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Analyzing the Use of Social Media to Communicate the Intersection of the Gut Microbiome and Mental Illness

Grace LaFrance
University of Maine - Main, grace.lafrance@maine.edu

ANALYZING THE USE OF SOCIAL MEDIA TO COMMUNICATE THE INTERSECTION OF THE GUT MICROBIOME AND MENTAL ILLNESS

by

Grace R. LaFrance

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Advisory Committee Members
Lynn A. Atkins, Instructor of Biology, Advisor
Jennifer Blossom, Ph.D., Assistant Professor of Psychology
Susan Bredlau, Ph.D., MSW, Assistant Professor of Philosophy
Melissa Ladenheim, Ph.D., Associate Dean of The Honors College

ABSTRACT

This study examines the availability and accuracy of information about the connection between the gut microbiome and the brain, specifically mental illness. Mental illness is a general term used to describe nearly 300 mental disorders, though the two most common, anxiety and depression, were of specific interest for this study. The current biological/ neural theories for anxiety and depression do not adequately illustrate many other factors that influence the development of mental illness. After determining that Generation Z is one of the age groups most affected by these mental illnesses, social media was used to analyze the availability of the information on the connection.

The range of birth years falling in Generation Z is approximately 1997 to 2010, This generation that succeeds Millennials precedes Generation Alpha is more likely than any other generation to use social media for scientific and medical knowledge, therefore it is imperative that the information they are consuming is accurate and recent. Thirty-five Instagram accounts were analyzed and classified into 5 categories. This was done to compare the effectiveness of different fields of study to communicate scientific information to the public.

The most followed type of account was the aesthetic/ encouragement category by approximately 414,000. This account type scored an average of 2 out of 4 on information accuracy, though the accounts did not communicate scientific information. These accounts had 0 posts containing information about the gut microbiome and brain connection. Accounts that were run by dieticians and nutritionists were the least followed, while simultaneously having the second highest accuracy score. They also had

the highest average number of posts with information pertaining to the gut microbiome and brain connection. Accounts run by MDs posted an average of 3 pertinent posts in the last 6 months, the highest of any category. This calculates to only about 0.02% of the total content posted in the last 6 months. Based on these results, *social media does not specifically and adequately address the connection between the gut microbiome and depression and anxiety.* This thesis suggests future implementations to close the knowledge gap between scientists and medical professionals and the communication needs of the general public, specifically Generation Z. It also discusses the other social science lenses needed to completely understand the causes of mental illness and do justice to the millions of people that live with them every day.

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INTRODUCTION

Nearly 52.9 million people in the United States live with mental illness which equates to about 1 in every 5 adults (37). The most common mental illnesses include generalized anxiety disorder and major depressive disorder (53). According to the American Psychiatric Association, an anxiety disorder is characterized by “feelings of worry, anxiety, or fear that are strong enough to interfere with one's daily activities” (40). Depressive disorders are characterized by “persistent sadness and a lack of interest or pleasure in previously rewarding or enjoyable activities” (13). In the last several decades, American society has worked to reduce the stigma and shame that are associated with living with mental illness. Throughout the history of western civilization, starting as early as Cartesian philosophy, mental illness has been associated primarily with the brain (31). In 1950, the World Health Organization (WHO) defined mental health as, “a condition, subject to fluctuations due to biological and social factors...” Though some variation of this definition has remained since, there is not a generally accepted definition today. Medical professionals and scientists operate under a predominantly biological and neurological lens of mental illness. Similarly, psychologists and social scientists use a biological lens, though they possess a cultural lens as well. This dominant neurological view of mental illness is demonstrated by the type of help that individuals struggling with these illnesses receive. For every 8 adults that suffer with mental illness, 1 person seeks treatment for their mental illness, or about 12.1%. 86% percent of the individuals that seek treatment receive prescription drugs, and 25% receive psychological therapy. Only 11% receive a combination of both (35). The drugs prescribed target aspects of the brain

physiology, specifically post-synaptic transmission of important neurotransmitters involved in emotion regulation and response.

The transmission of neurons is stimulated both electrically and chemically. It begins with an electrical impulse, also called an action potential, travelling down the axon of a neuron. The action potential will cause a chemical change that causes vesicles carrying neurotransmitters, or chemical messengers, to fuse with the presynaptic membrane and release them into the synaptic cleft, which is the space between the axon terminal of one neuron and the dendrite of another. The Neurotransmitters then bind to receptors on the surface of the postsynaptic neuron, which then creates an action potential that will travel down the axon of that neuron. The neurotransmitters are released from the receptors and are carried back to the presynaptic membrane by reuptake pumps to be repackaged into the vesicles. Low levels of serotonin would theoretically cause dysfunction in the regulation of stress-induced cortisol responsiveness and activation of the neural circuits involved in mood and anxiety disorders (12). At the neuronal level, a decrease in serotonin would lead to a reduction in neurotransmission in the frontal areas of the brain to inhibit the firing of the amygdala. As the part of the limbic system in the brain that controls fear and other emotional responses (41), dysfunction can lead to symptoms of anxiety and depression. Though approximately 10% of serotonin is produced in a part of the brain called the raphe nuclei, located in the midline of the brainstem, it is estimated that 90% of the body's serotonin is produced in the digestive tract (2).

