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# ARTICLE
# Using Equivalence-Based Instruction to Increase Efficiency in Teaching Neuroanatomy

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A goal of all instruction is to efficiently allocate time spent teaching -- balancing redundancy that enhances learning with redundancy that is irrelevant to increasing student understanding. Efficient allocation of time allows the instructor to present additional material and go into more detail about the information being presented. Here we borrow laboratory research on concept formation and apply these formal principles in teaching introductory neuroanatomy within a lecture course on Behavioral Neuroscience. Concept formation is taught by pairing multiple stimuli, for instance brain name, location, and function, in such a way that novel associations within a category emerge without direct training. This study demonstrates that careful selection of associations by the instructor can encourage the spontaneous emergence of novel associations within a concept or category, thereby increasing efficiency of teaching and by extension, the depth of material that can be taught.

*Key words: equivalence classes; instruction; lecture; neuroanatomy*

Learning neuroanatomy often consists of associating various characteristics of brain structures such as the name of the region; the location of the brain region using a diagram, model, or tissue; and the functions associated with that brain region**.** Various characteristics of a single element can be conceptualized as a stimulus class, or concept; and associations among stimuli within a class can be taught using equivalence-based instruction (EBI). EBI involves teaching how physically disparate stimuli (e.g., a brain picture and name of brain structure) are functionally equivalent, or interchangeable. Behavioral theory underlying EBI is drawn from mathematical set theory: If A=B and B=C, then A=C (Sidman, 1994). From an instructional standpoint, letters A, B, and C can be substituted with the location (A), name (B), and function (C) of an anatomical structure, such that teaching the location-name relation (A→B) and name-function relation (B→C) should result in the emergence of location-function (A→C) relations without direct training.

This paradigm uses specific language to categorize relations. After teaching that A goes with B, relating B back to A is called symmetry. After learning two relations, like A goes with B and B goes with C, relating the A to C stimulus is called transitivity, and relating C back to A is called equivalence. The paradigm has previously been verified under tightly controlled conditions, in which instruction is provided via computer, for algebraic and trigonometry concepts (Ninness et al., 2006, 2009) and statistics concepts (Fields et al., 2009; Fienup and Critchfield, 2010, 2011).

EBI has also been applied to teaching brain anatomy concepts**.** In a laboratory study, Fienup et al. (2010) taught undergraduate students information about the four brain lobes (frontal, occipital, parietal, and temporal). Participants were first taught to choose two different functions in the presence of lobe names. Participants were then taught to choose a picture of the location and a statement about the behavioral outcome of damage to this region in the presence of the lobe names. Overall, participants were taught four relations (name → function 1, name → function 2, name → picture, name → result of damage) for each of four brain lobes. Teaching these 16 relations resulted in an additional 64 spontaneous untaught relations (a total of 80). Participants were able to interchange all of the stimuli in novel ways not formally taught. This research highlights the efficiency of teaching that can result from carefully planning what is necessary to teach and what is likely to emerge without direct training. Teaching overlapping relations (e.g., name related to all other characteristics) resulted in learning that far exceeded what was formally taught.

Whereas laboratory research demonstrates the efficacy of this teaching strategy, the transportability of EBI to natural instructional settings has not yet been fully established. There are two examples of this research that were conducted with students enrolled in a course, learning course-related content (Critchfield and Fienup, 2010; Fienup and Critchfield, 2011); however, besides participant selection, these studies were essentially laboratory studies that took place in highly controlled environments, limited in distraction, and not in the context of the normal demands, stressors, and motivators that are part of an academic course (Rehfeldt, 2011). In other words, while these studies demonstrate that EBI can enhance efficiency in achieving complex concepts, it does not demonstrate that comparable outcomes will occur when embedded in the ongoing lecture practices of a college course. In fact, it is not always the case that successful interventions maintain effects when applied under more naturalistic conditions (Schoenwald and Hoagwood, 2001).

