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Article

Statistically Analyzing the Effect of Various Factors on the Absorbency of Paper Towels

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SUMMARY

The spread of SARS-CoV2 virus and COVID-19 has caused a surge in demand for paper towels, with a 264% increase in sales growth as customers enhance their hygiene efforts. Though there have been many studies on the characteristics of various paper towels, relatively little research has been performed on how different types of liquid, different fat concentrations, and different properties of paper towels impact their absorbency. In this study, we examined the effect of these factors using samples of the Bounty Select-a-Size paper towels obtained by simple random sampling, and random assignment procedure. We constructed comparative graph displays, verified the data's normal distribution, and performed statistical analysis. A two-sample mean significance test gave us strong statistical evidence to reject the null hypotheses in favor of the alternative hypotheses at the alpha level of 0.05. We found that different liquid types did impact the absorption capability of a paper towel — milk tended to have a higher absorption amount into paper towels than water, and vegetable oil tended to have a higher absorption amount than milk. We also found to a certain degree that fat concentration tended to increase a liquid's absorption amount into paper towels. We reported a cause and effect relationship from the paper towels' properties (whether folded or not) and its absorbency. Our results could help restaurants and other businesses save expenses by minimizing paper towel usage according to spill types and by using paper towels in more efficient ways.

INTRODUCTION

The emergence of SARS-CoV2 and COVID-19 has caused a surge in demand for paper towels and other disposable paper products. Consumers are moving away from reusable cleaning cloths in favor of disposable paper towels out of concerns that reusable cloths may harbor germs if not properly disinfected. Some health experts have also advised using paper towels to disinfect bathroom faucets and door handles to avoid contamination (1). The Bangladesh government further suggested that people should use paper towels instead of jet dryers because paper towels are more effective in removing pathogens missed by ineffective washing (2). Due to suggestions such as this, the paper towel industry saw a 264% increase in sales growth as consumers enhance their hygiene efforts (3). Paper towel companies have advertisements on television, radio, newspapers, magazines, billboards, and even packaging, claiming they are the superior brand. There have also been many studies and projects on the characteristics and evaluation of various paper towels. Five different paper towels were rated on absorption, scrubbing strength, and strength when wet (4). Other studies went further to perform cost analysis based on the absorption of paper towels, questioning if the expensive option is always the most effective (5), or discussed the importance of absorption, strength, and ease of separation among various paper towels (6). A similar study concluded that the paper towel brand Bounty won the comparison in terms of absorption quality (7).

We chose to conduct this experiment for the following three purposes: (i) to learn the effect of liquid type on the absorption ability of paper towels by studying the average absorption of water, milk, and vegetable oil, (ii) to learn how the fat content of a liquid impacts paper towel absorption, and (iii) to assess how different the structure of a paper towel, such as whether they are folded or not, affects their absorption. We identified milk with different fat concentrations (whole milk versus skim milk) and compared their absorption into the same brand of paper towels. We found that paper towels had a significantly higher absorption capacity for vegetable oil, when compared to milk or water. We also found that paper towels when folded absorbed more liquid than when not folded at all. This information would help estimate the number of paper towels required to clean a particular type of spill. In particular, businesses such as restaurants that are seeking to save expenses would be able to minimize the number of paper towels according to the types of the spill and by using paper towels in ways more efficiently. Other than seeking to answer interesting questions, this project aims to add further knowledge on paper towels currently lacking in the literature.

