Null Matching: The Fundamental Observation Process in Science

Scientific knowledge is derived from the replicable sensory experiences of the scientist.

Ultimately, every facet of science, every theory, every fact, depends upon the observations of scientists. An observation is a record of a scientist's sensory experience--what was seen, heard, smelled, tasted, touched, etc. However, only those observations that can be replicated are incorporated into science. By requiring replication, the social endeavor of the process of science assures that knowledge derived using science doesn't reflect just the whims or biases of the researcher.

What does a scientist do to produce observations that are replicable. What does the scientist have to do to convince peers they will be able to redo the work and get comparable observations. Of course, one vital component of the argument is when the scientist publishes work, a complete description of the context of the observations is included. This description is vital and, as you will see during the semester, is an essential component of scientific report writing.

Objective procedures are the basis of reliability.

Providing an accurate description of the procedure for making observations is NOT sufficient in and of itself to assure the observations can be replicated. The process of observation itself must be devised such that as few biases as possible enter into the measurement process.

Let me give you an example of a situation. A physicist notices as a light source is moved away from a reflecting surface (a wall), the surface appears dimmer. How does the brightness of the surface change as the light source is moved closer or further away. If you move the light till it is twice as close, is the surface twice as bright? If you double the distance is it half as bright? Actually, what the physicist wants to know is how the amount of energy falling on the surface changes with distance of the light source. So the question really is, "As I double the distance, does the amount of energy falling on the surface halve ? If I halve the distance, does the received energy double?" Back when physicists were asking this question and providing answers to this question, sophisticated measuring devices did not exist. They couldn't take a light-meter and get a reading. How would you setup the observation process (experiment if you will) to answer this question? Would your observations be replicable? Would they be public?

Well if you don't know (or you do only because you were told), don't feel badly. It has taken humanity a long time to figure out how to obtain reliable knowledge from the natural world. The process of obtaining reliable knowledge from the nature world is the development of the scientific method and scientific procedures.

Null Matching Procedure

> **Adjust a stimulus of known intensity until it exactly matches the appearance of the stimulus of unknown intensity.**

The techniques developed by chemists and physicists over a century ago were based on the principle of "null matching" or "no difference" matches. A solution of ***unknown*** concentration or a light of ***unknown*** energy, or whatever, has its appearance matched exactly by another stimulus over which the scientist has complete control.

Example: how acidic is a particular solution? We'll titrate it. Add a marker substance which has particular colors at particular acidities. Now mix up a solution with acid and alkaline chemicals of known concentrations that exactly matches the color of the unknown solution. Since the colors match, the acidities are identical. The scientist knows the acidity of the standard solution and thereby knows the acidity of the unknown solution.

The only sensory judgment required is to decide whether the two stimuli has the same appearance or not. (Incidentally, the observer also has to know how they differ so the comparison stimulus can be appropriately altered.) The observer is ***NOT*** asked to decide how big a difference there is.

Now that you know what a null match is, how could a physicist decide how the intensity of illumination is affected by distance?

• What the physicist might do is to take two identical surfaces and place them at a 90º angle so they can be illuminated by different light sources. Now the physicist can set up process of measuring how the amount of energy changes.

•Illuminate both screens at IDENTICAL distances with identical light sources BUT use more of them to illuminate one screen. That screen will be brighter.

• Now move the single light source closer or further away until the two screens appear equally bright.

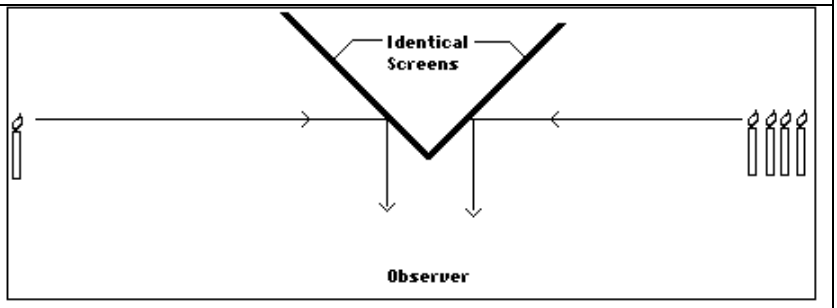
What Is Seen	The Stimulus Situation.
	
	The Observers task is to move the single candle closer or further away from the screen until the two halves of the screen appear equally bright.