The goal of the current study is to determine whether EBI is effective in teaching neuroanatomy in a large classroom setting (*n*=93 undergraduates) in the context of an introductory level course in Behavioral Neuroscience. We focused on the following basic neuroanatomical information: recognition of the location of a brain region on a diagram (A), the name of the region (B), and the function of the region (C). First, we asked whether there was a difference in outcome of a multiple choice test when the question provided the region name (B) and the students were required to identify the function (C) as opposed to when the question provided the function (C) and the student was required to identify the region name (B). In other words, does teaching B→C give rise to the symmetrical C→B relation? Second, we asked whether explicit teaching of an association between brain location and name (A→B) and brain name and function (B→C) resulted in the emergence of transitive responding (A→C). We also determined whether explicit teaching of A→C improved the performance for this relation over not teaching the association. The last research question specifically assessed teaching efficiency: Whether an instructor should teach all relations or whether some relations can be expected to emerge without direct training.

## MATERIALS & METHODS

***Overview.*** Prior to the study, fourteen brain regions were identified for which location on a diagram (term A), name (term B), and function (term C) were regularly taught and tested within the course (Table 1). Fourteen A→B and B→C conditional relations were then explicitly taught throughout three lectures using PowerPoint© slides. For seven of these 14 regions, the A→C transitive relation was also explicitly taught (last column of Table 1). The relations taught in lecture were also provided on study guides, which, along with the PowerPoint© lectures, were available to the students on the first day of class. All students queried reported studying from the study guides and PowerPoint© presentations prior to the test.

On the exam, all of the directly-taught relations were assessed as well as two relations that, based on an EBI paradigm, should emerge in the absence of direct training. The emergent relations were the symmetrical relations "Does C→B?" and transitive relations "Does A→C?".

***Students.*** Ninety-three undergraduates were enrolled in a semester-long, introductory level Behavioral Neuroscience course that met once per week for a 3-hour lecture. The class included freshmen through seniors, 63 females and 30 males, and consisted predominantly of Psychology majors (56.6%), followed by undeclared majors (23%), Neuroscience Majors (5.7%), Biology Majors (3.4%), and other (11.3%). The prerequisite for the course was Psychology 101, Introduction to Psychology.

***Stimuli.*** Teaching and testing stimuli involved 14 brain regions and the following characteristics: A) brain location on a diagram, B) the name of the brain region, and C) a particular function of the brain region (Table 1). A→B and B→C relations were taught for all regions. A→C was explicitly taught for seven of the 14 regions, identified in Table 1, last column.

Because the study was embedded within an existing course, we did not change the course material in order to test for specific emergent relations. We selected three lecture topics to use as the basis for the experiment: Emotion, Brain Rhythms, and Memory Systems. The lectures corresponded to the text *Neuroscience: Exploring the Brain* (Bear et al., 2007) chapters 18, 19, and 24, respectively. Our criteria for selecting brain location-name-function relations used in this study were: 1) those that students specifically had demonstrated difficultly with in previous semesters, and 2) those that students were unlikely to know already from past courses or general knowledge. For instance, a substantial component of the lecture on Memory Systems is devoted to understanding the role of the hippocampus in memory formation: in hippocampal-dependent types of learning, in spatial memory (including a discussion of place cells), and in relational memory. Given the emphasis on these structure-function relations in class, the majority of students in past semesters were successful in answering exam questions about the roles of the hippocampus in learning and memory. Therefore, we excluded these relations from the present study anticipating a ceiling effect.