RESULTS

Effect of liquid type

We chose tap water and 2% reduced fat milk as the two experiment groups for this study to determine the effect of liquid spill type because of their easy availability and different properties. For each test, we used one sheet of Bounty Select-a-size paper towel and submerged it into a liquid, either water or milk, in a large graduated cylinder. We then pulled the towel out of the liquid, keeping it above the

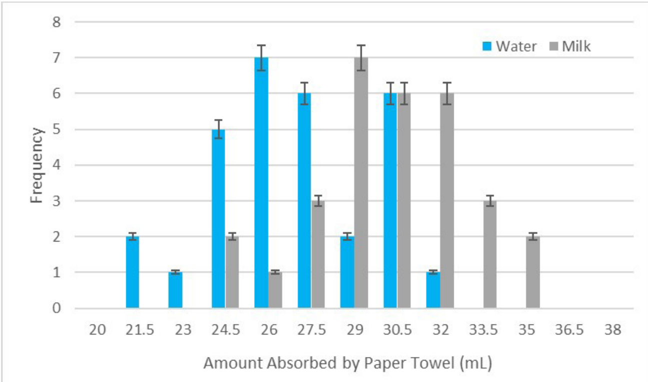


Figure 1. Paper towels absorb more milk than water. The number of times that a paper towel absorbed a specific volume (mL) of milk (grey) or water (blue) was recorded (n = 30 trials per liquid). Error bars denote standard error.

cylinder until it stopped dripping. Next, we measured the absorbency as the volume (mL) of liquid absorbed by one sheet of the paper towel, reflected as the changes between the initial and final marks on the cylinder. We observed the shape, outliers, center, and spread of the data distribution for each experiment group before conducting two-sample t-test analysis.

The shape of the distribution displayed a slight right skew for the water treatment and a slight left skew for the milk treatment on the comparative histogram (bar graph) (**Figure 1**). Right skewing indicated that the mean was greater than the median for water treatment, while left skewing indicated that the mean was less than the median for milk treatment. Data from the final summary statistics (**Table 1**), as 27.738 mL (mean) > 27.60 mL (median) in the case of water treatment and 30.993 mL (mean) < 31.60 mL (median) in the case of milk treatment, confirmed the shape distribution tendency on the histogram. However, the skews were miniscule enough that they did not affect the assumption about the normal distribution of the experiment data.

We calculated outliers using the summary statistics (**Table 1**). The interquartile range (IQR) was multiplied by 1.5, added to the third quartile (Q3) and subtracted from the first quartile (Q1) to produce a range of non-outlier values. The range of non-outlier values for the water treatment was 18.95 – 37.35 mL. There were no outliers for the water treatment dataset as no value was less than 18.95 mL or more than 37.35 mL. On the contrary, two low outliers appeared for the milk group dataset but with minimal significance due to their closeness to the range of non-outlier values.

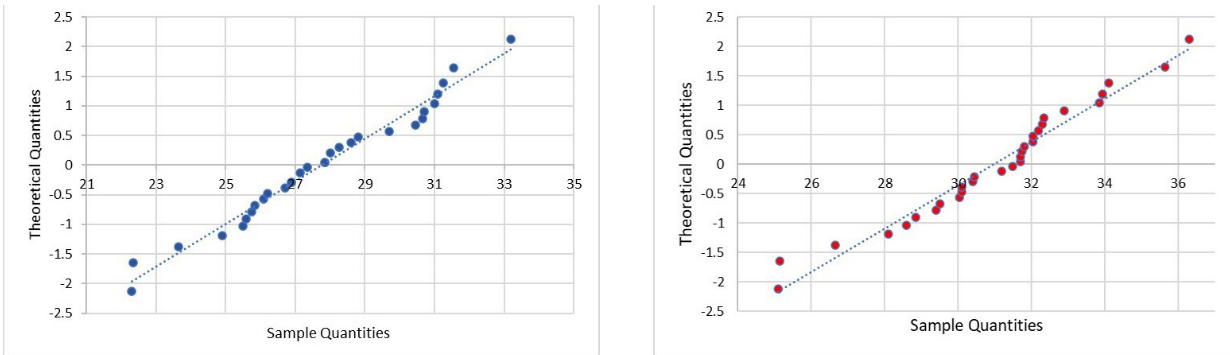
The central tendency analysis showed that a paper towel tended to absorb approximately 27.60 mL of water and approximately 31.60 mL of milk on average (**Table 1**). Therefore, the central tendency for the absorption for the milk was greater than water. In fact, 14.50% more milk than water could be absorbed into a paper towel on average.