Figure 1. How a physicist might answer the question, "How far away does a light source have to be so it looks four times as bright?"

When there is NO DIFFERENCE in the appearance of the two screens, they are illuminated by the same amount of energy. The physicist has used a NULL MATCH--a "no difference in appearance" match--to equate the energies. Null matching technique allowed physicists to discover that illumination varies as the square of the distance. In this example, the single candle will have to be 16 times closer than the 4 candles to produce a surface of equal brightness. Applying this principle means when I double the distance a light source is from a wall, the amount of energy is 1/4 as much; halving the distance increases the energy four-fold.

Single Candle Distance for Null Match	Multiple Candles Distance of 10 feet	Arbitrary Units of Energy Falling on Surface
10 Feet	1 Candle	100
10/4 feet (2.5 feet) Reduce distance by 4 times	2 Candles	200 Energy is doubled
10/16 feet (0.625 feet) Reduce distance by 4 times	4 Candles	400 Energy is doubled Again

The physicist might have used an observation-task which required the light sources be moved until one screen was twice as bright as the other. However, this "doubling" measurement procedure won't answer the question, "Does doubling the brightness also double the amount of energy?"

The Null Matching task is the fundamental observation procedure of science.

As instruments were invented, they were calibrated against null-matching observations. So, if you were to use a light meter you would be indirectly using the results of null-matching procedures of the past. "They" put the numbers on the dial of the light meter to correspond with the results of null matching procedures which used the unaided human eye.

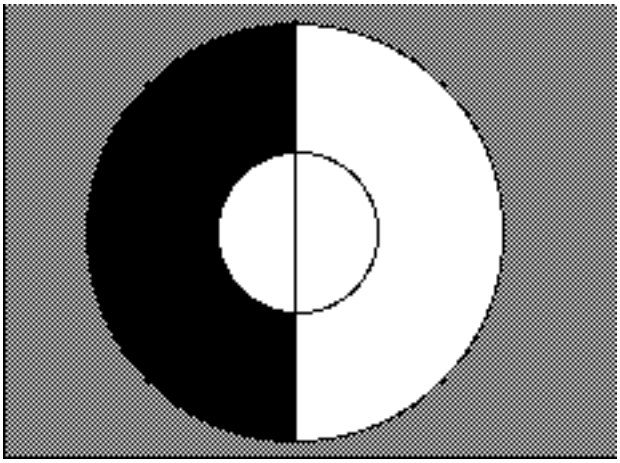
The Method of Adjustment -The Method of Average Error

The first measurement procedures in psychology, the classical psychophysical procedures developed by Gustav Fechner use the null-matching task. The observer is only asked to decide whether two stimuli are the same or different

The "Method of Adjustment" [MOA] (aka "The Method of Average Error") is one of the three classical psychophysical methods developed by Gustav Fechner who worked in the second half of the 19th century.

- The observer is presented with 2 stimuli.
- The observer's task is to adjust one stimulus (the VARIABLE [VAR] or COMPARISON [Co]) until it exactly matches the other (the STANDARD [STD]).
- The aspect of the ***Method of Adjustment*** that is unique to this procedure is the observer is making "no difference" judgments directly. *In the other two methods developed by Fechner, the observer is either determining whether or not a stimulus is detectable or which stimulus is more (or less) intense (but NOT how much more or less).*

Sometimes the MOA is used to investigate the psychological intensity of experiences that cannot be measured any other way. The illustration is such an example. The light reaching your eye from the two halves of the small inner circle is the same. However, as you inspect the figure you will probably realize that the right half of the small circle doesn't look quite as bright as the half surrounded by black. It may not be a big difference, and it is there. This stimulus configuration illustrates the visual phenomenon of simultaneous brightness contrast: areas surrounded by darker surfaces appear lighter; areas surrounded by lighter surfaces appear darker. How different in brightness are the two halves of the smaller circle? Another question that might be asked is, "What stimulus characteristics affect the difference?"



