn't, "not getting the drug", but a vehicle injection. What does it mean to have a vehicle injection? I try to stress that the aim of any experimental design is to have only one variable change between groups. When assessing data the variable between the groups should be determined, and then the effect that the variable had should be examined.

2. RECOGNIZING AND DIFFERENTIATING BETWEEN DIFFERENT GRAPHICAL SYMBOLS.

Students are often unaware what an asterisk over a data point might mean, or why there is an asterisk above one data point and a cross over another. I take the time to go over these fundamental concepts before describing the data.

3. THE IMPORTANCE OF STATISTICAL SIGNIFICANCE VERSUS A VISUAL DIFFERENCE.

Students have a tendency to say, for example, that a particular variable increased a response, just because its mean has a higher value. I emphasize the importance of statistical significance before saying there is a difference between groups.

4. THE IMPORTANCE OF GROUPS THAT SHOW NO SIGNIFICANT DIFFERENCE

Once students realize that the asterisks mean significant differences, then they have a tendency to only consider differences that are significant. I try to stress that if there is no difference in a baseline measure between a sham and lesion group for example, that provides very valuable information.

5. THE DIFFERENCE BETWEEN INHIBITING A RESPONSE AND PREVENTING AN INCREASE.

For many students this is a hard concept to grasp. But we have many instances of this occurring. For example, a stressful experience could cause an increase in a plasma hormone level, and prior administration of a drug prevents that stress-induced increase. The drug itself doesn't cause a decrease in the hormone level; that could be ruled out with the baseline controls showing no significant difference.

6. EXPERIMENTS THAT SHOW SOMETHING IS NECESSARY FOR A RESPONSE

If you want to show something is necessary for a response, you need to take it out of the picture. So, if you think a brain region is necessary for a response you could lesion it. If you think a particular neurotransmitter receptor is necessary, you could inject an antagonist for the neurotransmitter receptor.

7. EXPERIMENTS THAT SHOW SOMETHING IS SUFFICIENT FOR A RESPONSE

If you want to show something is sufficient for a response, you need to activate it. So, if you think a brain region is sufficient for a response you could stimulate it. If you think activation of a particular neurotransmitter receptor is sufficient for a response, you could inject an agonist for the neurotransmitter receptor.

8. OVERALL INTERPRETATION OF THE DATA

Over time it becomes easier for students to verbally describe data that's visually depicted on a graph. To start with they might say, "there's a significant difference between the V/HC and V/Stress group". Then they might improve to include the direction of the change and specificity of the response, and say, "V/Stress has a significantly higher corticosterone response compared with the V/HC group." The most difficult part to learn seems to be the overall interpretation, especially if multiple variables are included, as in the above example. That is, the data support the hypothesis that restraint stress causes an increase in the level of plasma corticosterone in rats.

JOURNAL ARTICLE SELECTION

ARTICLE 1

The first article is discussed at the beginning of week 7, so students have had some experience with the topic of stress and the interpretation of data. This first article is a relatively simple article to read and is a human study that claims to have found a biomarker for psychological vulnerability to future life stress. I have students answer short answer questions on D2L before we discuss the article. I have students consider things like how prestigious the journal is (and in this case the data are published in Neuron, which is very prestigious in the field of neuroscience) and consider if that causes any bias in how they view the data. We consider the experimental design (which is sound) and so on. The quiz leads students through the paper, which describes a well-controlled study, with the final question asking to what extent (and why) the student agrees with a statement that the authors make, that "individual differences in a readily assayed neural biomarker, threat-related amygdala reactivity, predict psychological vulnerability to common life stressors as much as 1 to 4 years later." The data presented do support this conclusion, statistically. However, the effect size is so tiny, it could never be used as a biomarker. This shows there are additional aspects to thinking critically about data, beyond sound experimental design and statistical significance.