Because of the slight skew of the datasets, the interquartile range is the most appropriate measure of spread in this context compared to the sample standard deviations (8). The interquartile range (IQR) was 4.60 mL and 2.80 mL for the water and milk treatment datasets respectively (**Table 1**). The spread of the water treatment was approximately 1.64 times that of the milk, as there tended to be more variability in the water data values than in the milk data values. Since the sample sizes were equal for both treatments, there may have been other factors between the two liquids that influenced this variability. The normal quantile plots for the water vs. milk treatment groups (**Figure 2**) suggested the experiment data for water and milk treatment groups followed the normal distribution.

Based on the two-sample t-test, the *p*-value was 9.038 x 10^{-6} and the confident interval at a 95% confidence level

Experiment Test	Treatment Group	Sample Size	Mean	Standard Deviation (S)	Min	Quartile 1 (Q1)	Median (Q2)	Quartile 3 (Q3)	Max
effect of liquid type	water	30	27.738 mL	2.741 mL	22.30 mL	25.85 mL	27.60 mL	30.45 mL	33.20 mL
	milk	30	30.993 mL	2.653 mL	25.10 mL	29.50 mL	31.60 mL	32.30 mL	36.30 mL
effect of fat concentrations	whole milk	30	23.983 mL	1.095 mL	21.5 mL	23.5 mL	24.0 mL	24.5 mL	27.0 mL
	skim milk	30	26.833 mL	0.735 mL	25.0 mL	26.5 mL	27.0 mL	27.38 mL	28.5 mL
	vegetable oil	30	37.667 mL	0.968 mL	35.5 mL	37.0 mL	37.5 mL	38.0 mL	40.0 mL
effect of a paper towel's structure	no folding	30	22.759 g	1.826 g	19 g	21g	23 g	24 g	26 g
	folded	30	34.897 g	2.110 g	30 g	34 g	35 g	36 g	39 g

Table 1. Summary Statistics for Each Treatment Group. The experiments testing the effect of liquid type and the effect of fat concentrations measured the amount of liquid absorbed by paper towels in milliliters (mL). The experiments testing the effect of the structure of paper towels measured the mass of paper towel after fully absorbed in water, in grams (g).



(a) (b)

Figure 2. Sample data are in a normal distribution. We plotted the sorted data vs. values selected for the samples (n = 30). The data points are roughly close to a straight dotted line. (a) Water sample data passed the pencil test. (b) Milk sample data passed the pencil test.

was (1.827, 4.683) mL for the study of the effect of liquid type (**Table 2**). Since the *p*-value was less than 0.05, we rejected the null hypothesis in favor of the alternative hypothesis at the alpha (α) level of .05. The mean volume of water absorbed was less than the mean volume of the milk absorbed by the Bounty paper towels, and the difference between the mean volume of absorption was within the confident interval.

Our results were significant due to the fact that zero did not fall within this interval, confirming that the *p*-value obtained in our two-sample t-test was statistically significant. This suggested a cause and effect relationship between the type of liquid (water or milk) and its absorbency into paper towels.

Effect of fat concentrations

In order to determine the effect of fat concentrations, we used whole milk, skim milk and vegetable oil as the three experiment groups. These three types of liquids are widely available at grocery stores and have distinct fat concentrations. Whole milk has approximately 3.5 percent fat by weight while skim milk has 0 gram of fat, and both have 8 grams of protein per 8-ounce glass (9, 10). On the other hand, vegetable oil contains 100% fat. We followed a similar procedure as the above experiment for the effect of liquid type. For each test, one sheet of Bounty Select-a-size paper towel was fully saturated by dipping it into a liquid. The towel was then pulled out of the cylinder and hung in the air until it stopped dripping. The amount of liquid absorbed was measured as the changes between the initial and final marks on the cylinder. We observed the shape, outliers, center, and spread of the data distribution for each experiment group before conducting two-sample t-test analysis.