Instead, for the hippocampus, we targeted a topic that was less well known, but nonetheless was normally covered in the Emotion lecture of the course: the brain regions and functions of the Papez Circuit, as presented by Bear et al., (2007, see also Shah et al., 2012). In the text, the Papez Circuit is shown as a schematic diagram (boxes and arrows) and also in a brain diagram along with a simple emotion-related function associated with each region. The Papez Circuit diagram was taught in the context of discussing whether there was more anatomical evidence for the Cannon-Bard model of emotion or the James-Lange model. Papez proposed that the hippocampus was involved in emotion because it is one of the central targets of rabies infection, resulting in hyperemotional responses and expressions of fear and aggression (Bear et al., 2007; see also Stein et al., 2010). We chose to include this relation in the EBI study, within the historical context of Papez's proposition. Two other regions of the Papez Circuit were also used: the neocortex and the anterior nuclei of the thalamus. Regions of the neocortex that are interconnected with the cingulate cortex are described by Bear et al., (2007) as providing "emotional coloring" of emotional experiences (see also Mériau et al., 2006). We discussed in lecture how cognition and emotion may reciprocally influence each other. Thus, we selected "enriches and fine tunes emotional experience" modified from Bear et al. (2007) as the particular function of the neocortex that we tested with EBI. Papez also suggested that the anterior thalamus contributed to emotional expression, based largely on anatomical connections within Papez's Circuit (review in Armstrong, 1990). Case studies report that lesions of the anterior nucleus of the thalamus lead to emotional disorders such as spontaneous laughing and crying (presented in Bear et al., 2007). In keeping with the text, the description of the Papez neural pathway was followed by a discussion of criticisms of the models of both the Papez Circuit and the limbic system in describing a single "emotional system."

In selecting brain structure-function relations presented within the Memory Systems lecture and text chapter, past semesters have demonstrated that it was more difficult for students to learn brain regions outside the medial temporal lobe that function in declarative memory formation, than to learn associations between memory and temporal lobe regions as noted above. For this reason, we selected the stimuli of the anterior and dorsomedial nuclei of the thalamus and the mammillary bodies and their functions in declarative memory formation (e.g., Mitchell and Dalrymple-Alford, 2006). In the lecture, the case study of "N.A." was used as an illustration. This patient was speared through the left dorsomedial thalamus while fencing and suffered anterograde amnesia (Squire and Moore, 1979; Pinel, 1993). To test the EBI strategy, we used only the term "thalamus" in pairing with the role in memory formation, rather than the specific nuclei, because the specific names of the anterior and dorsomedial nuclei were not normally taught or tested in association with memory in this introductory level class.

The mammillary bodies of the diencephalon and the pathway of the fornix contribute to declarative memory formation and damage to the mammillary bodies can be caused by extreme thiamine deficiency as occurs in Wernicke-Korsakoff syndrome, resulting in anterograde amnesia (Pinel, 1993).

Likewise, other brain region functions shown here as stimuli were used in the context of assessing the success of EBI. For instance, the striatum is presented here in the context of Memory Systems, and other functions of the striatum taught in the course are not listed in the table and were not included in the EBI evaluation. Carefully controlled teaching presentations of these particular relations between brain location, name, and associated function allowed us to increase the likelihood that the emergent relations we observed in testing did not arise from exposure to the non-taught relations in other contexts outside of the course or in other areas throughout the course.

| | **Brain location Diagram (A)** | **Name (B)** | **Function (C)** | **Topic** | **A→ C Taught** |
|---|---|---|---|---|---|
| 1 | Coronal | Striatum | Procedural memory | Memory | Yes |
| 2 | External lateral surface | Inferotemporal cortex | Visual memory for object discrimination | Memory | No |
| 3 | Sagittal section | Amygdala | Conditioned fear learning | Memory | No |
| 4 | Midsagittal section | Mammillary body | Declarative long term memory formation | Memory | No |
| 5 | Midsagittal section | Thalamus | Declarative long term memory formation | Memory | Yes |
| 6 | Midsagittal section | Fornix | Axon fibers functioning in pathway for declarative long term memory formation | Memory | Yes |
| 7 | External lateral surface | Prefrontal cortex | Working memory | Memory | No |
| 8 | External lateral surface | Lateral intraparietal cortex (lateral intraparietal sulcus) | Working memory specifically for directing eye movements | Memory | No |
| 9 | Midsagittal section | Suprachiasmatic nucleus | Biological "clock" generating some circadian rhythms | Rhythms | No |
| 10 | Midsagittal section | Hypothalamus | Directs emotional expression | Emotion | Yes |
| 11 | Midsagittal section | Neocortex | Enriches and fine tunes emotional experience | Emotion | Yes |
| 12 | Midsagittal section | Cingulate cortex | Necessary for emotional experience | Emotion | Yes |
| 13 | Midsagittal section | Anterior nucleus of thalamus | Lesions lead to emotional disorders such as spontaneous laughing and crying | Emotion | No |
| 14 | Sagittal section | Hippocampus | Disease infection leads to hyperemotional expression | Emotion | Yes |

Note. Stimuli are presented from top to bottom in the order in which they appeared on the exam.

