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Lab on the Relationship Between the Sound Frequency and the Rate of Plant Growth

Research Question:

How do the different sound waves of different frequency (0hz, 500hz, 1000hz, 2000hz, 4000hz) affect the rate of the plant growing, which is measured through the height change after 10 days?

Variables		
Independent Variable	The frequency of sound. (0hz, 500hz, 1000hz, 2000hz, 4000hz) Unit: Hertz	
Dependent Variable	The rate of plant growth over 10 days.	Unit: millimeter / day
Control	The rate of growth of plant exposed to 0hz. (No sound)	

Controlled Variables	Details
The same electronic scale (Uncertainty: ± 0.01g)	This is probably not the most important controlled variable involved in this lab, for the dependent variable is not measured through the electronic scale. However, many other aspects of this lab are done with the use of an electronic scale such as the measurement of soil. This will obviously not have a significant effect on the results but it still is theoretically an element with the possibility of altering my results. This will be kept controlled by the usage of one scale and continuous taring.
Room temperature/ sunlight (Ideal Temperature: 27.5°)	The temperature, or sunlight, is a significant factor that could affects the results if not constantly controlled. This is a factor that can be the independent variable itself, and therefore should be controlled by keeping the plants where they will receive the same amount of sunlight or the temperature. (This could be tricky since the plants should somehow be separated in different if not having an acrylic box.
The type of plant grown.	This is the subject of this lab and definitely should be kept controlled. Different plants not only differ in the speed in growth but pretty much everything so changing the actual plant or planting different seeds will for sure cause devastating results when it comes to making an analysis of the gathered data. However, this can also be controlled the easiest; one just has to prepare enough seeds of one breed. (Preferably a fast-plant).
The type of sound/ sound waves (Hz)	This is also very important for it is the actual independent variable. The independent variables should not be altered throughout the entire lab and the type of sound should also not be different. For example, although in different frequency, one sound cannot be a sound of an instrument and the other digital-based. The source of sound is also

	what varies the sound waves slightly. This can be easily kept through the use of "ToneGen", a program that produces a constant sound for all frequencies.
The type of water given to plants (tap water)	Tap water and distilled water varies a lot in the minerals and the composition. It is, therefore, why a constant source of water should be used. Distilled water is not an easily accessible material to be found in the house so just simply using the same tap water will solve this problem.
The amount of time the plants are exposed to the certain sound. (Hours)	This directly relates to the independent variable; we must keep the time same since we are trying to see which sound will affect the plant in certain ways. It is mentioned in my process, but for this lab, the plants will be exposed to the sound 24 hours each day. (All-day)
Type of soil the plants are planted in	Soil does not really highly affect the plant growth unless it varies significantly such as fertilized soil and rocky soil. Technically, the normal dirt from the same area is not perfectly equal. However, for this lab, it would e okay to use any soil other than fertilized soil. The best thing to do is to buy a bag of soil or to dig soil from places nearby.
Method of determining the plant's height (± 1mm)	This is a tool that should be kept constant. Since this directly alters the dependent variable, the measuring tool should be constant. However, the method should also always be constant. Since plants do not always grow straight, few plants will be tilted more than others. It is the person doing this lab's job to determine whether they will measure the net height or the actual height of the plant. A logical solution would be to straighten the plant and to measure the height of the plant.
Same pipet (± 0.1ml)	Similar to the electronic scale, the pipet should be kept constant just for the sake of a more reliable and accurate lab. The plants should be given equal amount of water everyday and therefore will need to use one pipet for 10 days.

Background Information:

The effect of music on plant's growth has been a subject of controversy over many centuries. Even after centuries of research, the answer is still yet very vague. However, another debate that has taken place within this debate is the differentiation between sound and music. The controversy is in whether it is the actual sound waves or the 'harmony' of sounds that affects the plant's growth. Either way, it remains concrete that this subject does not only require knowledge on sound, but also on botany.

