United States and South Korean Citizens' Interpretation and Assessment of COVID-19 Quantitative Data

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Background

Early in 2020, governments, scientific organizations, and the media used quantitative data to make arguments for and against taking disruptive measures to prevent the spread of COVID-19. The data representations varied (e.g., text, graphs, charts, tables) and relied on mathematical concepts including rate of change, percentages, exponential growth, probability, accumulation, and mathematical modeling. Mathematics education researchers have created models of how students and teachers understand these concepts and representations. These same researchers argued people's schemes for these concepts and representations vary in their productivity. We extended this work to identify the extent these previously reported schemes are productive or unproductive for a citizen interpreting COVID-19 data. Namely, we ask: ***How do citizens' mathematics support them in assessing the severity of COVID-19?***

Brief Methods

In Phase I we conducted task-based clinical interview with 25 US citizens and 7 South Korean citizens between April 2nd, 2020 and May 11th, 2020. Our sample was diverse, not representative. We relied on Pew Research Center to learn about COVID-19 opinions from a representative sample of US citizens. Interviews were recorded using a video communication software (Zoom). Our final interview protocol consisted of 11 items including the topics of rate of change, comparing percentages, slope and graph. We analyzed participants' responses by transcribing and coding interviews using models of mathematical thinking as guidance

Summary of Results

Analysis of our data revealed two major themes. First, that citizens with productive schemes for comparing percentages, rate of change, slope, and graph supported understanding the severity of COVID-19, and unproductive schemes hindered citizens in drawing accurate conclusions. Secondly, we found that beliefs about the scientific and medical communities and the reliability of their data and recommendations could override both unproductive and productive interpretations of COVID-19 data.

Conclusions

We discovered that the models of mathematical thinking created by mathematics education researchers are helpful in creating hypotheses about which representations of novel COVID-19 data will be difficult for many to understand as intended. For example, our hypothesis that many citizens would unproductively use a scheme for slope as steepness to interpret the logarithmic scaled graph was well supported in our sample. We also correctly anticipated that some people would ignore the quantities and measures on the *y*-axis and that this would make it difficult for them to interpret graphical data as intended. Our hypothesis that comparing the relative size of 2.1% and 0.1% is difficult was also well supported. However, our hypotheses that some people would make an additive comparison and say 2.1% is only 2% more than 0.1% was not supported by any interviews. Many citizens knew a multiplicative comparison was appropriate even if they were not sure how to make that comparison. As a result of these interviews, we feel that the media could dramatically improve data representations by considering models of people's thinking from mathematics education research.

Read the following statement comparing the flu and coronavirus.
Comment on the argument the person is making.

> The CDC estimates in the U.S. from October 1st 2019 to April 4th, 2020 there have been 24,000-62,000 deaths from flu, 39-56 million flu illnesses and 410,000-740,000 hospitalizations. We don't shut down the economy and life for the flu. Today, April 20th, in the U.S. there are 789,745 confirmed cases of coronavirus, with 42,186 deaths. The flu is worse than the coronavirus and we don't shut things down for the flu so we shouldn't for the coronavirus.

Figure 2. The item, "Flu vs. COVID-19 deaths"

Table 1. Responses to "Flu vs. COVID-19 deaths"

	"Flu vs. COVID-19 deaths"			
	Compared flu and COVID-19 deaths using the idea of average rate of change	Referred to exponential growth	Medical argument of COVID-19 such as novelty, lack of vaccine	Expressed distrust that data presented is accurate
Flu is more severe than COVID-19	0	0	2	4
COVID-19 is more severe than flu	7	4	22	1
Unsure if flu or COVID-19 is worse	0	0	2	0
Subtotal	7	4	26	5

Excerpt 2. Kenneth's responses to the item "Flu vs. COVID-19 deaths"

Kenneth	[Read the argument] Yes, I agree with that. I guess it's the same argument like sugary foods and smoking killed more people than the coronavirus, but we don't outlaw those or we don't shut down stores that sell them.
Int.	What about the numbers specifically leads you to agree with the argument?
Kenneth	The higher numbers of the flu.
Int.	As compared to the lower numbers of the coronavirus?
Kenneth	Yes.

Kenneth focused on the number of people who died without thinking about how long it took for them to die or the potential for exponential growth of COVID-19. Kenneth's comparison of the consumption of sugary foods and smoking to COVID-19 is also notable; failing to acknowledge the fundamentally different risk structure and scope between personal choice in a disease process that physiologically affects only that person and a contagious disease where personal choice can affect many others can have significant impact on how one assesses these risks.

Scientists (such as Wu and team) estimate the death rate for COVID-19 is between 0.66% and 2.1%. The death rate for the seasonal flu is usually about 0.1% in the U.S.

a. How should this data impact decision making about social distancing?

b. Suppose there are two hypothetical situations.
In one situation 50 million people get the flu. In the other situation 50 million people get the coronavirus. Assuming the death rates of 0.1% and 2.1% how many times as many people will die from the coronavirus as the flu.