The distribution displayed a slight left skew for the whole milk and the skim milk treatment groups and a slight right skew for the vegetable oil treatment on the comparative histogram (bar graph) (**Figure 3**). Data from the final summary statistics (**Table 1**) confirmed the shape distribution tendency on the histogram. The skews were too insignificant to affect the assumption about the normal distribution of the experiment data.

Based on the data from the summary statistics (**Table 1**), the whole milk group had one lower and one upper outlier. There was one upper outlier for the vegetable oil group and no outlier for the skim milk group. All the outliers

Experiment Test	Treatment Group	Df	Test Statistic	p-value	T-critical Value	Confident Interval at 95% Confidence Level
effect of liquid type	water vs. milk	57.9	-4.67	9.038×10^{-6}	2.0018	(1.827, 4.683) mL
effect of fat concentrations	whole vs. skim Milk	51	-11.84	2.995×10^{-16}	2.0078	(2.376, 3.333) mL
	skim milk vs. vegetable oil	54	-48.82	2.314×10^{-46}	2.0048	(10.388,11.278) mL
effect of a paper towel's structure	flat vs. folded paper towel	56	-23.73	6.696×10^{-31}	2.0032	7.673, 15.763 g

Table 2. Two-Sample T-test Results (at significance level an alpha (α) = .05) and the Confidence Interval (at 95% Confidence Level). *p*-value (< 0.05) indicates that the experiments support the alternative hypothesis. The comparison of water vs. milk, and skim milk vs. vegetable oil shows that liquid type affects the absorption capacity of paper towels. The comparison of whole milk vs. skim milk vs. vegetable oil suggests that fat contents in liquid potentially impact how much paper towels absorb a liquid. The comparison of flat vs. folded paper towel indicates that certain property of paper towels makes a difference in their absorption ability.

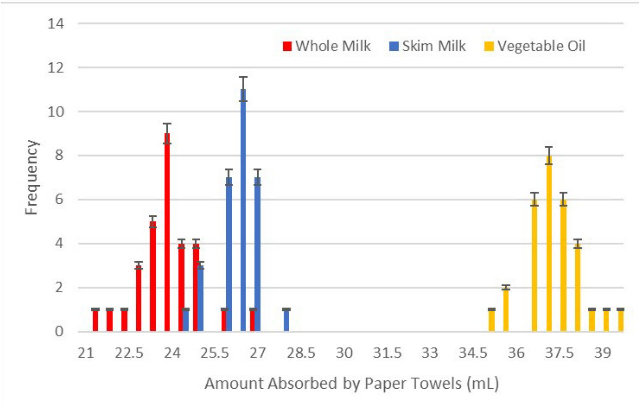


Figure 3. Paper towels absorb much more vegetable oil than milk. Among milk, paper towels absorb more skim milk than whole milk. The number of times that a paper towel absorbed a specific volume (mL) of whole milk (red), skim milk (blue), or vegetable oil (yellow) was recorded (n = 30 trials per liquid). Error bars denote standard error.

were not significant enough to affect the data analysis. The central tendency analysis revealed that the absorption for the skim milk is 3 mL greater, or 12.5% greater than that for the whole milk. The absorption for vegetable oil was 10.5 mL, or 39.62%, greater than skim milk. The interquartile range (IQR) was 1.0 mL, 0.875 mL, and 1.0 mL for the whole milk, skim milk, and vegetable oil treatment group, indicating their having similar variability among the samples.