According to the Merriam-Webster's Dictionary, sound is defined as a "mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (as air) and is the objective cause of hearing" (Sound). This waveform of sound can be characterized by many factors such as wavelength, period, amplitude, and frequency. Wavelength is described as the distance between two waves in a sound. Period is similar to wavelength in terms of sound. However, wavelength measures length, and period measures the time between the two waves. Amplitude is the maximum fluctuation that a wave has. A single strand of sound will have a constant amplitude, and altering the amplitude will change the entire pitch of the sound. It is not a problem for me since I use a program, but keeping the amplitude constant would have been also a controlled variable in the past. Frequency is the frequency that we normally refer to in sound; it is what many people mistake as the pitch of the sound. However, frequency is actually the how

'frequent' waves take place during a certain time. It is the different frequencies that this lab will focus on. (Sound and Music)

It is a scientifically proven fact that plants cannot 'hear'. If so, the effect of music on plants will have to be explained differently, and scientifically. What some scientists think is that the reaction does not happen in a physical level, but in a cellular level. Plants are capable of interacting with the outside world through its epidermal cells. These cells are usually what 'exhales' and 'inhales' oxygen. Just like any physical waves, sound waves, along with light waves are capable of causing a microscopic disturbance in the air. It is the reason by sound waves are also strongly believed to be capable of affecting the cells and destroying it by crashing into them. (The Effect of Music on Plant Growth)

Method:

*Keep the Controlled Variables (pg 1) in mind when conducting the lab.

1. Even before starting on the lab, the period of this lab should be modified based on the type of seed that is going to be planted (research and make sure the lab endures to roughly 7 days after sprouting period)
2. If the acrylic boxes are not ready, find 5 distinct (sound-proof) places in your house where similar amount of sunlight comes through.
3. In each of the rooms or the box, place a speaker and connect it to a music source of the specific frequency. Label the room or the boy with paper tape.
    a. Also prepare an adequate number of chargers since we don't want the sound to stop without us even noticing it.
4. Put the dirt into the prepared pots. Do not completely fill them but leave 1-2cm of free space (The soil will be compressed once it is soaked with water)
5. Measure the mass of each pot and make sure that all pots are roughly the same mass.
6. Use your finger to make two 1cm-deep holes in the pots. (We are making two holed in case one seed does not grow.)
7. Drop one seed into each of the holes and fill the holes with dirt.
8. Use the same pipet to give 30ml of water to each pot.
    a. Choose a time that you can constantly water the plants everyday.
9. Label each pot according to the independent variable (0, 500, 1000, 2000, 4000hz) and the trial number (1, 2, 3)
10. Put the pots into the acrylic boxes or move the pots to the specific places.
11. Press 'play' on each of the sounds and keep the plants untouched for a day.
    a. The volume does not have to be very loud; it just has to be enough to fully resonate within the are (box/room)
12. At every designated time, water the plants with 30ml of tap water.
    a. Also check the battery of each device at this time and use a charger if needed
13. Start continuously recording the plant growth every other day. (Record the height as 0 is it did not sprout)
14. When the seed sprouts, start measuring the height with a constant method while you give them water.
    a. If the plant ends up dead, (It should not, but) mark the height as 0.
15. Record the data onto a table.
16. Repeat steps 11 – 14 for the amount of days you chose in the beginning.

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Materials:

- Pipet Pump + Glass Pipet (± 0.1ml)
- Electronic Scale (± 0.01g)
- Tap water
- 15 small pots
- At least 30 seeds of a fast-plant
- Ruler (± 1mm)
- Enough Soil
- 5 Acrylic Boxes
- 5 Speakers
- 5 Devices (Macbook, MP3, Ipod, etc)
- Free Program "ToneGen" or other frequency-generating program
- Paper Tape

Hypothesis:

If I change the frequency of sound waves that a plant is exposed to (0hz, 500hz, 1000hz, 2000hz, 4000hz) and observe the rate of plant growth dependent on the sound waves, then I predict that the result will actually be irrelevant and will not have a direct relation to the increase or the decrease of the sound waves. I predict that it would rather tend to grow the best at a certain range of frequency. I predict so because although the constant sound waves will influence the plant cells and increase the production of RNA, an excessive amount of sound waves (ex. Frequencies that are too high) will possibly harm the cells and cause the cells to die. The sound waves will be a catalyst to a certain extent, but it will act as a harm factor for the plant once it goes over the 'limit'. Overall, the theory is that the epidermal cells will notice the microscopic disturbance of sound waves and the physical waves will alter the amount of RNA created by physically affecting the cells.