The widely accepted cause of mental illness, specifically anxiety and depression is the miscommunication between neurons, or neurotransmission. This is a generally approved of or used theory used by doctors and scientists to explain mental illness to patients and discuss it amongst each other. This is not the most recent or accurate understanding of the cause, and one that is will be introduced and discussed later in this thesis. Those patients with disorders like anxiety and depression are thought to have abnormally low levels of serotonin, dopamine, or norepinephrine (38). Serotonin is a neurotransmitter responsible for many aspects of the brain including mood and cognition, as well as other physiological processes like blood clotting, digestion, and mineral deposition of bones (2). Dopamine and norepinephrine are both neurotransmitters that play roles in the brain's reward center and the fight or flight response, respectively (47). The concentration of neurotransmitters in the brain is something that cannot be tested. Medical professionals may test for the level of serotonin in the blood, but usually to gain insight on tumors outside of the brain that produce serotonin. The results are not indicative of serotonin in the brain (29). When depression or anxiety-like symptoms arise, the initial treatment is antidepressant medication, such as SSRIs. Considering that there is no diagnostic test to determine specifically which neurotransmitter the patient may lack, doctors or practitioners may prescribe different drugs at varying dosages until an effective treatment is found.

The most common class of drugs prescribed are called SSRIs (selective serotonin reuptake inhibitors), with common names like Prozac, Zoloft, Lexapro, and more. Serotonin is a monoamine neurotransmitter that is important for mood, cognition, and emotion regulation. These drugs are thought to act by inhibiting the reuptake of serotonin

onto presynaptic neurons, hence higher rates of post synaptic neurotransmission, increasing the concentration of free serotonin in the synaptic cleft between neurons (18). However, this explanation is only a hypothesis, though it has been widely accepted since their use became popular in the early 1990s. Some scientists are now starting to accept that the hypothesis must be an oversimplification of the pathway and are investigating how exactly what makes these antidepressant drugs effective. The 13.2% of American adults that take this medication and others like it may not be aware that the neuromechanisms of these drugs are mostly a mystery to the medical and scientific community. There are also many harsh side effects that can come with taking these medications even short-term, as well as unknown long-term side effects (33). Therefore, it is essential that other methods of treating depression and anxiety are discovered, researched, and made easily accessible by the public.

For years, causes of mental illness were thought to be confined to the brain, as a result of the serotonin hypothesis that was generally accepted in the 1960s. This hypothesis arose from evidence from postmortem brains and blood samples (14) and proposes that reduced or diminished activity of serotonin pathways plays a causal role in the pathophysiology of depression. This theory provided a plausible mechanism for how the most common drug used for treatment of depression and anxiety (SSRIs) works. Therefore, research on the gut microbiome and mental illness connection began long after the enteric nervous system was discovered a century ago. The enteric nervous system (ENS) is the largest of the three components of the peripheral nervous system, one of the two brain branches of the nervous system alongside the central nervous system (comprising the brain and spinal cord). The peripheral nervous system includes all the

nerves and components of the nervous system that extend from the brain and spinal cord (9). The peripheral nervous system is then broken into two parts, the autonomic and somatic nervous systems. The autonomic nervous system controls involuntary movements and bodily processes, and it comprises the sympathetic, parasympathetic, and the enteric nervous system. The sympathetic nervous system (SNS) is primarily triggered when there are increased levels of cortisol in the blood in response to stress. The outcomes of SNS activation can accelerate the heart rate, dilate bronchial passages, decrease activity of intestinal muscle, and constrict blood vessels, as well as other physiological fight-or-flight responses (1). On the contrary, the parasympathetic nervous system (PNS) is responsible for helping the body return to homeostasis after a period of danger or stress, as well as sustaining processes like digestion while the body is at baseline.

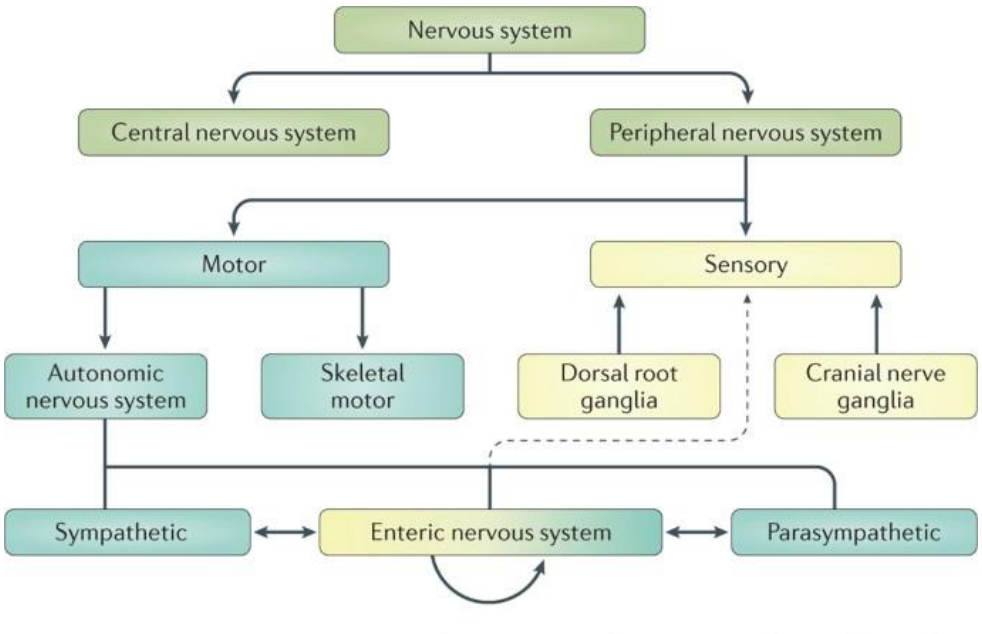

Figure 1. Relationship between the ENS and components of the peripheral nervous system (46).

