Summary of Tiemann & Markle's Approach to Concept Learning

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What is a Concept?

It is often difficult to get people to agree upon what a concept is. While most of us have little trouble discussing concepts, when it comes to pinning down a definition, things start to become difficult. Tiemann and Markle talk of a concept as a set of "things" that belong together. From a more behavioral perspective, a concept is equivalent to a stimulus class, that is, a group of stimuli that are treated as belonging to the same group (they all evoke a common response) due to some common property. Thus, conceptual learning can be viewed as a type of generalization and discrimination learning with stimulus classes. So, we say an individual has a concept when their behavior generalizes within the stimulus class and their behavior discriminates between stimulus classes. It is easier to speak of a concept not as something inside a person's head, but rather as a certain pattern of behavior (conceptual behavior).

Conceptual Learning

Concept learning is essentially discrimination and generalization training utilizing stimulus classes. Isolating the variables that determine whether or not something belongs within a stimulus class is often very difficult, even from people who are very accurate in their classifications. For example, people usually have no difficulty in deciding whether or not a stimulus is "human". However, if asked for the criteria (i.e., variables controlling their verbal behavior) they used when deciding whether or not the stimulus was "human", people fumble around and realize they can't verbalize all the relevant discriminative stimuli. They know how to apply the rules for the concept, even if they can't state what those rules are. For most stimuli you are asked to label, you don't pause and try to remember the definition (there are exceptions, particularly in academics), you just simply provide the name (i.e. tacts and intraverbals).

Conceptual learning involves more than simply providing definitions. For example, you could memorize that a response is “the neurally innervated action of an organism’s effector.” Even if you spit this definition back out word for word on an exam, it still has not demonstrated that you understand the concept (although rote memorization of definitions may not be a bad starting place, especially if the definition functions like a checklist or job aid). To demonstrate understanding, you have to correctly identify both examples (generalize) and nonexamples (discriminate). Furthermore, you have to classify multiple examples and nonexamples, both novel and familiar.

Systematic Approach to Selecting Examples and Nonexamples

When teaching a new concept, you could randomly choose a bunch of examples and nonexamples and teach from those. If you wanted to teach the classical music of Beethoven, you could utilize multiple Beethoven songs as well as songs from jazz, metal, and rap. Have you chosen the best examples and nonexamples to demonstrate accurate conceptual stimulus control? What about choosing a nonexample of the classical music of Mozart? The sounds of jazz, metal, and rap are very distinct from Beethoven’s music. Mozart’s music is a better nonexample than Miles Davis’ music for demonstrating that one understands the difference between Beethoven’s music and non-Beethoven’s music. Some nonexamples provide better evidence of discrimination than other nonexamples. You’ll also find that not all examples are equally efficient in demonstrating accurate generalization within a concept. So, how do you determine how to select your examples and nonexamples? Tiemann and Markle recommend using what they call the Prototype Approach.

Critical Attributes

The Prototype Approach is a strategy that begins with identifying a prototype. For example, if you wanted to analyze the concept of "bicycle", you'd first imagine the most generic, prototypical bicycle you can imagine. Next, you analyze the various features of your bicycle, and try to remove or alter those features to discover what's essential and what is not for evoking the response of "bicycle". Take the bicycle you're imagining and remove one of the wheels. Is it still a bicycle? Nope, now it is a unicycle. Trying adding a third wheel. Again, now it is no longer a bicycle, but a tricycle instead (sidestepping the issue of training wheels). Get rid all the wheels and you have an "exercise bike" (although there may be some debate, most would not call this a bicycle). So, having two wheels is an essential element to the concept of bicycle. It is what we'd call a critical attribute. To be more precise, a critical attribute is a feature that every stimulus within the conceptual class has, and if altered, causes the stimulus to be excluded from the conceptual class. So, every single stimulus we would call a "bicycle" will have two wheels. As soon as you change the number of wheels, the stimulus no longer qualifies as a "bicycle" and becomes something else instead. Most concepts will have multiple critical attributes. Spend some time thinking about it and you can identify other essential dimensions. Motorcycles and mopeds are nonexamples of bicycles, thus illustrating the importance of bicycles being human-powered (non-gas, non-electrical). How important are the foot pedals on our prototype? Imagine your prototypical bicycle without foot pedals. What's left is a scooter, which isn't considered a bicycle. So, foot pedals seem like a critical variable. Every single stimulus we would label as bicycle has these critical attributes and any stimulus lacking one of those attributes is not a bicycle.