Questions like this are important in understanding how the visual perceptual system functions. Finding answers to these kinds of questions are fundamental to the development of the understanding of vision-- how we know the physical world through the visual sense. The psychophysical procedure, Method of Adjustment, can be used to obtain a number describing the difference in brightness of the two halves of the inner circle. In an experiment to do that, the stimulus figure would be made up of four beams of light in exact registration so they don't overlap. One beam would be the dark outer half-ring; another the light outer half-ring; another the left half-inner circle; and the last the right half inner-circle. The observer would be asked to change the brightness of the right half-inner circle until it matched the other half. The difference in energies needed for a matching appearance would tell how much simultaneous brightness contrast is present in the figure. The observer would make several matches and the average matching stimulus could be used to describe the amount of brightness contrast.

All the examples I 've used are based on visual null matching. Null matches can be based on any sense modality: set two sounds until they are equally loud, etc.

The Magnitude of the Müller-Lyer Illusion Measured with the Method of Adjustment: < --- > vs > --- <

In the experiment implemented in this course, the two halves of the stimulus figure appear different when physically equal because the perceptual system processes the stimulus features in an unexpected manner. Using a human observer to set the two halves of the figure to look equal provides a way of measuring the magnitude of the effect. How different to the two halves have to be for an observer to say they are equal. That is the question you will answer by completing the experiment.

How "Null Matching" can be used to measure attitude.

Goal: Determine how pro-life/pro-choice a person's attitude is on abortion rights.

Procedure: Develop a series of statements from extremely pro-life to extremely pro-choice. Order the items from the most pro-life (or pro-choice) to the most pro-choice (alternatively pro-life). Start with one extreme statement and ask the person if that statement is the same as their attitude on abortion. If it is too extreme (and it

should be to use the methodology), read the next (and less extreme statement). Continue until the participant finds the statement that matches their attitude.

Using the information: You can compare the attitude of two persons by indicating one person's attitude matched the 5th item from the top. The other person's attitude matched the 8th item from the top. Or, measure the attitude of 10 persons, present them with a task/treatment/procedure you suspect might affect the attitude. Then repeat the measurement procedure. Has the typical "null match" statement changed (typical here indicates the modal or median "matching" statement)?

Two Important Terms

Point of Objective Equality (POE): The value of the comparison stimulus that matches the physical measurement of the standard stimulus.

If I measure the length of a line with a ruler and find out it is 10 inches long, then the length of the comparison line that is exactly the same length as the standard line is 10 inches. Whether or not the two lines look equally long is not relevant to the POE.

Two line segments made of hyphens are physically equal: " ----- " vs. " ----- ". The POE is the length of 5 hyphens.

A candle 2 feet away from a wall casts more light on the wall than an identical candle 8 feet away. Yet both candles generate the same amount of radiant energy (total amount of energy). The POE is the number of units of energy each radiates.

Point of Subjective Equality (PSE): The value of the comparison stimulus that looks the same as the standard stimulus.

It will take 16 candles at 8 feet to make the wall look as bright as one candle at 2 feet (4 times the distance means you need 16 times the energy to be equally bright). The PSE for 1 candle at 2 feet is 16 candles at 8 feet. *[Sixteen candles at 8 feet will cast as much light on a square of wall (5 inches on a side for instance) as a single candle at 2 feet away. The single candle is four times as close so it "paints" 4-squared units of energy on the wall.]*

If I add arrowheads to the lines (< ----- > vs > ----- <) then the two lines will not have the same length when they look the same. The PSE might be 6.5 hyphens when the POE is 5 hyphens.

Name: _____ Date: _____

Good Faith Effort: Null Matching Reading

***Remember**: Please prepare two copies--one to turn in and one to keep.*

1. In what way is the statement, "Science is based on the sensory experiences (aka 'observations') of an observer." incomplete?

2. In your own words, describe the "null matching procedure.

3. I know how sweet I like my coffee. So, I add sugar until it is just the "right" sweetness. This example does ***not*** illustrate a null matching procedure? Why doesn't it?

4. Fix two glasses of iced tea. Have someone else sweeten the iced tea to the sweetness they prefer using plain old table sugar. What procedure would you use to sweeten the second glass to the same sweetness using "Equal" (aspartame)?

5. Give an example of a null matching task you've used in everyday life.

6. Assume you cut out a 5-inch circle of construction paper and tape it on the wall at the end of the hallway. Then you walk to the other end of the hall. While there you pick out two nearby circles taped to the wall that "match" (in some manner) the far circle. One of the "matching" circles is 5 inches; the other is 2 inches. Which of the matching circles is the POE? Which is the PSE?