Raw Data:

Table 1: Height of Plant - 10-Day Period - Experiment

Sound Wave Frequency (Hz)	Sample Plant	Initial Height (± 1mm)	Day 2 Height (± 1mm)	Day 4 Height (± 1mm)	Day 6 Height (± 1mm)	Day 8 Height (± 1mm)	Day 10 Height (± 1mm)
0	Plant 1	0	0	53	102	120	134
	Plant 2	0	3	57	114	131	139
	Plant 3	0	0	46	108	127	150
500	Plant 1	0	5	62	120	139	154
	Plant 2	0	0	60	128	137	143
	Plant 3	0	0	61	126	136	148

1000	Plant 1	0	0	57	113	126	135
	Plant 2	0	6	65	122	132	0
	Plant 3	0	0	58	95	119	138
2000	Plant 1	0	0	63	132	144	150
	Plant 2	0	0	47	114	128	141
	Plant 3	0	0	60	113	126	0
4000	Plant 1	0	0	42	85	0	0
	Plant 2	0	0	54	100	119	130
	Plant 3	0	0	38	79	105	121

Observations –Pre Growth

- The acrylic boxes are effective, but not as effective as I thought. The cords that come out of the box make a small hole in the bottom where the sound seeps through. I therefore moved the boxes a bit far from each other.
- Sound waves are actually sensible if the volume is loud enough; the lab does not require such excessive volume.
- The soils were all in same shape in beginning but all became different after inserting water.

Observations – During Growth

- The sound is not closed whenever I try to water the plants since I then raise the box.
- Some plants have sprouted faster than others
- The growth rate seems to change everyday…some plants have over-grown other plants in few days.
- I accidently damaged few plants in the process of measuring height (tore a leaf, altered position)
- It is not possible to visually differ out the differences other than one box (4000hz)
- Some plants have died as much as 4 days faster than other plants
- The plants are all tilting towards the sun
- It is a bit moist in the boxes compared to the room.

Observations – Post Growth

- There isn't a vivid difference in the height
- All plants still look healthy other than the dead plants
- During the cleaning process, I noticed that some plants rooted deeper than other plants

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Data Processing

Table 2: The Total Growth of Plants over 10 days

Sound Wave Frequency (Hz)	Sample Plant	Minimum Height (± 1mm)	Maximum Height (± 1mm)	Total Change in Height (± 1mm)
0	Plant 1	0	134	134
	Plant 2	0	139	139
	Plant 3	0	150	150
500	Plant 1	0	154	154
	Plant 2	0	143	143
	Plant 3	0	148	148
1000	Plant 1	0	135	135
	~~Plant 2~~	~~0~~	~~132~~	~~132~~
	Plant 3	0	138	138
2000	Plant 1	0	150	150
	Plant 2	0	141	141
	~~Plant 3~~	~~0~~	~~126~~	~~126~~
4000	~~Plant 1~~	~~0~~	~~85~~	~~85~~
	Plant 2	0	130	130
	Plant 3	0	121	121

- Crossed the 'dead' plants and took them as outliers because these plants did not grow for 10 days and makes it complicated to calculate the Average Rate.

Calculating Rate of Growth

$$\frac{Maximum\ Height - Minimum\ Height}{10}$$

* It is divided by 10 because this lab was conducted for 10 days. If longer or shorter, change the denominator

Table 3: The Average Rate of Plant Growth

Sound Wave Frequency (Hz)	Sample Plant	Total Change in Height (± 1mm)	Rate of Growth (mm/day)	Average Rate of Growth (mm/day)
0	Plant 1	134.0	13.4	14.1
	Plant 2	139.0	13.9	
	Plant 3	150.0	15.0	
500	Plant 1	154.0	15.4	14.8
	Plant 2	143.0	14.3	
	Plant 3	148.0	14.8	
1000	Plant 1	135.0	13.5	13.7
	Plant 3	138.0	13.8	
2000	Plant 1	150.0	15.0	14.6
	Plant 2	141.0	14.1	
4000	Plant 2	130.0	13.0	12.6
	Plant 3	121.0	12.1	

Calculating Average Height

$$\frac{Sum\ of\ Height}{Number\ of\ Variables}$$

* It is likely divided by 3 in this case but do not include the 'outliers' mentioned in table 2 and if so, divide it by 2.