*Table 1*. Learning stimuli.

***Testing.*** Two test sections were administered sequentially in one sitting: Part 1, which had two versions, and Part 2, which was identical for all students. All questions were multiple choice (five answer-options). Part 1 (72 questions) was completed and turned in before beginning Part 2 (14 questions). All students completed the exam in the three-hour allotted time. Therefore, speed of response was not a component of the assessment.

Part 1 examined two outcomes. First, we assessed the relations that were explicitly taught in class: A→B (14 questions, brain regions 1-14 shown in Table 1) and B→C (seven pairs in version 1 and seven different B→C pairs in version 2, 14 pairs total). Questions testing A→B relations provided a diagram with the anatomical region highlighted (A) and five potential region names (B). Questions examining B→C relations provided the brain name (B) in the question and functions (C) were provided as choices. For instance, one B→C question asked: If the striatum is damaged, this will impair the ability to a) direct eye movements to a visual cue that is no longer present, b) associate a fearful stimulus with a certain location, c) learn a motor behavior used in forming a procedural memory, d) learn to navigate a new town, e) remember a phone number while dialing. The correct answer is c. Correct responses to both A→B and B→C questions for a given brain region were the criteria for determining whether to include an individual student's response to the non-taught transitive test in Part 2: Does A→C?

Part 1 also tested the non-taught symmetrical relations "Does C→B?". For example, the question C→B (matched to the B→C example above), was: Learning a motor behavior used in forming a procedural memory requires the: a) lateral intraparietal cortex, b) amygdala, c) striatum, d) hippocampus, e) prefrontal cortex. The correct answer is c.

The two versions of Part 1 differed in whether a given brain region was presented as B→C or C→B. Across both versions, all 14 brain regions were presented in both formats. In version 1, the B→C format was used for the odd numbered brain regions in Table 1 (n=7) and C→B was used for the even numbered brain regions (n=7). In version 2, the formats were reversed for the respective brain regions. This ensured that question formats were roughly evenly distributed across the lecture topics. To determine whether students demonstrated non-taught symmetry, we compared the mean percentage of correct answers to B→C and C→B, matched to brain region and function. This was a between-subject analysis because each student received only one question relating name to function (in one of the two formats) for each brain region. If symmetrical relations emerged, we would expect no difference in performance between B→C and C→B questions.

Test Part 2 was used to assess the non-taught transitive relation "Does A→C?". Part 2 consisted of a series of diagrams with 14 brain regions highlighted, one per question. Each question had five choice options for the function of the region, i.e., A (diagram) → C (function). Seven of the brain location-function pairs had been explicitly taught in class, seven had not been taught.

For transitive relations that had not been taught, we assessed whether the number of correct responses to A→C differed from chance to determine whether A→C equivalence occurs in the absence of explicit teaching.

Next, we compared the numbers of correct responses between these two sets of A→ C questions (taught and non-taught) to determine whether explicitly teaching A→C improves performance. As noted above, responses to A→C questions were noted as correct or incorrect only for students who had correct answers to A→B and B→C questions for the corresponding brain region. The criterion was put in place because previous laboratory research suggests that without mastery of these relations one would not expect A→C relations to emerge.

***Statistics.*** We used a paired *t*-test to compare percentage correct answers for B→C and the complementary C→B (matched to brain region and function, between students). Of the A→C pairs that met criteria (A→B and B→C were mastered) we compared the numbers of correct answers and incorrect answers for the taught and non-taught A→C pairs using a Chi Squared Test. We also determined whether the non-taught A→C and C→B pairs were answered correctly significantly more than chance using a binomial test. We report means ± SEM.