Swartz et al. (2015) A neural biomarker of psychological vulnerability to future life stress. Neuron 85:505-511. doi: 10.1016/j.neuron.2014.12.055

Link to Article 1

ARTICLES 2 & 3

The second and third papers are in areas relevant to material covered in class about a week prior to each discussion. Both are good quality, "data-dense" articles, published in high impact journals. Both are difficult to read because so much information is packed into a small space. Much of the information is presented in a supplementary data section, separate from the main article. These articles generally take students out of their comfort zone because not everything has been covered in class. For each article, there is a quiz that has to be completed before each article is discussed in class. The quiz includes multiple choice questions designed to expose the misconceptions that previous students have demonstrated when reading the article, and short answer questions that cover "bigger picture" material. Each article is discussed over 2 class periods. For these papers, students get into small groups and each group is required to present some data from the paper. For each data set I have a list of questions that the group needs to address. They discuss the data and the questions in their group first, and then each group of students presents the data to the rest of the class. Part of the aim of these data-dense papers is to determine why the authors performed the next experiment in the series of experiments presented. This is because one aspect of evaluating data in a scientific article is to recognize limitations of an experiment. These limitations are distinct from design flaws, and often require additional experiments to address them. An additional feature of these papers is the generation of additional hypotheses that are tested. These papers essentially present a series of experiments that go through this process, of recognizing limitations and testing additional hypotheses, before reaching an overall conclusion. One final aspect that is emphasized during student presentations is the importance of evaluating that specific data set, and avoiding over-interpretation based on information gathered from an experiment presented later in the paper.

Sorge et al. (2014) Olfactory exposure to males, including men, causes stress and related analgesia in rodents. Nat. Methods. 11:629-632. doi: 10.1038/nmeth.2935

[Link to Article 2](#)

Niwa et al. (2013) Adolescent stress-induced epigenetic control of dopaminergic neurons via glucocorticoids. Science 339:335-330 doi: 10.1126/science.1226931

[Link to Article 3](#)

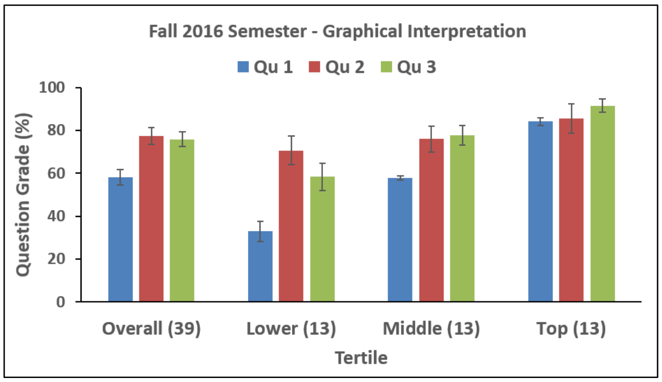
ARTICLE 4

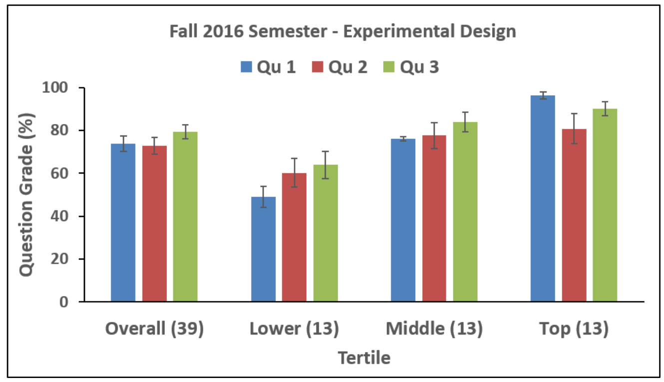
The final journal article is again relatively simple and short. The paper is presented without title, abstract or discussion, in preparation for the final exam. This is so that students are forced to evaluate the data presented in the paper, without the assistance of the author's interpretation. As part of the homework quiz preparing for in-class discussion, students are required to write a suitable title and abstract for the paper. I give feedback on these summaries prior to the final exam, when they again are presented with an original primary research article, without title, abstract or discussion. For both homework and the final exam, aside from summarizing the data presented in the paper in the form of a title and abstract, students additionally have to answer a few general questions that address common misconceptions, generate two distinct questions that the article provokes, and propose a general experimental approach to answer each of those questions. (This article is not referenced, to limit the access to future students taking the class).