Based on the two-sample t-test, the *p*-value was 2.99461×10^{-16} for the whole milk vs. skim milk test (**Table 2**) and was much less than 0.05, so we rejected our null hypothesis in favor of the alternative hypothesis at the alpha (α) level of 0.05, which showed that the mean amount of whole milk absorbed (mL) was less than the mean amount of skim milk absorbed (mL) by the same type of Bounty paper towels. The t-critical value was 2.0078 and the confidence interval was (2.376, 3.333) mL (**Table 2**). As this interval did not include zero, we were 95% confident that the difference between the mean volume of absorption for whole milk vs. skim milk was within this interval, and thus our results were statistically significant at a 95% confidence level. This experiment suggested a cause and effect relationship from the fat concentrations of milk to its absorbency into paper towels.

Similarly, the two-sample t-test for skim milk vs. vegetable oil yielded a *p*-value of 2.314×10^{-46}, so we rejected our null hypothesis in favor of the alternative hypothesis at the alpha (α) level of 0.05 — the mean amount of vegetable oil absorbed (mL) was much more than the mean amount of skim milk absorbed (mL) by the paper towels. The t-critical value was 2.0048 and the confidence interval was 10.388 – 11.278 mL (**Table 2**), thus we were 95% confident that the difference between the mean volume of absorption for skim milk vs. vegetable oil was within this interval, and that our results was statistically significant at 95% confidence level in showing a cause and effect relationship from the fat concentrations of a liquid to its absorbency into paper towels.

Effect of the structure of a paper towel

In this experiment, we chose to compare a folded vs. not-folded paper towel to determine the effect of a paper towel's structure because folding a towel is an easy operation to implement. It also addresses an interesting question in daily life about whether we should fold a towel to efficiently clean up a spill. In this experiment, we folded half of the total paper towels on a flat surface and pressed them tightly to compact them into smaller, thicker squares. We soaked a paper towel, either folded or not-folded, thoroughly with water, hung it in the air until it stopped dripping, and put it on a scale. We measured the amount of liquid absorbed as the mass (gram) of the paper towel. We observed the shape, outliers, center, and spread of the data distribution for each experiment group before conducting two-sample t-test analysis.

The shape of the distribution displayed a slight left skew for both the flat paper towel and the folded paper towel groups on the comparative histogram (bar graph) (**Figure 4**). Data from the final summary statistics (**Table 1**) confirmed these slight and insignificant skews, which did not affect much the data distribution characteristics.

Based on the data from the summary statistics (**Table 1**), two low outliers (30 g) showed up for the folded paper towel group while no outlier appeared for the flat paper towels. The interquartile range IQR was same for both the folded and flat paper towel groups, which also indicated that these two groups tended to have similar variability among the samples.

The central tendency analysis for folded vs. flat paper towels showed that folded paper towels are much more absorbent than flat paper towels. The absorption for the folded paper towels was 12g, about 52.18% greater than flat paper towels that were not folded.

The t-test gave a *p*-value of 6.696×10^{-31}, and the confidence interval of (7.673, 5.763) g (**Table 2**), thus

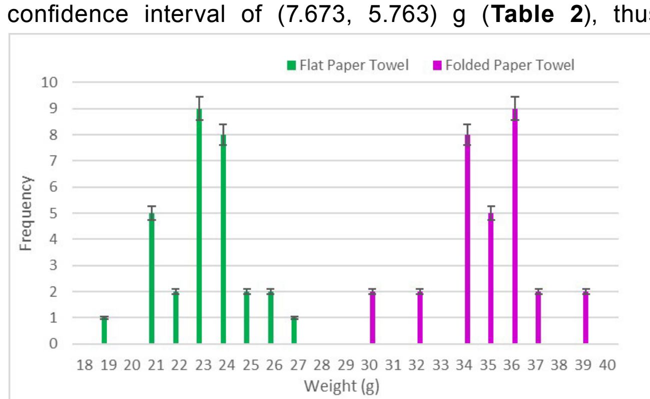


Figure 4. Paper towels absorb more liquid when folded up. The number of times that a paper towel absorbed a specific mass (gram) of flat paper towel (green) or folded paper towel (purple) was recorded (n = 30 trials per liquid). Error bars denote standard error.