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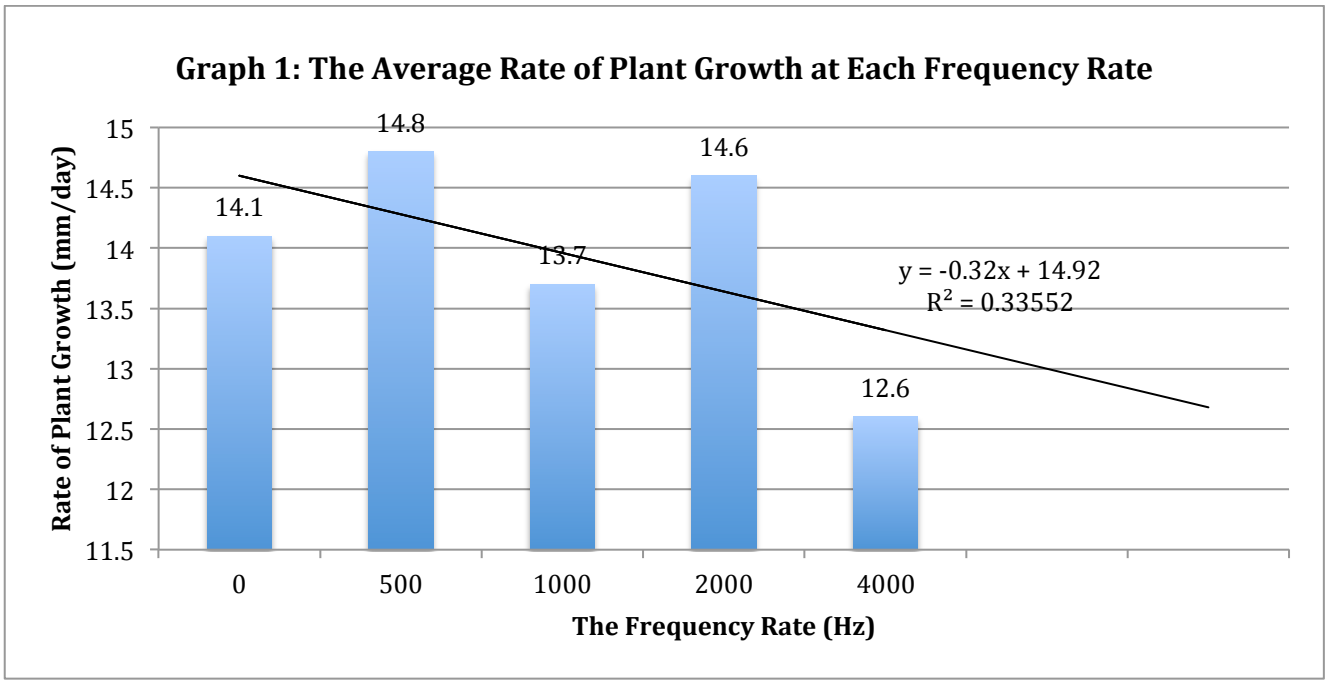
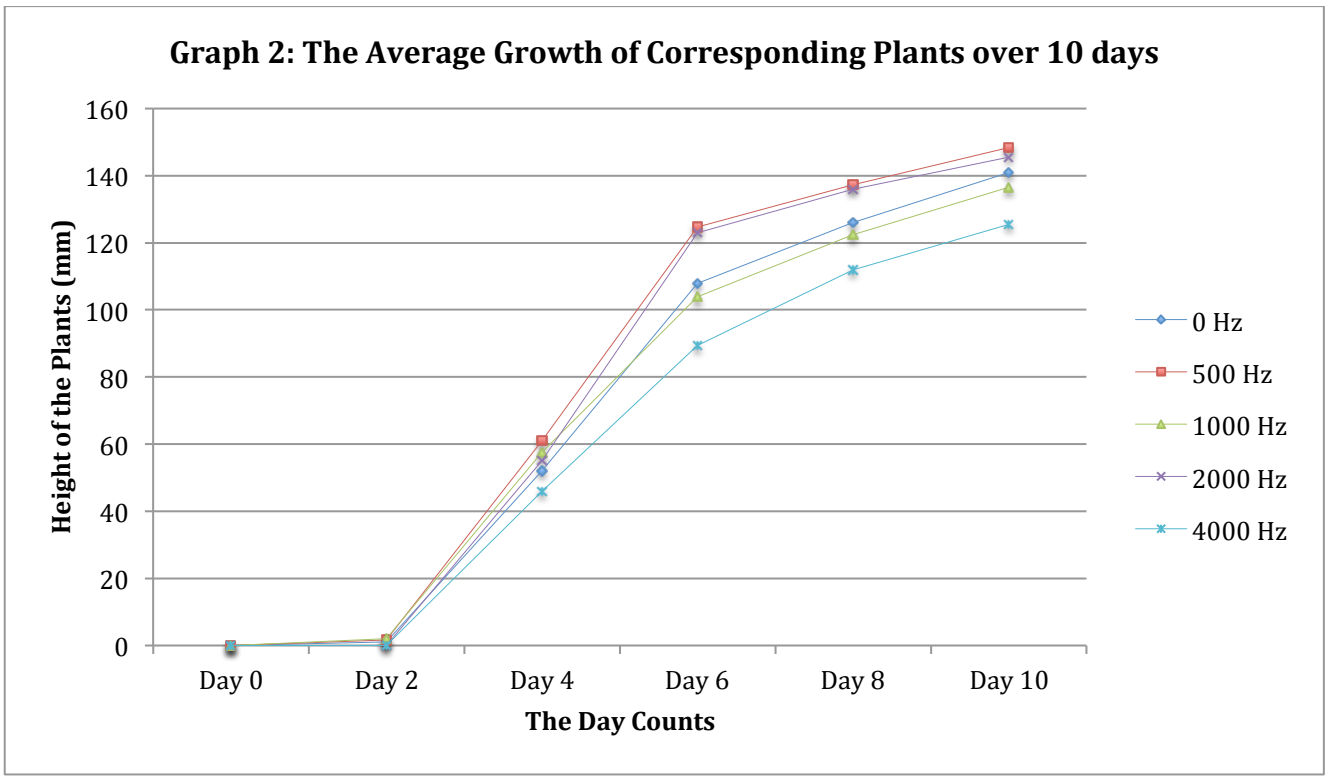
Table 4: The Average Change in Height Over 10 Days