The enteric nervous system (ENS) is the largest section of the peripheral nervous system that extensively connects with the sympathetic and parasympathetic systems. It is involved in the innervation and secretory components of the digestive system organs and extends from the esophagus to the rectum. The ENS contains about 100-500 million neurons (estimated to contain more than the whole of the spinal cord (22) and is similar to the brain in structure and function, sometimes called “the second brain”. Afferent nerve fibers that travel from the intestinal organs to the brain account for 80-90% of nerve fibers present, as the ENS is involved in both sensory and motor control (10). The tenth cranial nerve (the vagus nerve) is the longest nerve of the parasympathetic nervous system and runs through the ENS as well as the organs of the digestive system. The nerve connects the ENS to the medulla oblongata of the brainstem via the neck and thorax. The location of the enteric nervous system is unique because it can be influenced by both internal and external factors, because the neurons of the ENS are found in complexes between the intestinal walls.

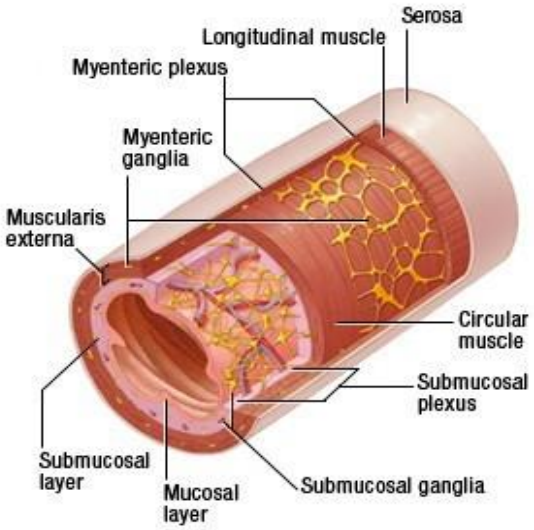

Figure 2. Graphic depicting the internal anatomy and muscular/ nervous structure of the intestinal walls (34).

The enteric neurons can be directly stimulated by the microbes native to the microbiome, mechanically or chemically stimulated by the food present in the lumen of the intestines, or by the vagus nerve. The exact mechanisms of interaction between the intestinal microbiome and the neurons of the enteric nervous system are not yet fully understood (22). These interactions are complex. There is evidence to suggest that gut microbiota can influence ENS activity by producing molecules that are able to act as local neurotransmitters, like GABA, serotonin, and acetylcholine (6). The bacteria can also produce an active form of catecholamines in the lumen. Catecholamines are neurohormones important in stress responses. The "fight or flight" response of the sympathetic nervous system is a direct result of cascades stimulated by catecholamines (39).

The gut microbiome provides benefits for the formation and function of the immune system (34). This is demonstrated when individuals undergo antibiotic treatments that kill foreign bacteria in the body that are causing infections in its host. Antibiotics are nonspecific and are not able to differentiate between the problematic foreign bacteria and the bacteria that is a part of the microbiome. These bacteria play a crucial role in the immune system and its processes (7). Individuals then become more susceptible to more severe infections, as their immune system is weakened because their gut microbiome is compromised. More recent discoveries are that the gut microbiome plays an important role in development of autoimmune diseases and other pathologies, as well as brain and nervous system functionality (34).

There are over 100 trillion bacteria naturally found in the body, and approximately 95% of that is in the gut microbiome, primarily in the part of the colon

named the cecum (17). The gut microbiota interacts with the ENS and therefore the central nervous system by influencing brain chemistry and neurological-endocrine systems responsible for stress response and anxiety (10).