## RESULTS

There was no difference in mean scores between students who took Part 1 version 1 (n=47, mean=72.8% ± 2.174, range 43-97%) and students who took Part 1 version 2 (n=46, mean=71.9% ± 2.975, range 41-98%) (t-test, $t$=1.19, 2-tailed $p$=0.261), demonstrating that both versions were of similar overall difficulty. All students took the same test for Part 2 (n=93, mean=71.39% ± 31.860, range=41-100%).

The 14 explicitly taught B→C questions were then graded for each student independent of the rest of the exam questions. On these questions, fewer correct responses were given to C→B questions compared with the respective B→C questions for the same brain regions (Figure 1, paired *t*-test on numbers (not percentages) of correct answers, $t$=3.420, $p$=0.008). However, C→B questions were answered correctly significantly more than the chance value of 20% (binomial, $p<0.05$).

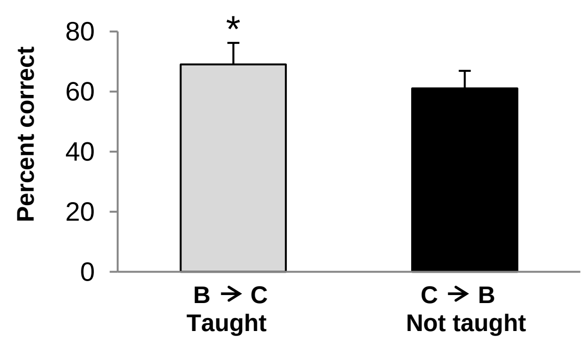


*Figure 1.* Significantly higher scores were seen in response to questions in which the brain region (term B) was part of the question and brain function (term C) was one of five answer choices (B→C, range of correct responses across students= 36%-100%) than in questions with the reverse format (C→ B, range of correct responses = 25%-85%). B→C relations were explicitly taught whereas C→B relations were not stated in class. The same brain region names and functions were tested in both format versions. Shown are means + SEM.

For each student we then identified the brain regions for which they correctly answered both A→B and B→C questions relating to that region. For these regions only, we calculated the number of A→C questions that were answered correctly. This resulted in a total of 636 A→C pairs across all students' exams (range 2-14 qualifying A→C questions per student). Answers to A→C pairs were not further divided into within-student or within-topic levels. We grouped all A→C questions that were explicitly taught across students and topics and separately grouped all A→C questions that were not explicitly taught. We found that A→C performance for non-taught brain relations was

83.33%, significantly better than the chance value of 20%, binomial test, *p*<0.001, p=.2, q=.8, Figure 2), demonstrating the emergence of A→C equivalence.

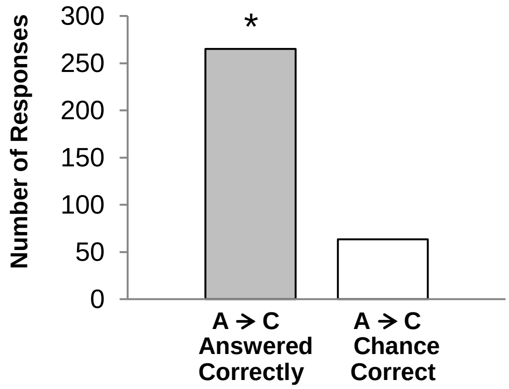


*Figure 2.* For seven brain regions, the association between brain location (term A) and brain function (term C) was not taught in class or presented in the study guides, but was tested on the exam. The A→C format provided a diagram of the brain region (A) in the question and required students to identify the brain function (C). For each student, we calculated scores only for the non-taught A→C relations for which A→B and B→C questions were answered correctly. The number of correct answers to these novel A→C questions was significantly greater than chance correct. Shown are the total numbers (not means) of correct and chance values for all A→C questions in the exam pooled across students. This demonstrates spontaneous emergence of transitive equivalence between the pictorial representation of a brain region and the function of the region.