we rejected our null hypothesis in favor of the alternative hypothesis at the alpha (α) level of 0.05 for this experiment. The average mass of water absorbed by a paper towel when folded was much more than the average mass absorbed by the same type of Bounty paper towel when not folded. Our results were statistically significant at the 95% confidence level and indicated a cause and effect relationship between different paper towel structures (folded vs. flat) and absorbency into paper towels.

DISCUSSION

We found that paper towels had a significantly higher absorption capacity for milk when compared to water. A possible explanation to support these findings may be because of the higher viscosity of milk due to its fat content (11). Fat molecules tend to cling to layers of paper material (12). Another reason could be because 2% milk fat has an average density ranging from 1.026–1.034 g/cm^3, while water has an average density of 1 g/cm^3 (13, 14). The slightly higher density of milk could influence the higher absorption amount of milk into Bounty paper towels.

To understand the effect of fat content on the absorption, we compared the absorption of whole milk, skim milk, and vegetable oil by the Bounty paper towels. It was surprising to see that skim milk had a higher absorbance than whole milk when whole milk should have a slightly higher viscosity than skim milk. However, a possible explanation could be that when the fat is stripped from whole milk to become skim milk, the skim milk is fortified with synthetic vitamins and milk solids to replace the lost proteins and calcium. These vitamins and solids may have greater attractive properties to the material of the paper towel. These substances could also have a substantially large mass that trapped them between the molecular spaces, increasing the overall absorbance for skim milk.

As expected, we found that paper towels had a significantly higher absorption capacity for vegetable oil, when compared to milk. Vegetable oil is mainly composed of fat and thus has a much higher viscosity than milk. Due to the large size of the fatty acid chains in vegetable oil, the triglycerides may be more easily trapped between the molecules of the paper towel. Hydrophobic interactions could also group fat molecules closely together in an otherwise hydrophilic surrounding due to the polar composition of paper towels (15). Furthermore, oil's high viscosity decreases leakage from the towel after the liquid has been absorbed. On the other hand, milk has a less viscous composition and smaller molecules (lactose, water, minerals, proteins, less fat) compared to vegetable oil that allow milk to escape from the paper towel more easily.

When testing the structure of paper towels, we found that paper towels when folded had a higher absorption capacity than when not folded at all. This may be explained by the properties of paper. In general, paper readily absorbs water because it is made of cellulose, which is hydrophilic. Paper towels are made to have empty spaces between their cellulose fibers to be especially absorbent. Water molecules tend to fill these empty spaces as they are absorbed by the cellulose in paper towels. Folding a paper towel creates more layers for water to fill, which is why the folded paper towels could hold more water and higher mass in the experiment. The study suggests that folded paper towels are more efficient at cleaning up spills and that we could use fewer paper towels for the same job if we use them properly.

One important note is that we were not able to purchase the exact same type of Bounty paper towels for the part two and part three of the experiment as the first part (the blank white vs. flowery print type). Our initial thought was to compare the results from all parts of the experiment together, but the difference in the paper towel type (though from the same brand) forced us to limit the comparison. We also question whether absorption potential is specific to brand, towel, or roll type.

For further study, we recommend data collection of the absorption of several different liquid types to obtain a wider range of knowledge about the properties of a variety of liquids. For example, we could test fruit juice, carbonated soda, and amongst others. Comparing these results would help us learn more about the effect of viscosity and/or surface tension on the amount absorbed. Another interesting experiment may be to test the impact of other properties of paper towels such as different types (i.e. flowery vs. bland Bounty) from the same brand.