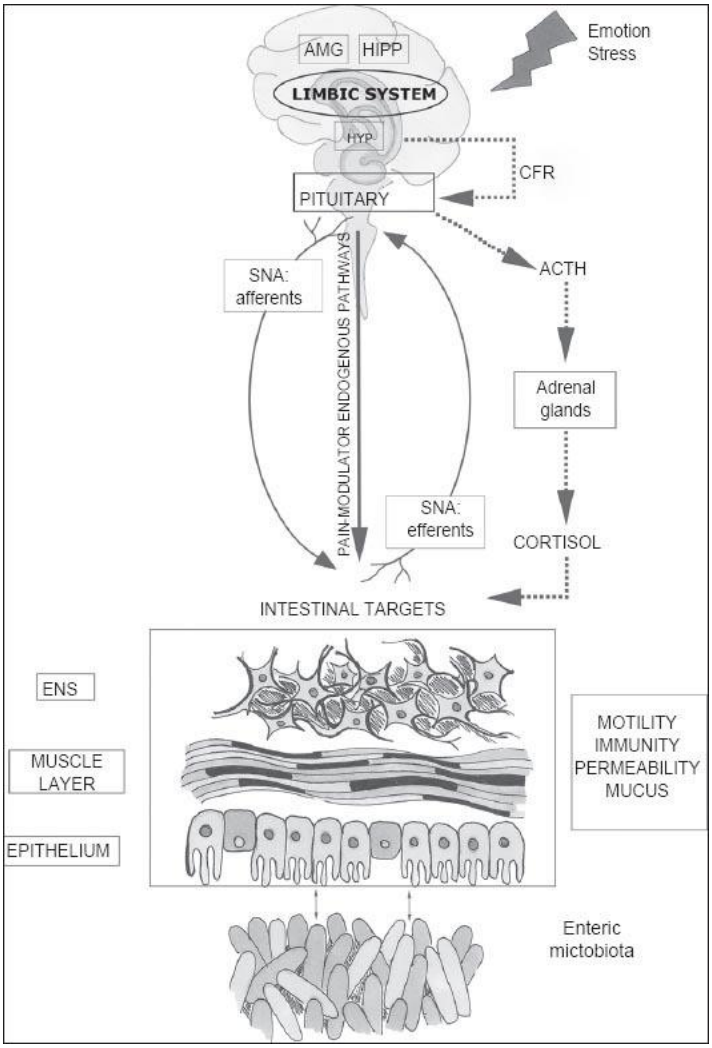

Figure 3. Graphical depiction of the microbiome gut-brain axis structure, how the brain influences the gut and vice versa (6).

Recent research has shown that the gut microbiome influences basic neurological processes, such as the formation of the blood-brain-barrier, myelination, neurogenesis, and microglia maturation, and modulates many aspects of animal behavior (34). Neurogenesis is the growth and development of nerve tissue, limited in adults to two regions of the olfactory system and the hippocampus (29). The hippocampus is a region

of the brain important for learning, memory, and emotional processing, like anxiety and avoidance behaviors, and plays important roles in long-term memory and emotional responses (20). Studies also found that postmortem, individuals with depression had smaller-sized hippocampuses than individuals who did not (20). Regarding the blood-brain barrier, when studies are performed with mice, the absence of gut microorganisms causes it to be more permeable to macroorganisms (47). The blood brain barrier is an endothelial-tight junction structure that surrounds the brain and protects it from harmful foreign particles like toxins and disease-causing pathogens that may be present in the blood flowing through the capillaries that supply the brain with oxygen. Increased permeability loosens the tight junctions, allowing larger molecules to enter the brain tissue, causing inflammation and sometimes death (44).

More extensive research needs to be performed by scientists and psychologists to gain more confidence in the evidence gathered. From there, they can work with medical professionals and legislators to find a way to incorporate and translate these important findings into usable and accessible treatments and options for people. Before that happens, the public needs to be aware of the connection and the possibilities it creates. That means that scientists and medical/ dietary professionals need to communicate their findings to the public in a way that is effective and accessible to the most people. In modern society, social media can be a very effective tool to communicate news and information for that purpose.

In a survey performed in 2022 by Pew Research Center, 91% of American adults consume news via social media. The study also revealed that social media provided more news to the public than print news (43). Twitter, Facebook, and YouTube were the most

popular social media platforms for news consumption for all adults in 2022 (24). The younger Generation Z is perhaps the one most affected by the rampant development and use of social media that has taken place during their lifetime. Unlike other generations, Gen Z has never lived without the internet, technology, and social media being such an integral part of society. In the last 3 years, the COVID-19 pandemic has shed light on the mental illness epidemic of the younger generation, and people have become more aware as symptoms have become exacerbated by isolation and political turmoil. Social media use has also only increased since the pandemic. Sixty-five percent of Gen Z consumers have increased their use of social media in the last year. How Gen Z uses social media is another way they are set apart from previous generations. Research performed by Healthline concluded that in general, 76% of adults use WebMD and other health-centric sites as the first source of information regarding health conditions. However, when specific age groups were analyzed, social media platforms became the primary source of Generation Z and Millennials to obtain information about health (31). Generation Z is twice as likely to look to social media platforms for health advice and information (28). On the contrary, older generations are more likely to seek advice or direction from their doctors and other medical professionals directly (31). This means that Generation Z is more likely to consume information about medicine and health issues from unreliable sources, as there is very little ability of social media platforms to censor or filter the information that is posted and consumed by users.

METHODOLOGY

Part 1: Establishing Connection

Forty-two percent of Generation Z have a diagnosed mental illness. Depression and anxiety were chosen as the specific illnesses and 9 out of 10 individuals diagnosed with a mental illness are diagnosed with anxiety, and nearly 8 out of 10 are diagnosed with depression (51). Twenty-four peer reviewed scientific articles were collected using 3 search terms to establish that there is a connection between the gut microbiome and mental illness, specifically anxiety and depression. Search terms were as follows: "Enteric nervous system and anxiety", "Gut microbiome and the brain", "Probiotic effect on mood". Eight sources for each search term were collected. Google Scholar was utilized because it provided many peer reviewed articles which are subject to a very rigorous review process, mainly the evaluation of methods and research process by recognized experts in the field. This part of the study draws upon others' published material and the conclusions drawn from them. These conclusions lie as the basis for the rest of the study. This connection between the gut microbiome and mental illness can be conclusively stated due to the analysis of many landmark scientific studies. These terms and keywords were chosen because they provided results related to the research question.