Variable Attributes

Of course, there are some dimensions of a bicycle that can be changed without excluding it from the conceptual class known as "bicycle". For example, you can change the color of the bicycle without changing the fact it is called a bicycle. Thus, a specific color is a non-essential feature of a bicycle. More specifically, it is what we would call a variable attribute: A feature of an example, that when changed, results in a new example that also belongs in the same conceptual stimulus class. If your prototypical bicycle had been red, and you change the color to blue, you now have yet another example of a bicycle. Size is another variable attribute. Both small bicycles for children and large bicycles for adults qualify as bicycles. Number of seats can also vary. Although most bicycles have one seat, some will have more than one (i.e. twin bicycles). The type of seat is a variable attribute. Bicycles can have a typical saddle-type seat or a reclined seat such as seen on recumbent bicycles. Although not typically seen, it is easy to imagine a bicycle without a seat. It probably wouldn’t be comfortable, but most people would still label it as a bicycle. The type of handlebar is another variable attribute. Handlebars can be straight or curved without changing the “bicycle-ness” of the stimulus. Many recumbent bicycles feature handlebars on the side of the seats, but are still considered bicycles.

Potentially, you can identify a rather large number of variable attributes. For example, the number of spokes can vary, the typical storage locations, the length of the chain, etc. However, you don't want to come up with every single possible variable attribute. Instead, just pick the attributes with the most salient properties. How do you determine which attributes are the most salient? Initially, you’d just use your best judgment. However, you must always field test your instruction with learners from your intended audience. If your learners are classifying examples as nonexamples due to some irrelevant feature, this suggests that you need to expand your list of variable attributes to directly address that irrelevant feature. Markle liked to state that it was impossible to tell if an instructional program would work just by looking at it. You must repeatedly test your program with the full range of learners from your intended audience.

So, for our bicycle analysis, we can list these as the critical attributes:

1. Two wheels

2. Completely person-powered

3. Foot pedals

Let's go with these variable attributes (we may need to refine later based on learner errors):

1. Color (red, blue, yellow, green)

2. Size (small, large)

3. Type of seat (saddle, recline)

4. Type of handlebar (straight, curved, side)

Minimum Rational Set of Close-In Nonexamples

Now that we have critical and variable attributes defined, we can introduce a new term: close-in nonexample. A close-in nonexample is a nonexample that lacks one and only one critical attribute. Close-in nonexamples are the best stimuli to choose when trying to teach discriminations. For example, a moped is a close-in nonexample for the concept of bicycle. A moped has two wheels and pedals. The only critical attribute that is missing is being person-powered. The “closeness” of a moped is what makes it a much better nonexample for teaching and testing the concept of bicycle than, say, a car, apple, fish, etc. This is also why Mozart was a much better nonexample than Miles Davis for teaching the concept of Beethoven’s music. For each critical attribute, you can develop a close-in nonexample. This relates to the idea of the Minimum Rational Set of Close-In Nonexamples. To create this set, you need to have one close-in nonexample for each critical attribute. Since the concept of bicycle has three critical attributes, the Minimum Rational Set of Close-In Nonexamples would require a set of three stimuli.

1- Stimulus with two wheels, foot pedals, but not person-powered (i.e. moped)

2- Stimulus with two wheels, person-powered, but no foot pedals (i.e. handcycle or scooter)

3- Stimulus with foot pedals, person-powered, but not two-wheeled (i.e. unicycle or tricycle)

Human invention may create the need to come up with new critical attributes. Imagine if they invented a pedal-operated, motorless Segway. Although this hypothetical transportation would have two wheels, be person-powered, and have foot pedals, most people probably wouldn't call it a bicycle. Why? Having parallel wheels seems to deviate from the bicycle concept. If such an invention is created, then "tandem wheels" (i.e. one in front of the other) would have to be added to the list of critical attributes. Rickshaws (Google it) come close to being motorless Segways, but also lack the critical attribute of foot pedals (so the tandem requirement still is not necessary). For now our list of three critical attributes seems to be complete.

Minimum Rational Set of Examples

Your set of close-in nonexamples helps teach discriminations to learners so that they can correctly identify *nonexamples*. However, you also want to learners' behavior to generalize, so that the full range of *examples* are also correctly labeled. The Minimum Rational Set of Examples addresses this by varying every dimension on the variable attributes selected. The variable attribute with the most dimensions corresponds to the number of stimuli your Minimum Rational Set of Examples should have. Our variable attribute of color has the most dimensions (four), so our Minimum Rational Set of Examples will have four examples. In the process of constructing this set, you want to make sure that every variable attribute is varied as much as possible. So our examples might look like this:

- A bicycle that is red, small, saddle seated, with straight handlebars
- A bicycle that is blue, large, recline seated, with curved handlebars
- A bicycle that is yellow, small, saddle seated, with side handlebars
- A bicycle that is green, large, recline seated, with straight handlebars

Notice that every single variable attribute has been varied. Of course, we could have come up with even more dimensions for the variable of color (black, white, pink, etc). You do not have to show every single possible dimension for a variable attribute. In fact, it would be an infinite list if we tried to vary every possibility for size. How variable the dimensions need to be will depend on how sophisticated your learners are. Only through empirical testing can you discover if you have too many or too few dimensions.