METHODS

The experimental design description (**Figure 5**) outlines the experimental design, which can also be visualized in a simple graphic (**Figure 6**). To carry out our experiment, we ran independent trials, one paper towel sheet for each

Experimental Design Description

Explanatory Variable (IV):	The explanatory variable in this experiment is the "type of the liquid spill" (water vs milk, whole milk vs skim milk, milk vs vegetable oil), or the "property of paper towel" (folded vs flat). This variable is categorical and binary.	
Treatments:	Water (100 mL)	Milk (100 mL)
	Whole Milk (100 mL)	Skim Milk (100 mL)
	Milk (100 mL)	Vegetable Oil (100 mL)
	Folded Paper Towel	Flat Paper Towel
Number of Repeated Trials:	30 repeated trials (using one sheet of paper towels in each independent trial)	30 repeated trials (using one sheet of paper towels in each independent trial)
Response Variable (DV):	The response variable in this experiment is the "amount of liquid absorbed by one sheet of paper towel" (measured in mL) or the "mass of paper towel fully absorbed with water" (measured in gram). This variable is quantitative.	
Constants:	- Type (brand) of paper towel - Size of paper towel - Types (brands) of milk - Type of water - Measuring tool (graduated cylinder) - Measuring unit (mL,g) - Tool used to saturate the paper towel with the liquid (tweezer) - Location in which the experiment is performed.	

Figure 5. Experiment Design Description. Explanatory Variable is also called Independent Variable (IV). Response Variable is also known as Dependent Variable (DV). Four pairs of treatments are listed, each will test one hypothesis regarding to the experiment purpose.

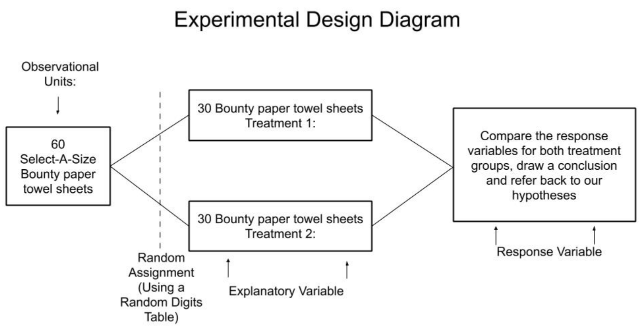


Figure 6. Experiment Design Diagram. During the experiment, a treatment (i.e. type of liquid) is imposed onto observational units (paper towels) in order to gather data on a response variable. The confounding variables balance out through random assignment of paper towels to treatments. Random Assignment creates treatment groups that are similar in all aspects, so the statistically significant difference in the data collected can be attributed to a cause and effect relationship.

trial. Each trial was independent because we measured the absorbance amount of each sheet of paper one at a time so that the trials did not affect one another.

We used two types of hypotheses in this study: a null hypothesis and an alternative hypothesis. The null hypothesis (H_0) was the one we attempted to disapprove. The alternative hypothesis (H_a) was the one we suspected to be true and attempted to prove.

For example, for the experiment of water vs. milk, we let μ_W and μ_M represent the mean amount of water (mL) and milk (mL) absorbed by all Select-a-Size paper towels by the paper towel brand Bounty. The Mathematical null hypothesis is H_0: $\mu_W = \mu_M$. The contextual null hypothesis H_0 was: the mean amount of water absorbed by all Bounty Select-a-Size paper towels is equal to the mean amount of milk absorbed by all Bounty Select-a-Size paper towels at the α-level of .05. The Mathematical alternative hypothesis is H_a: $\mu_W < \mu_M$. The contextual alternative hypothesis was: the mean amount of water absorbed by all Bounty Select-a-Size paper towels is significantly less than the mean amount of milk absorbed by all Bounty Select-a-Size paper towels at the α-level of .05

Experiment Setup

During the experiment, we randomly assigned the observational units to the treatment groups. Thirty sheets of paper towels were randomly assigned to each of the two treatment groups (water or milk, whole milk or skim milk, etc.) to be measured of each of their amounts of absorbance of liquid. The random assignment process of paper towels was done using a Random Digits Table as described below.