GRAPHICAL INTERPRETATION AND EXPERIMENTAL DESIGN GRADE SUMMARY

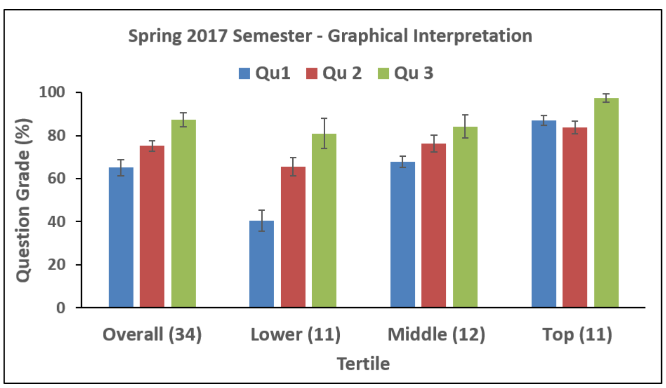
For the fall 2016, spring 2017 and summer 2017 semesters, students were required to respond to exam questions to assess their ability to describe and interpret graphical data previously discussed in class, and design simple experiments based on a hypothesis relevant to concepts learned in class. Graphical interpretation questions were not deliberately different in difficulty across exams. The first experimental design question was deliberately less complex than the two subsequent questions, which also required students to provide a hypothetical graph showing data supporting the hypothesis. Questions are not provided here as they will likely be used in a similar format in future exams. Data were similar across semesters, with students showing improvement across exams in both question areas, particularly for students initially scoring poorly. For fall and spring semesters, data are shown for the whole cohort, and also divided into lower, middle and upper tertiles, according to the student's score on the first exam question in that area. When there was overlap across tertiles in score for the first exam, the tertile assignment was further determined by the student's score on the second exam question. For the summer semester, there were too few students to divide the data into meaningful tertiles. The number of students for each data point is shown in parentheses.

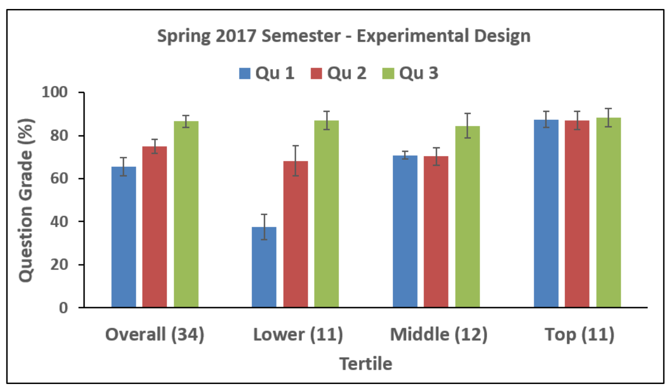
FALL 2016 SEMESTER



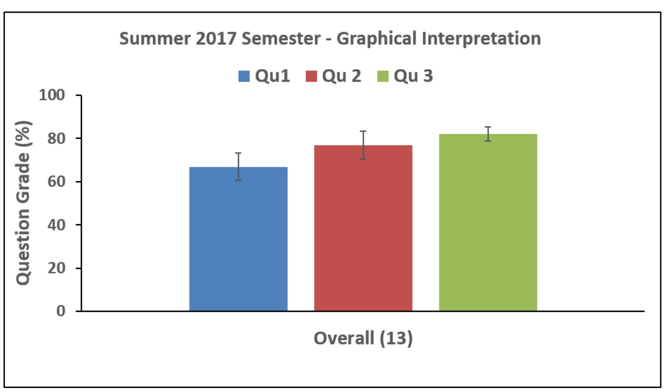


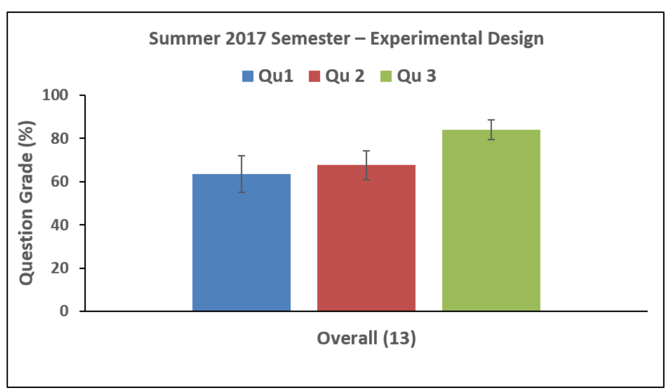
SPRING 2017 SEMESTER





SUMMER 2017 SEMESTER





END OF SEMESTER STUDENT SURVEY FOR NRSC 4062

Questions were asked a clicker questions in class after the final journal article discussion. Data from surveys taken at the end of the spring and summer 2017 semesters can be found in Survey Summary

Questions 3-10 were answered on a scale of 1 to 5.