Divergent Examples and Matched Nonexamples

When teaching concepts, it is often convenient to show pairs of stimuli to help illustrate the range of examples and nonexamples so that learners can compare and contrast features. If you want to show a pair of examples, it is best to have them be divergent. This means that they will differ on every single variable attribute. Here is an example of a divergent pair:

- A bicycle that is red, small, saddle seated, with straight handlebars
- A bicycle that is blue, large, recline seated, with curved handlebars

This is not an example of a divergent pair:

- A bicycle that is yellow, large, saddle seated, with side handlebars
- A bicycle that is green, large, recline seated, with straight handlebars

Notice that on the first pair it is divergent because every single variable attribute differs. The second pair is not divergent because the variable attribute of size does not differ.

If you want to show a pairing of an example and a close-in nonexample, it is most effective to have every single variable attribute match as much as possible. So a matched pair might look like this:

- A bicycle that is red, small, saddle seated, with straight handlebars
- A tricycle that is red, small, saddle seated, with straight handlebars

Testing Conceptual Stimulus Control

All of the preceding information has been devoted to teaching concepts. But what about testing to see if a person understands the concept you've been teaching (i.e., appropriate stimulus control)? You can only test for a concept using novel stimuli, examples and nonexamples that were not used during teaching. Otherwise, it is unclear if the learners are generalizing and discriminating correctly or if they simply got it correct due to rote memorization.

Let's say you wanted to test the concept of "conditioned reflex". This concept has the critical attributes of 1) being learned behavior and 2) being respondent (i.e. consequences irrelevant to probability of the response). You taught this concept with the following stimuli:

- Example of salivating at sight of cake
- Nonexample of startling due to loud noise
- Example of rapid heartbeat at sight of significant other
- Nonexample of saying "please" when asked to "say please"

If you tested the learner by asking if "startling due to loud noise" is a conditioned reflex or not, you would not be testing the concept. Instead, this would only be a test of rote memorization. Asking the learner to classify "salivating at sight of cookies" would also be testing rote memorization. Although it is not exactly the same, it has too much formal similarity to be called truly novel. For the following test stimuli, ask yourself if these items are testing generalization, discrimination, or rote memory:

- Sweating after being asked to give a speech
- Rapid heartbeat at sight of long lost friend
- Coughing to get attention

The sweating item is designed to test for generalization because it is a novel example. The rapid heartbeat item is testing rote memorization because it is not novel. The coughing item is designed to test for discrimination because it is a novel nonexample.

If learners *correctly* identify novel *examples*, they are demonstrating appropriate generalization. If learners *correctly* identify novel *nonexamples*, they are demonstrating appropriate discrimination. If learners *incorrectly* identify novel *examples* (by calling them "nonexamples"), they are demonstrating undergeneralization. If learners *incorrectly* identify novel *nonexamples* (by calling them "examples"), they are demonstrating overgeneralization. Try to classify the following as generalization, discrimination, overgeneralization, or undergeneralization of the concept "conditioned reflex":

Test stimulus	Learner response
1. Shivering after viewing pictures of arctic	"Conditioned reflex"
2. Chattering teeth to get grandma to make hot cocoa	"Conditioned reflex"
3. Sneezing at sight of plastic flower	"Not conditioned reflex"
4. Pressing button to dispense cola	"Not conditioned reflex"

The learner is demonstrating appropriate generalization with the first item and demonstrating appropriate discrimination with the fourth item. However, the learner is incorrect on the second and third items. The learner is overgeneralizing with the second item and undergeneralizing with the third item. If during testing, you find learners often make overgeneralization errors during testing, this suggests you need to teach with more close-in nonexamples. If you find learners often make undergeneralization errors during testing, this suggests you need to teach with more examples. However, this does not mean you want to overload your instruction with too many examples and nonexamples. Doing so would only serve to make your instruction tedious and inefficient (possibly evoking escape behaviors). Only through testing with real learners can we discover the appropriate number.