Sound Wave Frequency (Hz)	Initial Height (± 1mm)	Day 2 Height (± 1mm)	Day 4 Height (± 1mm)	Day 6 Height (± 1mm)	Day 8 Height (± 1mm)	Final Height (± 1mm)
0	0	1.0	52.0	108.0	126.0	141.0
500	0	1.7	61.0	124.7	137.3	148.3
1000	0	2.0	57.5	104.0	122.5	136.5
2000	0	0.0	55.0	123.0	136.0	145.5
4000	0	0.0	46.0	89.5	112.0	125.5





Analysis

In answering my research question through this experiment, I was able to achieve a quality set of reliable data. This was a unique experiment in which it is very hard to make a solid conclusion even after achieving a quality set of data. Even if this topic were not a very controversial topic, it would have been hard to make a generalization based on the non-independent variable-related result as demonstrated in Graph 1. The general trend of the growth itself was clearly visible as shown in Graph 2. It was just that there were no specific relationship between the frequency and the rate of growth shown by my processed data. None of the individual graphs or tables fully supports a firm data. It is through the collective analysis of the entire process that will enable people to deduce a valid argument on this lab.

Conclusion

Unlike most of the labs I conducted in the past, the data from the tables and the graphs of this lab does not portray a solid answer. Instead, the data of this lab leads in forming more of a 3-dimentional conclusion. The data from this lab does show and conclude a rather strong relationship between sound and plant growth. As demonstrated in Graph 1, the plant growth was definitely altered by a factor. Keeping in mind that all the controlled variables were kept controlled through a majority of the period, the only variable that could have caused such difference is the presence of sound and the different frequencies. A singular conclusion that 'different sound wave frequencies affect the rate of plant growth in different ways' is a rather very strong and valid claim to make as it is supported through my data such as Table 3 and Graph 1. However, the aspect that is yet very vague is the direct relationship between the frequency lengths and the plant growth. The trend line does portray a decreasing trend overall as the frequency increases, but the R^2 value of the trend like is very low as 0.34, making the direct relationship a weak claim.