1 = Strongly Agree

2 = Agree

3 = Neither Agree nor Disagree

4 = Disagree

5 = Strongly Disgree

QUESTIONS

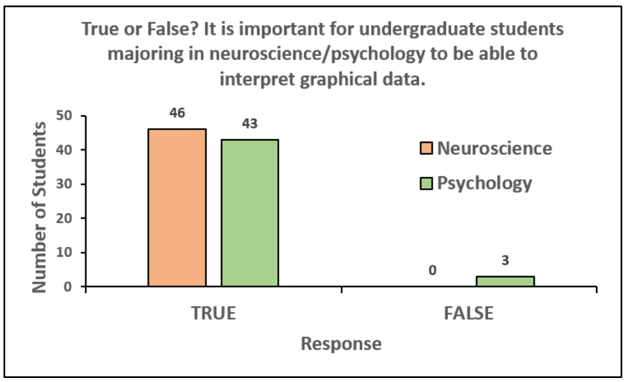
1. True or False? It is important for undergraduate students majoring in neuroscience to be able to interpret graphical data.
2. True or False? It is important for undergraduate students majoring in psychology to be able to interpret graphical data.
3. After taking this class, my ability to interpret graphical data has improved.
4. After taking this class, I am more aware of the importance of looking at the data presented in a journal article, rather than only reading the author’s words.
5. After taking this class, I am more likely to look at the data presented in a journal article, rather than simply reading the author’s words.
6. After taking this class, my ability to think critically about a journal article has improved.
7. After taking this class, I am more likely to think about the limitations of data presented in a journal article.
8. After taking this class, when I read a journal article, I am more likely to think of additional scientific questions.
9. After taking this class my ability to design an experiment to answer a scientific question has improved.
10. After taking this class, I think more critically about the scientific claims I see in the media.

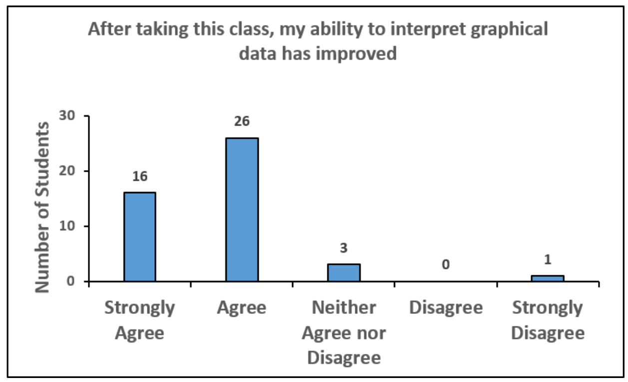
SURVEY SUMMARY

Students were surveyed at the end of the spring and summer 2017 semesters using in-class clicker responses. Data from the two surveys are pooled in the following graphs. Overall, the results were very positive, with students recognizing the importance of understanding how to interpret graphical data, and thinking their ability to do so had improved. Similarly, they reported their ability to think critically about journal articles. Students generally reported they were more likely to think of additional scientific questions and would be better able to design an experiment to answer those questions. Finally, they felt able to apply these skills to thinking critically about scientific claims made in the media

INTERPRETING GRAPHICAL DATA

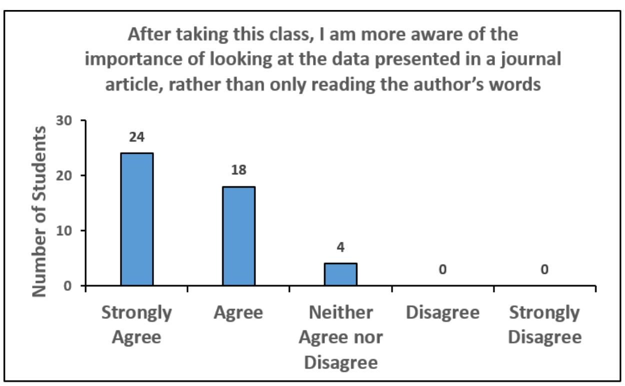
Students overwhelmingly agreed that it is important for undergraduate students majoring in either neuroscience or psychology to be able to interpret graphical data, and generally felt that their ability to do so had improved after taking this class. Numbers above each bar represent the number of respondents.