Part 2: Social Media

The next part of data collection was to research which social media platforms are used the most in the age group of interest, Generation Z. For the last 5 years, the most used platform was found to be Instagram (52). In 2022, TikTok and Snapchat had a

higher percentage of users than Instagram, but Snapchat accounts can only communicate with each other when both parties add each other (think of Snapchat as an instant messaging app with photos instead of texts), and TikTok has an algorithm that accounts for users seeing the videos that they do (8). Users do not need to be following accounts that post videos for them to appear on the user's feed. Therefore, neither of those platforms can provide accurate or measurable information about user consumption.

Next, Instagram was used to search for accounts pertaining to depression, anxiety, and the gut microbiome. Hashtags were searched based on key words pertaining to the study and accounts were obtained from the results. Hashtags searched included: #depressionhelp, #depressionsupport, #depressionscience, #gutmicrobiome, #brainhealth, #gutbrainconnection, #anxiety, #mentalillness. In order to examine whether the field of study of an account holder was associated with the accuracy of what they post and the amount of content on the gut microbiome and brain connection, the accounts were classified into the following categories: Run by dietician/ nutritionists, run by representatives for nonprofits, run by MDs, for the purpose of encouragement/ awareness using aesthetics, or other. Accounts under the other category were accounts that contained scientific information about mental illness or the enteric nervous system but did not fit into any of the categories listed above. Accounts were only included as a part of the study if they had over 1,000 followers and were presently active. Any account that had not been updated for more than 2 weeks was not included. Thirty-five accounts fit the inclusion criteria of over 1,000 followers and active status. The websites of scientific organizations were examined for links to social media pages. Those organizations that included links to Instagram pages were included in the study. The following

organizations met the inclusion criteria: The Gottman Institute, National Institute of Mental Health, Brain and Behavior Research Foundation, and the National Alliance on Mental Illness.

Data was collected from each of the 35 accounts in addition to what was accumulated using the rubric (table 1).

Information Gathered	**Justification**
1. Country of origin	To determine if any country is more effective than another at getting information about mental illnesses and ways to treat it to the public via social media
2. Number of followers	To estimate the reach of the account and about how many people are seeing its posts
3. Status of verification*	To confirm that it is the authentic presence for that person or brand

Table 1. Additional data gathered from the accounts, as well as the justification for inclusion.

*Verified status was tracked, though it is worthwhile to note that "a verified badge is not a symbol to show importance, authority or subject matter expertise." (20). Also, if an account is not verified, it does not necessarily mean the account is falsified or a non-authentic presence. Higher number of followers may be correlated with verified status as when an account becomes more notable, they would be more likely to be noticed by Instagram to get that verified status.

Part 3: Evaluating Sources

The rubric (Fig.1) was created to evaluate the sources, or Instagram accounts.

	4 (great)	**3 (good)**	**2 (okay)**	**1 (bad)**
Correctly defines terms	Definitions are accurate, consistent	Definitions are accurate but inconsistent	Definitions are mostly accurate, inconsistent	Definitions are mostly inaccurate or absent
Information is accurate	Information is factual, not opinion based	Information is mostly factual, very little opinion based	Information equally both factual and opinion based	Information is not factual, mostly opinion based
Sources are recent and cited	Sources from within last 5 years	Sources from within last 10 years	Sources from within last 15 years	Sources from within last 20 years or absent
# of advertisements in last 2 months	3>	5>	7>	7<
Pertinent information about enteric nervous system/ gut microbiome	5 relevant posts within last 6 months	3 relevant posts within last 6 months	1-2 relevant posts within last 6 months	No relevant posts within last 6 months
# of posts weekly	7 or 8	5 or 6	3 or 4	3>

Table 2. The rubric used to evaluate and later analyze each account collected as a source.

Every component of the rubric used to evaluate the accounts was created purposefully (table 3). The terms *mostly* accurate and *mostly* factual used in the first two

components are used to qualify approximately 80% of the content. If 80% of the content posted was determined to be accurate or factual, it was given a score of 2 for “correctly defines terms” and 3 for “information is accurate”. The score was determined using posts in the last 6 months. The accuracy and correctness of information was assessed using published peer reviewed articles accessed using Google Scholar. The descriptions of levels of each component often had to be changed slightly based on what was being found during data collection. For example, when the rubric was first created, “Pertinent information about enteric nervous system/ gut microbiome”, the window of time was the month prior to data collection. As I started to collect data and fill out rubrics, I realized that the majority of the accounts did not contain posts in the last month, therefore the time frame needed to be adjusted in order to be suitable for the data.