Randomization

Randomization was key in the experiment. We implemented both simple random sampling and random assignment in this study. Simple random sampling was implemented into the process to obtain our observational units. In our experiments, we took 60 sheets from one roll of paper towels (regarded as independent) as the paper towels were formed as a large sheet before they were cut and randomly sorted into packages during the manufacturing process. This gave all of them an equal chance to be part of this study. In addition, random assignment was implemented into the process to sort our observational units into our two treatment groups to limit the influence of confounding variables. We numbered each paper towel sheet with a number from 1–60 and using a Random Digits Table to determine which digits belonged to which group.

The randomization protocol in the experiment was as follows: We numbered each of the 60 sheets of paper from 1–60. Then, using a Random Digits Table and starting at any row, we began counting the first two numbers of the five-digit numbers, disregarding any values greater than 60 and any repeats. If necessary, we chose another row of random numbers. The occurrence of the digit zero allowed for the possibility of choosing a towel marked with one digit (01, 03, 09). After recording 30 distinct numbers between 1 and 60, the corresponding paper towel sheets (the ones with the same numbers given to them) would be part of one treatment group (i.e. water) and the remaining 30 would be part of the other group (i.e. milk). These two treatment groups each had their own separate towel stack.

Data Collection

For each trial in experiment part one (water vs. milk) and part two (whole milk vs. skim milk vs. vegetable oil), we measured 100 mL of liquid with a graduated cylinder and dipped the sheet of paper towel in the liquid until it was fully saturated and could absorb any more liquid. We then recorded the milliliters of liquid absorbed into each sheet. Then, we subtracted the remaining amount of water in the graduated cylinder from the original amount, thus obtaining the number of milliliters of liquid that was absorbed into a sheet of paper.

For the experiment regarding paper towel structure (folded vs. flat paper towel), we placed a paper towel flat on the table surface, wet it thoroughly using water, and then hung it until all of the excess water dripped out. We then weighed the paper towel on the kitchen scale, and recorded the mass. For each trial of the folding paper towel, we followed a similar procedure as for a flat paper towel, except that we first folded it twice by the middle line so it turned into a rectangular-shaped small paper towel in four layers before wetting it. We kept it still folded when we hung it.

Statistical Analysis

In Rossman and Chance (2011), three conditions are required for a two-sample t-test (8): 1) populations are greater than ten times the sample sizes, 2) random assignment of subjects to treatments (experiment) or independent random samples from two populations (observational study) is satisfied by using random assignment, and 3) sample size (n) is greater than or equal to 30 or population is normally distributed. This condition is satisfied by a sample size of 30 paper towels.

The standard error of the sample mean can be calculated by the following formula (16):

$$SE_{\bar{x}} = \sqrt{\frac{s_W{}^2}{n_W} + \frac{s_M{}^2}{n_M}}$$

Test Statistic can be obtained by this expression (16):

$$\frac{\bar{x}_W - \bar{x}_M}{\sqrt{\frac{s_W{}^2}{n_W} + \frac{s_M{}^2}{n_M}}}$$

The degree of freedom is one less than the sample size. It can also be found on a TI-84 calculator (Stat=>Tests=>TwoSampleT-test). Similarly, *p*-value can be obtained on calculator as well where *p*-value = Pr (T_{df} < t).

To construct a Confidence Interval: we use a 95% confidence level (t-interval) which can be calculated using formula (16):

$$(\bar{x}_W - \bar{x}_M) \pm t^* \sqrt{\frac{s_W{}^2}{n_W} + \frac{s_M{}^2}{n_M}}$$

where the critical value can be obtained on calculator by t* of 95% CI = InvT (probability, df) = InvT (0.975, df). The probability is calculated as the sum of confidence level (95%) and the left tail (2.5%).

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