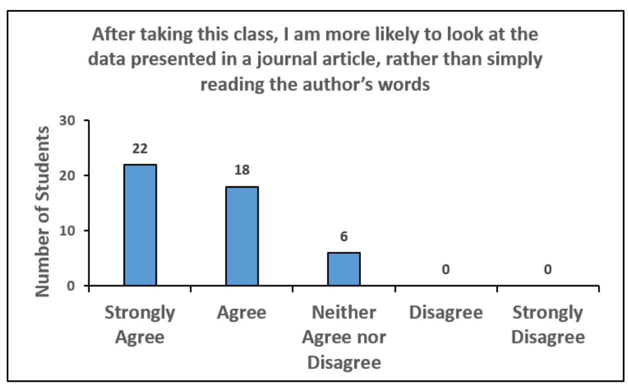


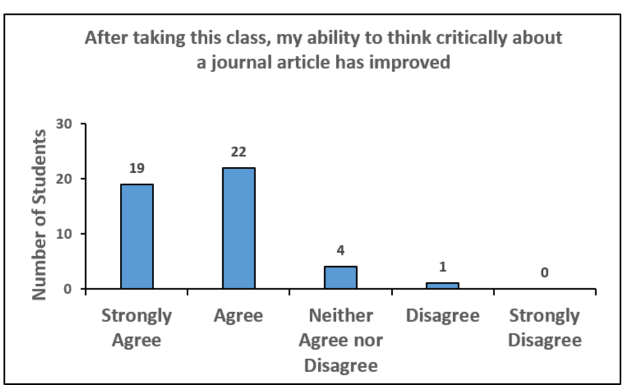


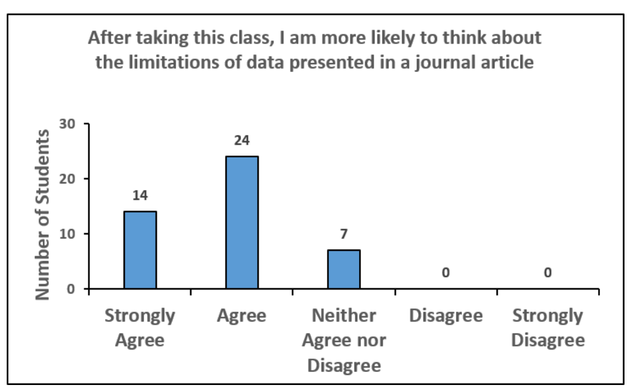
CRITICAL THINKING ABOUT JOURNAL ARTICLE DATA

In general, students responded that they were more likely to look at the data presented in an article and critically think about that data, including recognizing limitations of the data, after taking this class.



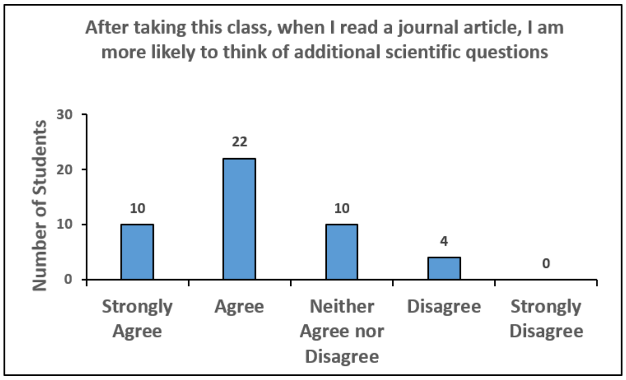


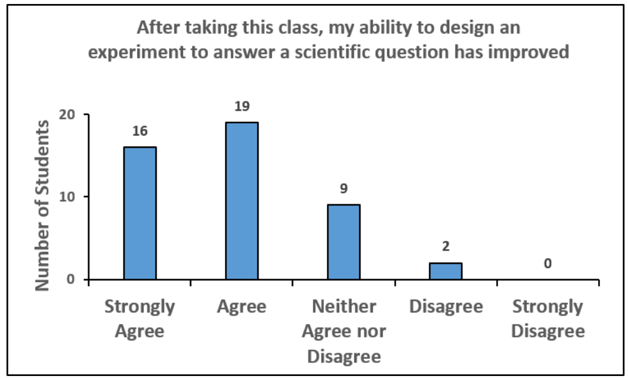




THINKING ABOUT THE NEXT STEPS

It was gratifying to see that students were more likely to ask additional scientific questions and generally felt better equipped to design experiments to answer those questions after taking this class.





APPLYING WHAT'S BEEN LEARNED TO THE REAL WORLD

Although not a specific focus so far, students felt they were better able to critically think about scientific claims made in the media. In future semesters I would like to explore this further, where we look into a current claim about stress and think critically about the data that supports or refutes that claim.