Component of Rubric	**Justification**
Correctly defines terms	As those are the mental illnesses in question and is the first indication if the viewers of the posts can trust the account's material.
Information is accurate	Speaks to the knowledgeability of the person sharing the information, and the quality of information being spread to the people following them. Having opinion or experience based subjective statements may lead to misinformation in the public.
Sources are recent and cited	Speaks to the accuracy of the information being shared and prevents the spread of misinformation. Exhibits knowledge of the scientific process on the account owner's part.
# of advertisements in last 2 months	Displays the account owner's motivation for posting- to truly inform and educate people, or to benefit from paid partnerships.
Contains information about enteric nervous system/ gut microbiome	The topic of interest in my thesis is if Gen Z is getting exposed to the connection between the enteric nervous system, the gut microbiome, and mental illness.
# of posts weekly	Shows engagement, more posts means more likelihood that followers will see them in their news feed or in the discover page.

Table 3. Components of the rubric used to evaluate accounts and justification for inclusion.

Part 4: Data Analysis

Each account was classified into 5 categories (table 4). It is important to note that the categories were created after the completion of all data collection, the accounts were not selected or analyzed with the classifications in mind. The accounts that were run by

dieticians or nutritionists had specific person(s) listed in the biography of the account that had credentials such as LD (licensed dietician) and RDN (registered dietary nutritionist). The accounts run by representatives for nonprofits did not have a specific person listed in the biography but were run by a person or group of people that posted on behalf of the organization. Accounts run by MD's were only classified as such if they listed a medical board-certified individual(s) in the biography of the account. The accounts classified under aesthetics/ encouragement/ awareness were not run by professional individuals and posted content with the goal of raising awareness, sharing tips and aesthetic or artistic imageries and quotes. Any account in the study that did not fall under any of these 4 categories was labeled as other and did not contain content that was classifiable.

Classification	**# of accounts**
1. Run by dietician/ nutritionists	7
2. Run by representatives for nonprofits	5
3. Run by MDs	9
4. For Aesthetics/ Encouragement/Awareness	10
5. Other	4

Table 4. The 5 categories accounts were classified into following data collection, and how many accounts fell into each.

The average number of followers for all the accounts was calculated, as well as the averages for each category, with and without outliers. The data with outliers is presented, as their exclusion did not alter the conclusions drawn from it. The average number of posts per week was calculated. The accuracy of the information and

correctness of definitions for each account was rated from 1-4 using the rubric. These two variables were combined for this statistic, because in most cases, these scores were the same. There were no accounts that scored more than one point higher or lower in one of these categories than the other. In the case of the scores being one apart, the account was given the average score. For example, an account with these ratings- Correctly defines terms: 4, Information is accurate: 3- would receive an overall rating of 3.5. The average number of posts containing information about the gut microbiome and brain connection for all of the accounts combined, then each category as well.

RESULTS

This study was conducted in order to determine if *social media specifically and adequately addresses the connection between the gut microbiome and depression and anxiety.* Data collected were analyzed quantitatively and qualitatively.

The accuracy of the information on each account was rated from 1-4 using the rubric (table 2), then the 5 averages for each category. The average number of posts containing information about the gut microbiome and brain connection for each category was calculated. The average number of followers for each category was calculated.

Category	Avg. accuracy	# Of pertinent posts	Avg. # of posts/ week	Avg. # of followers
Dietician/ Nutritionist	3.1	2.7	4.8	154,625
Nonprofits	2.91	0.2	5.8	227,705
MDs	2.92	3	5.14	296,778
Aesthetic/ Encouragement	2	0	4.5	710,729
Other	2.875	1.75	3.75	161,741

Table 5. Average scores and followers determined using rubric for each category.

The dietician/ nutritionist category of account had the highest average accuracy scoring than any other category (3.1), while the aesthetic/ encouragement category had the least (2). MDs had the number of posts pertaining to the gut microbiome and brain, with an average of 3 posts in the last 6 months. The aesthetic/ encouragement category

had the least, with 0 posts in the last 6 months. The nonprofit category had the highest average number of posts per week (5.8), while the "other" category had the least (3.75). The aesthetic/ encouragement category had the highest average number of followers by almost 414,000 (table 4, figure 4). Four other categories had 1 calculated outlier each, which made their averages skew higher. The aesthetic/ encouragement category had no outlier skewing its average.