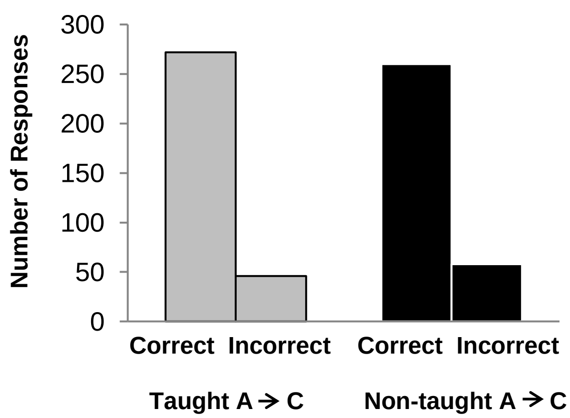


*Figure 3.* For each student, we computed transitive A→C results only for those brain regions for which A→ B and B→ C relations were answered correctly. We then compared the numbers of correct and incorrect answers to A→C questions when A→C had been explicitly taught (gray bars) with those for which A→C relations were not taught (black bars) and found no difference in the distribution of correct and incorrect answers. Shown are the total numbers of correct and incorrect responses, not means.

We next asked whether teaching the A→C equivalence improved performance above that which emerged spontaneously. For the 318 explicitly taught A→C pairs, 272 (85.53%) were answered correctly and 46 (14.47%) answered incorrectly. For the 318 non-taught A→C pairs, 260 were answered correctly (81. 76%) and 58 (18.24%) were answered incorrectly (Figure 3). There was no difference in distribution of correct and incorrect responses between equivalence pairs that were taught and those that were not ($\chi^2$=0.27, df =1, *p*=0.603). Therefore, teaching the A→C equivalence between brain location on a diagram and function of the region did not improve performance on the exam.

## DISCUSSION

This study reports evidence of the transportability of EBI to a natural classroom environment. Previous research using EBI has been conducted under tightly controlled conditions and results have suggested that this paradigm may have implications for more traditional teaching practices (e.g., Fienup et al., 2010). The current study verifies the utility of the paradigm in designing college-level lecture instruction of neuroanatomy.

We found successful use of EBI with A→C transitive relations. Students received direct training on seven transitive relations and no training on seven others. Of the transitive relations not directly taught, students scored higher than chance responding. Comparing taught to non-taught transitive relations, students responded equally as well. Therefore, direct teaching of A→C transitive relations was unnecessary to promote student learning. Overall, these results support the notion that the EBI paradigm can be used as a model for planning which relations to teach explicitly and which are likely to emerge without direct training. The implications are that instructors can more efficiently plan what is taught and use time saved to increase the amount of information covered in a course.

Functional neuroanatomy in this course has historically been taught without regard to balancing the A→B→C information for all brain regions covered in the content. The locations of brain regions are normally shown on diagrams while introducing the name of the region (A→B and B→A). The name is associated with the function in a strict B→C association. We have only recently begun to explicitly teach A→C, by showing a diagram and questioning the class "what does this region do?" In part, this was begun in a deliberate effort by the instructor to better engrain the material by creating more associations or "links" within brain region sets or categories. However, the A→C teaching was not systematic and was not presented for every brain region. The utility of teaching A→C, and the question of whether to comprehensively teach all A→B, B→C, A→C relations prompted this study. The results suggest it may not be necessary.

The majority of EBI research has been conducted in laboratory settings using volunteer participants. A few studies have examined the utility of this paradigm with students enrolled in a course, learning course-related material; however, the EBI was separated from the actual classroom teaching. For example, Fienup et al. (2011) taught students enrolled in a research methods course about inferential statistics and hypothesis decision making. This study compared the effects of no-instruction, EBI instruction, and the performance of a group of students who learned all possible relations (including formal training on symmetrical, transitive, and equivalence relations).

Similar to the results found here, EBI was as effective as learning all relations, but required less formal training. However, instruction was computer based and conducted in a relatively distraction-free setting.