I have mentioned this in my 'background information', but this occurrence of inconsistent relationship could possibly be explained through the effect sound waves have on the cells. As aforementioned, a likely explanation to this phenomenon is that sound waves will microscopically cause a disturbance in the air, which would then travel through the epidermal cells and contact the cells, accelerating the production of RNA. Since the production of RNA directly relates to the growth of the plant, it is why such sound waves would be capable of affecting the growth. The frequencies that caused the plant to grow less than the control indicate a different aspect to this explanation. It is possible that some frequencies affected the cells to lack in performance. Since frequency is essentially the length and occurrence of the waves, some frequency's only disturbed the RNA production rather than to stimulate it (Ex.1000hz and 4000hz).

Although the data set is rather inconsistent, the results actually appear to have stated my hypothesis to be correct. With such graphs and configurations of the data, the most likely conclusion would be similar to the one I predicted in my hypothesis. The only conclusion that can be fully supported through my data is that the relationship between sound and plant growth is simply not a direct correlation. Instead, there are specific ranges of frequencies that will affect the plants as a stimulus and other ranges that will act as a deterrent. The frequency that I hypothesizes to accelerate plant growth the best was proven through by my set of data to be around 500hz. Growth rate-wise, the strongest stimulus was a frequency of 500hz, followed by 2000hz, 0hz, 1000hz, and finally 4000hz.

I believe that my control also acted as a great margin for comparisons. As I have already used above, a plant grown with only the essential factors provided a idea of how significantly or insignificantly the independent variables

affected the dependent variable. Graph 1 is a good visual example of a valid comparison between the control and independent variables. The reliability of this lab is also very reliable through the data in Table 1, but still does lack some reliability in sense that some plants actually dies much earlier than other plants, which I assumed as an outlier. The conclusion was rather very complicated to deduce, but the fact that this topic is still very controversial improves my conclusion and data's validity.

Evaluation

Although this lab is based on a topic that is not fully explained through science and does not have an 'answer' to it, that does not make my lab any more reliable or valid. My lab still consisted of numerous factors that could have altered the data significantly or insignificantly. Usually, a pre-written method is where many issues related to reliability occur. However, my method did not consist of reliability issues both pre and post experiment. I mentioned all the controlled variables that was related to the method and also made sure that three trials were conducted. Due to the characteristic of this lab, all three trials were conducted at once, as mentioned in the method. I also considered the people who did not have access to a transparent (acrylic) box; I mentioned the additional variables to be considered when conducting the lab in different rooms. It is obvious that the data set will become more reliable with more trials. For that reason I mentioned '3' as the number of trials in my entire lab and in my method, but I technically have asked for 6 trials just in case the seed will end up not sprouting. A mystery in my method when I conducted it was that several plants died much earlier than other plants (Table 1). I had kept the controlled variables controlled and also treated the plants equally; all three plants of an independent variable should have died in my case. However, the fact that only few plants died indicate either that I have an invisible flaw in my method or just that the plant were weak in the beginning. All calculations were also conducted with close care to the 'significant digit law'.

Although I theoretically did everything that could keep my lab reliable, the varying heights of the plants in Table 2 indicate some problem. Unlike chemical labs, labs including live plants or animals are easily altered due to the numerous controlled variables. The fact that all living organisms are different in the slightest way also sometimes causes unexpected problems (Ex. some of my plants dying early). I was actually lucky that I was able to keep my controlled variables under control; a small change in the variables could have significantly altered my data causing a huge lack of reliability. It is also why I conducted all three trials all at once; I wanted to avoid the possibility of a lack in reliability.