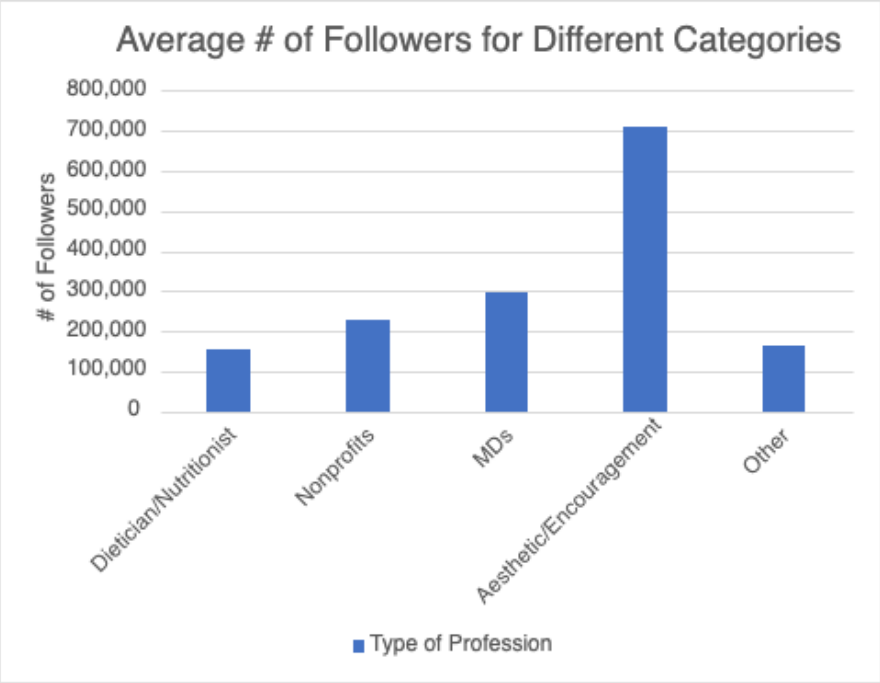

Figure 4: Histogram depicting average number of followers for all 5 categories of accounts.

DISCUSSION

Research on the connection between the gut microbiome and the brain has become more widespread in recent years. It is imperative that this information be distributed in a manner that is appropriate and effective for the general public. One of the most effective ways to offer this content to the public, specifically Generation Z, is through social media. The most used social media platform by Generation Z is Instagram (38). After comprehensive analysis of 35 Instagram accounts classified under the categories of mental health, illnesses, gut health, and the gut microbiome, it could be concluded that *social media does not specifically and adequately address the connection between the gut microbiome and depression and anxiety.* This is problematic for a generation that is substantially affected by mental illness.

The nutrition/dietary category was found to have the highest overall accuracy rating of all the groups. MDs were the next highest, then nonprofits. The difference between the first and second highest average rating was only 0.17, and only 0.01 between the second and third (table 5). This result demonstrates that the nutrition professionals, MDs, and nonprofits all communicate accurate and up to date information. Though it is important to note that very few of these accounts listed the sources from which their information was derived. Though the content was accurate, it may not appear as credible as accounts that had both a knowledgeable and accredited individual behind the account in addition to having recent sources cited.

The type of accounts that had the highest average number of posts per week was the nonprofit category. The number of posts per week can demonstrate involvement and engagement on the account owner's part. One explanation for this category having higher engagement is that the account owners are representatives for the organization that the account reflects. It is likely that one or more people have the designated job to post content to the account. The other categories may have to make time to post content outside or a part of their professional careers.

The accounts that had the highest average number of posts about the gut microbiome and brain connection in the last 6 months were MDs, then dietician/ nutritionists, then the "other" category. These accounts still had very few posts on this subject. MDs had just 3 posts in the last 6 months. They had an average of 5.14 posts per week, or approximately 134 in the last 6 months. Therefore, approximately 0.02% of the posts in the last 6 months contained information regarding the connection between the gut microbiome and the brain. Of these posts, even less extended that connection to the impact on mental health and illness. This could be because the connection is not well known within the scientific/ psychiatric professional community, just as it is not well known to the public.

Instagram accounts for research organizations or institutions posting about scientific breakthroughs in mental illnesses and its treatments were the least followed accounts, while the accounts for the purpose of aesthetic and encouragement, had almost 414,000 more followers than the next highest category: MDs (table 5). Potentially this is due to scientists and medical professionals not effectively communicating such

information to the public, only among colleagues that are knowledgeable in the field of medical dialogue. In recent years, the popularization of "social media influencers" has revolutionized the way brands and companies advertise products to the public. Users tend to feel connected to these influencers because there is an ability to interact and become familiar with them, which makes them appear more authentic (36). It is important to note that research indicates that human beings are predisposed to trust those with whom we can see more similarities and likeness to ourselves, as a result of the need we as a species have for engagement and connection (31). This tendency, combined with the ability of the influencers to utilize social media to portray their lives as exemplary and desirable, users are more likely to purchase or adopt habits that they promote. This is a dangerous idea because the phenomenon does not only apply to business and advertising, but also the health/wellness and other professional fields in which they likely have no expertise.

Scientists and medical professionals play a key role in communicating accurate information to the public, particularly when discussing complex or technical content that may be difficult for the average person to understand. Due to their training and extensive education in the fields they study, they are much more credible and knowledgeable than the influencers and content creators on social media. Effective communication of scientific information to the public can help to promote understanding, dispel myths and misconceptions, and promote public support for science. Alternatively, doctors have the power to spread misinformation if they themselves are not effective communicators or are misinformed. Making sense of scientific information is no easy feat- especially when consumers are faced with many contradictory ideals. For example, the internet and media are rampant with contradictory claims about the risks and benefits of fat, salt, added

sugar, and genetically modified organisms (GMOs) in food. On a political and economic note, policy makers must make decisions based on imperfect, often incomplete information. Those decisions often relate to issues—such as environmental regulation, new technologies, and food and drug safety—that are deeply rooted in science, though as a result, inevitably contain a degree of uncertainty (41).

The results of this study helped to determine if *social media specifically and adequately addresses the connection between the gut microbiome and depression and anxiety.* Though addressing this connection is important for Generation Z, in addition to previous and future generations, it is equally as important to understand all the factors that contribute to mental illness. In reality, there are many that create an environment in which human beings are susceptible to mental illness, specifically those in Generation Z. These factors include but are not limited to biology, society, technology, and socioeconomics.