Figure 4. The item, "Flu vs. COVID-19 rates" (Data from Wu et.al., 2020 and the CDC)

Table 2. Responses to "Flu vs. COVID-19 rates"

	"Flu vs. COVID-19 rates"					
	Approximately correct multiplicative comparison.	Incorrect multiplicative comparison.	Asked to make multiplicative comparison but citizen didn't respond	Said 2% of a large number is very large.	Said 2.1% and 0.1% are both small so COVID-19 is not too serious	Said scientists incorrectly estimated infection fatality rates for COVID-19.
Flu is more severe than COVID-19	1	1	2	3	1	2
COVID-19 is more severe than flu	12	9	1	12	1	0
Unsure if flu or COVID-19 is worse	0	0	1	2	0	0
Subtotal	13	10	4	17	2	2

Excerpt 5. Katie's comparison of infection fatality rates

Int.	Alright. One point five. What does it mean to have a death rate of one point five percent?
Katie	It is a very low death rate.…It is very low. Especially, if you think about how many people there are in the world or are in the US. It is very, very low. If you look at rates of cancer, rates of heart disease, they are much, much higher. So, umm…I mean it is not a very high death rate. But there has also been a lot of discussion that people that have the coronavirus have lung damage afterwards.
Int.	I'm going to just highlight the two numbers [1.5% and 0.1%]. What kind of comparison can you make?
Katie	Well, I mean, the seasonal flu probably has such a low death rate because we have vaccines for it…
Int.	Right. What about the values themselves? The numerical values of 1.5% and the 0.1%.
Katie	Well that would make COVID-19 much higher.

Katie said both infection fatality rates are very small (albeit with 1.5% much higher than 0.1%), and she did not say a small percentage of a large number of people still meant a large number of deaths. In fact, she suggested the opposite – that a small percentage was insignificant because it applied to so many people in the world or the US. She compared infection fatality rates from contagious viruses to non-infectious causes of death. The infection fatality rates did not perturb her original belief that COVID-19 did not warrant extreme measures outside of current hotspots. Katie's responses indicates that what people infer from data is subject to their prior beliefs.

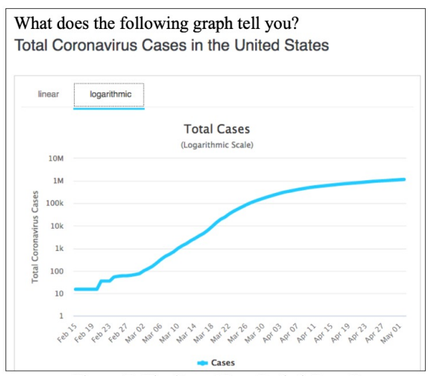


Figure 7. The item, "Log Scaled Cases"

Table 3. Responses to "South Korea Cases", "Three Country Cases", and "Log Scaled Cases" items

	"South Korea Cases", "Three Country Cases", and "Log Scaled Cases"		
	Focused only on steepness	Gave quantitative meanings to steepness	Unclear
The log scaled graph looks different or less scary than other graphs	10	5	3
The log scaled graph looks same as other graphs	0	7	0
Unclear	2	2	3
Subtotal	12	14	6

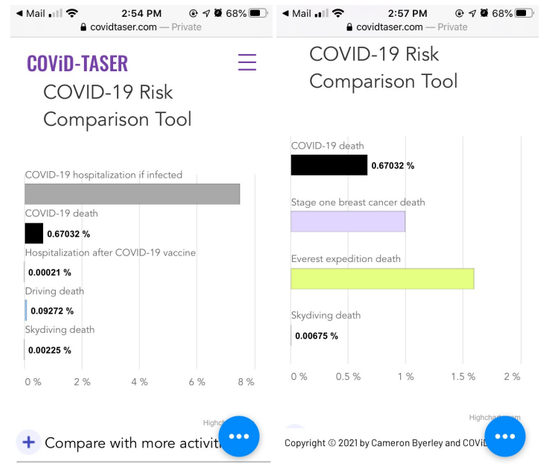
Ten citizens only focused on steepness and not the graph's axes or scale, concluding that the log scaled graph looks less severe than the linear graph.

Support

Our National Science Foundation RAPID grant (DUE- 2032688) incorporates a diverse project team to investigate how people interpret media used quantitative data representations (QDRs) of COVID-19 data. Drawing on our respective areas of expertise, we also produce novel QDRs to support individuals in making data-informed decisions regarding their behavior, personal health risk, and the health risk of others.

Future Direction

In Phase II, the project team applies findings from Phase I and STEM education research to create research-based, project-designed QDRs while simultaneously investigating the extent these QDRs better support individuals in understanding the pandemic. In Phase III, the project team enacts an active dissemination plan in order to draw attention to project generated knowledge and products. Current risk assessment tools in development are available at **www.covidtaser.com**.



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