Because the present study took place within the context of a natural course context, we did not control for student behavior. In computer driven laboratory studies of EBI, participants are not allowed to take notes or "study" – the computer program teaches overlapping relations immediately followed by a test of the whole concept. In the present study, the contribution of student behavior is unknown. Taking notes and studying likely occurred to some degree for each student. In fact, some portion of students may have studied the seven A→C relations that were not directly trained. However, regardless of whether the A→C relations emerged during the test or in the course of studying, test performance demonstrates that an instructor can model teaching behaviors on the EBI paradigm and expect new associations to be demonstrated.

An interesting finding was that there was a significantly greater number of correct responses to B→C than the non-taught symmetrical variant C→B, although C→B answers were correct more often than predicted by chance. The result might be explained by the type of stimuli: names and functions. A recent basic study found that classes of familiar stimuli are more likely to form equivalence classes than unfamiliar stimuli (Fields et al., *in press*). In the current study, brain names may be more familiar than functions; and therefore, it could be that the particular stimuli influence the outcomes. In addition, the direction of training (A→B, B→C v. A→B, A→C) may impact concept formation (Arntzen and Holth, 1997). A number of basic (e.g., Adams et al., 1993; Arntzen and Holth, 1997) and applied (Fienup and Critchfield 2011) studies have shown that full concepts, based on an EBI paradigm, do not always emerge as planned. Research in this area has begun to look at different instructional components that influence the spontaneous formation of new associations (for a review, see Fienup, et al., 2011). According to mathematical set theory, familiarity with stimuli and direction of training should not influence EBI and concept formation, but the data examining these issues point in a different direction. In sum, a number of factors could have influenced the differences in responding to B→C and C→B relations and EBI research has yet to provide an explanation for discrepancies of this sort.

Laboratory studies of EBI have demonstrated that a large number of non-taught equivalence associations may emerge spontaneously as concepts are formed and merged. For instance, Fienup and Critchfield (2010) taught 40 statistics relations and generated 144 total emergent relations, a total of 4.7 times as many relations as had been directly taught. In the present study, although we taught and assessed fewer relations, it is easy to see how additional information can be added as stimuli to anatomical sets thereby increasing the amount of spontaneously emergent equivalences. For instance, we taught brain location on a diagram, region name, and a single function. Additional relevant stimuli could be included such as: multiple functions, a disease or disorder that targets that region (or the disorder resulting from damage to the region), the name of a case study giving rise to our understanding of the region, the neurotransmitter(s) used in that region, projections to/from the region, functional and/or anatomical subdivisions within the region. As the complexity of relations increases, so does the number of expected emergent relations, thus increasing efficiency in teaching.

Set formation in Neuroscience instruction also need not be restricted to neuroanatomy. For instance, a set for understanding how sound intensity is encoded in action potential firing may include: increasing sound volume → increased displacement of the oval window → increased basilar membrane wave amplitude → increased bending of hair cell cilia → increased depolarization → higher rate of action potentials. Here we have A→B→C→D→E→F. As in Fienup and Critchfield (2010) teaching targeted relations would be expected to result in multiple emergent relations: e.g., increased bending of hair cell cilia results in a higher rate of action potentials (D→F). Use of EBI requires that the instructor identify the information belonging to a set ahead of the lecture, determine which relationships to teach, and emphasize those pairs in class and on any of the presentation materials such as slides, study guides, and test question banks.

To our knowledge the current study is the first to use EBI within the natural teaching and testing context of an undergraduate course. These results demonstrate that EBI may be a valuable strategy to focus teaching time on carefully selected associations between elements of a conceptual class in order to encourage larger concept formation. In particular, EBI may be particularly valuable in large classes in which instructors do not receive individual feedback on whether students master all individual associations taught. Therefore, by balancing redundancy in teaching relations among stimuli within a set with efficiency of not teaching all associations, instructors may aim to maximize the emergence of complete concepts while maintaining efficiency in time allocation.

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