Validity is also a factor that should be considered along with reliability when evaluating a lab. In this lab, the biggest validity-related problem was my choice of apparatus in measuring the height of the plant. Because I used a normal ruler, I had problems with the uncertainty, which is why I chose to make my measurements in millimeters. However, despite this small error, I believe that my lab was fully capable of answering the question that I asked. The vast amount of data and the measurements were vivid enough to demonstrate a conclusion for this lab. As mentioned continuously, the raw data (Table 1) reveal some problems associated with validity as well as reliability. However, after processing all the data, the final graph (Graph 2) demonstrates a unique 'trend' that supports my hypothesis. Considering the fact that my hypothesis was purely based on my background research and the 'facts' I researched, the correlation between my data and hypothesis also partly justifies how my lab was 'valid' in testing what I intended to test. I also had a pretty dominant control over most of the controlled variables for the majority of the time. I only caused any difference in the environment other then when I had to open the box while I gave the plants water. Although there were not much

materials used in this lab, materialistic controls were also constant since I used the same pipet and electronic scale for the entire lab. The only controlled variable that I could not keep constant is probably the temperature of the environment. I tried to keep the temperature constant when I was at home, but when I left my house the sunlight could have raised the temperature during the day and lowered it during the night (The clear acrylic box unintentionally acted as a greenhouse for the plants). My lab did not have big errors that affected the data significantly, but did have some minor errors that affected the lab insignificantly.

Error	Reason	Improvement
The first error and perhaps the most 'significant' error I made during this process are probably to plant more than one seeds into a pot. Some pots later had one plant and some pots had two plants	This was a way I thought would prevent the possibility of one seed dying and only having 2 trials. It did work in that purpose since few of my pots had one plant growing when I planted two. I found out later on that this should have also been the controlled variable. Since both plants require nutrients from water, soil, and sun, it is an obvious fact that a plant in a pot with another plant will gain fewer nutrients than a plant in a pot alone. This could have caused significant differences, or rather insignificant differences. I don't know now; I will have to conduct this lab again to find it out.	This error is an error that is really easy to improve. Honestly, it really does not require one to prepare 30 pots (although it would be much better and reliable if done so). A much easier solution to this error is just simply pull one plant if both plants sprout. When the plant is just sprouting, the root will be very shallow, and therefore will be intertwined with the other plant if planted properly in the first place.
A second error that I noticed after doing this lab is that the acrylic boxes actually became a green house and also trapped all the moisture inside. There was a small opening, but the moisture was still sensible and could have affected the growth.	I'm not really sure how moisture scientifically affects the plant growth, but it still is something that could have affected the growth. Also, along this line, the reason for such moisture was due to the 'greenhouse effect'…temperature was also trapped in the box too. Because the sunlight heated the air inside the box the temperature that the plant was exposed to was actually technically higher than the actual room. The difference, as I felt it with my hand, was not a huge difference, but still was slightly sensible. This slight difference could have possibly the reason why some plants died…this was actually a controlled variable that I mentioned I should have kept under control.	The improvement for this issue is actually pretty hard to come up with since the plants have to be kept under the same environment, but also need to be isolated with sound. I thought that a transparent box would be the best choice of material for these purposes. A possible solution is to actually insert a 'moist-eating' thing inside the box. That way, most moist would be solved and the heating inside the box would be less significant.

After conducting this lab and answering my research question, I was able to make further inquiries on this topic. The first further inquiry that could make from this topic is to then expand my lab into more music-related than sound-related. I explained in the background information that another controversy is in the different effects that sound and music makes on the plant. Instead of using frequency as my independent variable, I would then be using different genres of music such as rock, ballad, electronic, etc. However, a very significant problem that could possibly hold me from doing this lab is in the irrelevance of the independent variable. For frequency, the different frequencies were all just different measurements of one thing whereas music would be a totally different concept. To make the lab effective, a best solution would be to actually find a song that has different versions of it. Otherwise, all the difference in the musical

elements could also become an independent variable, eventually leading to a failure. A maybe more reasonable inquiry could be on the effects of a singular element of music such as beat, or tempo. These variables would be able to be expressed in numerical values and would be inter-related.

However, if I manage to succeed in the lab with plants and 'music', I could possibly actually, with a bit of a stretch, relate to the effect of music to plants to the effect of music on human. Effect of music on human is just like plants, a yet controversial topic. There are many studies upon the many aspects of music and its effect on the human brain; there even is a specific name for the effect of music on the brain called: neuromusicology (Godbole). If I have the chance in the future, I could perhaps also develop myself into studying maybe the biological changes that happen when people listen to music rather than the changes that happen in the brain. If so, this lab on music and human would be the ultimate further inquiry' I would make. Perhaps this study could help develop music as a treatment in biological terms, not psychological terms.

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