Group name:

Group members:

You are a food scientist for Hershey. The Marketing Department has just come in and told you that Van Halen has boycotted brown MnMs, and they are getting calls to remove Brown MnMs from the package by fans. The Marketing Department does not know what to do, and wants you to see if brown MnMs actually taste different from other colors. If it does, they will have to revise the coating or withdraw the color, costing the company millions of dollars.

**Hypothesis.**

State your hypothesis, and your null hypothesis for this experiment (Please refer to the handout on hypothesis for guidance).

Hypothesis:

*Brown MnMs taste different than other MnMs.*

Null Hypothesis:

*BrownMnMs taste the same as other MnMs.*

Now turn to your classmate, and share your hypothesis with one another. Are they the same? What is the difference? Which more closely, directly and simply relates with the scenario described? Why do you think a hypothesis should be direct and simple?

*Hypothesis should be as simple and direct as possible because this allows it to be more easily tested and proven correct or proven wrong. This allows a new hypothesis to be formed and tested. Thus science advances.*

**Experimental Design**

In your assigned group, work together, discuss and design an experiment to test your hypothesis.

*(Experiments should directly test the hypothesis stated. The results of an experiment should either support the hypothesis, or disprove it. Start with discussing the following questions within your group.)*

*The experiment should be that one of you (the subject) will be asked to eat a number of MnMs.*

What question should the subject be asked after (s)he eats each MnM? Remember, this question should directly test the hypothesis.

*Was the MnM you just ate a brown MnM?*

**Statistical Confidence.**

When planning an experiment, one important step is to identify possible results, and if those results will support or falsify our alternate hypothesis.

What is your expected result if the null hypothesis is correct?

*That 50% of the guesses would be correct.*

What is your expected result if your alternate hypothesis is correct?

*That the number of correct guesses would be higher than 50%. Discussion: What does it mean if it is much lower than 50%?*

How many MnMs should the subject taste during the experiment? Are more MnMs tasted more likely to make you believe the results?

*Intuitively, the more you taste, the more likely to believe the result. But in this exercise, we want to do this mathematically. (Follow instructions on Getting to Statistical Significance on Faculty\_StatSig).*

A subject identified the color of the MnM (brown or not brown) correctly 60%. A second subject, using the same experimental conditions, correctly identifies the color of 80% of the MnMs. Which do you believe more; ie, Of these two results, which one would give you greater confidence that your alternate hypothesis is correct? Why?

*80%. But the information missing here is the sample size. Without that, it is hard to make a prediction if either of these results are statistically significant. Ask student what it would mean if the sample size was 10. What if it was 100? 1000? At what point does 80% become significant? 60%.*

In one experiment, one subject correctly identifies 70% of tasted MnMs.

Does this support your alternate hypothesis?

You decide to repeat the experiment with the same subject again. Now he correctly identifies only 50% of MnMs? Does this make you more or less confident of your results?

Another group in your class now reports that they found that someone in that group correctly identifies 75% of MnMs. Does this make you more or less confident of your results?

*There are two possible sources of difference here. The first is natural variance. What is the spread of the data? If someone just guesses the flavor of the MnMs, will (s)he get 50% correct every time? Or will some be higher and lower than 50%? For an example of spread. The question is if we were to get a result, what are the chances that result is by chance, and we can calculate that below.*

*The second source of difference is reproducibility. Why is it important to be reproducible? Factors might include some experimental error in the first group, but not the second. (Note: IF using the Philosophy of Science sub-teaching unit, this reinforces the idea of objectivity in science; facts independent of time and space and scientist.) One important consideration when faced with different results is which of these experiments are better designed. Which of these results are statistically significant? Which has a larger data set?*

Put all these answers together. What factors determines how much you believe/ are confident that the results from an experiment are *real* and not simply a fluke?

*Deviation from expected (null) results, sample size in each experiment, number of repeats/reproducibility.*

**Experimental Conditions.**

Many different factors can affect the results of an experiment beyond the hypothesis that the experiment is supposed to test. Therefore, it is important to identify factors that might affect your results, and to plan experimental conditions that minimize these factors.

