Experimental Inquiry in the Kitchen

I

Miko and her 12-year old brother Jomo bought hot chilly pepper seeds, and planted some under a tree in their backyard. When the chillies were ready to be eaten, Miko was disappointed because they were not hot. Why were the chillies not hot? Jomo's ***hypothesis*** was that the plants were not watered enough. Miko disagreed. Her hypothesis was that the plants didn't get enough sun. They decided to conduct an experiment to find out who was right.

Describe an experiment that would tell us whose hypothesis was right, spelling out what kinds of experimental results would support each of the conclusions in (1)-(4) below.

1. They were both right.
2. They were both wrong.
3. Jomo was right, and Miko was wrong.
4. Miko was right, and Jomo was wrong.

II

There are two hypotheses here, namely,

A. If chilly plants do not have adequate water, the chillies won't be hot.
B. If chilly plants do not have adequate sunlight, the chillies won't be hot.

Each of these hypotheses could either be true or false. So, Miko and Jomo need to conduct two experiments, one to test A, and another to text B.

In hypothesis A, there are two ***variables***, namely, *water* and hotness of *chillies*. Because Miko has hypothesized that it's the water that has the effect on hotness, water is the ***independent variable*** and hotness is the ***dependent variable*** (i.e., the hotness of the chilly depends on the amount of water the plant receives.) To design an experiment to test if this is right, we need two groups of chilly plants that have the same treatment in all respects except the quantity of water they receive. In group 1, for instance, the plants receive adequate amounts of water (the ***control group***). In group 2, the plants receive an inadequate amount of water (the ***test group***). If the chillies from group 1 are consistently hotter than those from group 2, hypothesis A is correct. If not, A is wrong.

Likewise, we test hypothesis B with an experiment in which two groups of chilly plants have the same treatment in all respects except that of sunlight. In the control group (group 3), the plants receive adequate amounts of sunlight, but in the test group (group 4) they receive an inadequate amount of sunlight. If the chillies from group 3 are consistently hotter than those from group 4, hypothesis B is correct. If not, B is wrong.

One way of conceptualizing the combination of the two experiments is to use what is called a "two-by-two matrix":

	Adequate amount of sunlight	Inadequate amount of sunlight
Adequate amount of water	Group 1	Group 3
Inadequate amount of water	Group 2	Group 4

We have four possibilities:

P-1: A is right, B is wrong.
P-2: B is right, A is wrong.
P-3: A and B are both right.
P-4: A and B are both wrong.

For each of the potential results given below, select the conclusion you would make.

Results	*Conclusion*			
groups 1 and 3 yield hotter chillies than groups 2 and 4,	P-1	P-2	P-3	P-4
groups 1 – 4 yield equally non-hot chillies	P-1	P-2	P-3	P-4
groups 1, 2 and 3 yield hotter chillies than group 4	P-1	P-2	P-3	P-4
groups 1 and 2 yield hotter chillies than groups 3 and 4	P-1	P-2	P-3	P-4

Answers:

Expected results	*Conclusion*			
groups 1 and 3 yield hotter chillies than groups 2 and 4,	**P-1**			
groups 1 – 4 yield equally non-hot chillies				**P-4**
groups 1, 2 and 3 yield hotter chillies than group 4			**P-3**	
groups 1 and 2 yield hotter chillies than groups 3 and 4		**P-2**		

IV

What would be your conclusion if groups 2-4 are equally non-hot, and group 1 is hot?

This result shows that it is only when both conditions are met (i.e., if there is adequate sunlight AND adequate water) that the chillies are hot. If the claims that Miko and Jomo make are

Water is the only causal factor (i.e., sunlight is not causal factor)

Sunlight is the only causal factor (i.e., water is not a causal factor)

the result would show that they are both wrong. However, if their claims are

Water is a causal factor (whether or not sunlight is also a causal factor)

Sunlight is a causal factor (whether or not water is also a causal factor)

They are both right.

Learning point: to maximize the benefits from our inquiry, it is important to formulate our hypothesis clearly and precisely.

V

Let us consider another aspect of the problem. Suppose we used a single seed from each of the groups 1-4. Suppose also that the seed we used for group 1 came from a plant that has genes for very hot chillies. If that were the case, our conclusions about the ***correlation*** between hotness of chillies, the amount of sunlight and the amount of water would be wrong, because the variable relevant here is the genes, not the environment. How would you eliminate the effects of this ***confounding variable***? (A confounding variable is a factor other than the independent variable under investigation that can affect the dependent variable.)

One way of eliminating the confounding variable of genes is to select all the seeds from the same packet. However, this may not be sufficient, since there is a possibility that the seed sellers put seeds from different genetic pools in the same packet. What measures would you take to solve this problem?

Congratulations if you said that the safest way to factor out (eliminate?) the effects of genes in our investigation of chillies is to use a sufficiently ***large sample*** of seeds (say, between 30 and fifty), randomly selected from the same batch. Yet another would be to use seeds of chillies from the same plant.

VI

In your design, did you consider the possibility that the nature of the soil might have an effect on the hotness of the chillies? For instance, suppose the soil for A contained nutrients that increased the hotness of the chillies. If that were the case, your conclusion about the relevant correlates of hotness would be unjustified, because the variable relevant here is the soil, not water or sunlight. How would you eliminate the effects of this confounding variable?

Let us suppose that the design of your experiment has taken care to avoid all the potential sources of error and distortion we have looked at so far. After the plants yield chillies, both Jomo and Miko taste them, and they go back to write their reports. In his report, Jomo writes that chillies from groups 1 and 3 are hotter than those from groups 2 and 4. And in her report, Miko writes that chillies from groups 1 and 2 are hotter than those from groups 3 and 4. They are surprised that their findings are contradictory, and conclude that the subjective nature of their tasting the chillies, combined with each researcher's eagerness to support his/her own hypothesis, could have resulted in the differences in the observational reports.

Have you encountered this problem in any of the earlier tasks? Can you design a satisfactory strategy to avoid the problem?