How many of the MnMs tasted should be brown? How does this change the expected result if the null hypothesis is correct?

*Half the MnMs tasted should be brown. If the subject knows that not half of them is brown, (s)he is more likely to guess the uneven number, and therefore, more likely to guess correctly.*

In each experiment, only one subject (one of your group-members) should taste the MnMs, to determine if (s)he can identify the brown MnMs correctly. Why not have each and every group member taste MnMs and combine into one experiment?

*That would complicate the experiment, as each person might have different taste-buds, or different abilities to taste. By using multiple tasters in one experiment, if only some of the tasters can taste the difference between the MnMs, that result will be hidden.*

*Alternatively, if there are multiple experimental repeats (i.e different subjects in each experiment), then results can be compared between subject. If results across subjects agree, this would mean the experiment is validated. However, if experiments do not agree, this might suggest that there are problems with the experimental design, or that there might be some subjects who are able to taste the difference. Further experiment necessary.*

*(Note: There is a large body of literature on science of taste; and it might be interesting to go down this path if you want to talk about sub-population and large number of experiments using multiple subject).*

Should the non-brown MnMs all be one color? Why or why not?

*There are some assumptions that are inherent in any experiment. Here, if you decide to compare brown to non-brown, the assumption is that all other MnMs taste different than Brown MnMs. Furthermore, it would suggest that all other color of MnMs taste the same. However, if you choose only one color, you are ONLY testing if Brown MnMs taste different from that other color that you chose, and does not test other colors.*

*(Note: This question is important if you are teaching the Philosophy of Science sub-teaching unit. These are assumptions inherent in the experimental set-up, but are different from paradigms identified later. Paradigms are assumptions inherent in the hypothesis itself, not merely assumptions in the experimental design).*

Should the subject (taster of the chocolate) be able to see or be told what color the M&M is?

*No. Concept of Blinded. Eg. Coke v. Pepsi*

Should the person who gives the MnM to the subject be able to see what color the MnM is? Why?

*No. Concept of double-blinded. Prevent inadvertent hints to the subject of the color of the MnM, including giggling etc. This is especially true when the tester has a bias as to what the outcome should be.*

Should the subject first be trained (i.e., allowed to eat a number of brown and non-brown MnMs such that the subject knows what they taste like. How many of each MnM should be allowed during training?)

*Yes. If there is a difference between the brown MnM, then subject needs to be trained to tell the difference between brown and non-brown. However, if the number of correct guesses in the experiment is significantly below 50%, this would suggest there is a difference between brown vs non-brown, it’s just that the blinded subject was not properly initially trained. The number should be about 6-8 each, enough such that the subject is familiar with the taste of Brown vs. Non-brown MnMs (Note: training not needed if experiment suggested is if the second MnM is the same or different color than the first).*

In a question above, we said that there will be greater confidence of results if the subject tastes more MnMs. What is the limiting factor for the number of MnMs tasted by each subject?

*Limiting factors include the number of MnMs available, and the taste-bud/ability to eat MnMs of the subject (Note: this level of understanding is sufficient for core exercise. However, if you are teaching the Hypothesis testing and Experimental Design in the Real World sub-teaching unit, this discussion is crucial for the later follow-up when we have limitations on resources).*

Write your protocol below. Record your experimental results as well.

Result:

Suggest to your students that they should enter the data on excel. Ask how they would code for a correct or a wrong answer. After results are done, teach how to draw a graph using excel.

Percentage of correct identification of color of MnMs:

Are your results significant? To find out, we will need to calculate the p value of the results; or do a statistical significance test. There are many different types of statistical significance tests and formulas, depending on type and size of data. For the data today, we will use a Chi Square Test (Refer to Faculty\_StatSig)

Conclusion:

Another important part of scientific experiments is to consider what experiments would come next based on the results of the previous experiment. What should we test next? Suggest a new hypothesis