There are many biological explanations circulating the scientific community, but the reality might just be that not any one of the theories or associations can adequately illustrate the causes of mental illness. One of the most widely used theories is the idea that there is a diminished amount of serotonin and/or other neurotransmitters in the brain. Theoretically, this would lead to a reduction in neurotransmission in the frontal areas of the brain to inhibit the firing of the amygdala. As the part of the limbic system in the brain that controls fear, and other emotional responses (45) dysfunction can lead to symptoms of anxiety and depression. However, this mechanism is a theory, and there is very little evidence to suggest that this is the actual cause. It is possible that this

explanation works in combination with the gut microbiota in the development of mental illnesses. Microbiota can influence ENS activity by producing molecules that are able to act as local neurotransmitters, like GABA, serotonin, and acetylcholine. The bacteria can also produce an active form of catecholamines in the lumen. Catecholamines are neurohormones important in stress and the "fight or flight" response.

The expansion of the viewpoint of mental illness from the brain to include other parts of the body like the gut and its microbiome is very beneficial to the community of people that struggle with them. It not only opens the door for new research on new treatments and explanations for mental illnesses, especially the most common ones like anxiety and depression, but also continues the process of shifting the responsibility of the illness away from the individual. At first glance, the gut microbiome may still seem to pertain only to the individual, but there are many factors that are involved in the microbiome of the gut, both internal and external. Though biology may play a role in mental illness, it is not appropriate to use only a biological lens to study and address mental illness as a whole.

Modern society can be stressful and overwhelming, with high demands for productivity, success, and achievement. With the focus of individual progress and constantly reaching and working towards having or being something better, social scientists warn that perfectionism is heading towards being an epidemic and a public health issue (49). Perfectionism is characterized by a "combination of excessively high personal standards and overly critical self-evaluations" (11). While striving for excellence can be a positive trait, perfectionism can lead to feelings of inadequacy,

anxiety, and depression when unrealistic expectations are not met. The individualistic system of society urges personal achievement, and therefore competition between individuals. This allows for increased social mobility, or changes in socioeconomic statuses, but also leads to increased social anxiety and puts strain on interpersonal relationships (49).

Starting as early as infancy, Gen Z has been surrounded by a world where a constant stream of information and social media use is prevalent. Maturing and developing in this environment can lead to increased pressure to always be connected, as well as feeling overwhelmed by the amount of information and stimuli they are exposed to. Social media use and exposure has also created a generation that lacks critical social skills. Human beings as a species rely heavily on social cues and nonverbal communication to connect with each other (19). As a result of teenagers spending time online and not communicating face to face, they are excluded from experimenting, trying out skills, and succeeding and failing in small social interactions that allow us to form and maintain meaningful relationships (4). Additionally, many Gen Zers have faced significant stressors such as economic instability, political upheaval, and the COVID-19 pandemic. These situations, especially COVID-19, cause humans to feel out of control. This feeling drives actions that attempt to regain control and find an outlet for fear, which became evident with global shortages of supplies and a large amount of the population placing fear and distrust in the government. It also required long-term social isolation, which deprives humans of connection and interaction they need. This was detrimental to many people globally, but especially Generation Z who was at a critical age for relationship forming and face-to-face social interaction at the time of the lockdown.

Social media as a medium for the communication of scientific and medical progress can be very beneficial, especially because it can reach a wide audience. As of 2021, 4.26 billion people were using social media worldwide (53). It can also promote scientific literacy when content and explanations are comprehensible to someone without a scientific background. Though there is great power in social media as a tool for communication, it comes with many limitations. Content on social media may be oversimplified or misrepresented, leading to the spread of misinformation. Additionally, social media may not be the best platform for discussing complex scientific topics in-depth. Out of the 35 accounts used in the study, there were several that contained information on recent scientific research, but the information was not presented in a way that was comprehensible or intriguing to the average person without a scientific background. This can lead to misunderstandings between the public and the scientific community, which furthers the separation between the two.

Beyond that, there are harmful impacts that Instagram itself can have on its users, whether the individuals are consuming any misinformation. Instagram is reported to have the worst impact on mental health than any other social media platform in a study by the United Kingdom's Royal Society for Public Health (35). Instagram is among the platforms where users can share photos and videos of their lives, which oftentimes are posed and edited. This can lead to anxiety and self-worth issues in Gen Z and causes or aggravates existing issues of mental health. Research indicates that the more social media a young adult uses, the more likely they are to report symptoms of anxiety or depression (50). Though there may be value in mental health accounts that advocate and spread

awareness, the harm of an individual's presence on the social media platform in the first place might outweigh any benefit.

The fact that Gen Z accesses social media for health and medical information much more readily than other groups (23) signifies the crucialness of understanding credibility and accuracy of these accounts. Upon searching for accounts using keywords representative of the research, the hashtags #entericns (fewer than 100 posts), #entericnervoussystem (1000+ posts) yielded few results that fit the inclusion criteria. This poses the question of the depth of knowledge that the public possesses about the enteric nervous system. A component of the nervous system that can operate completely independently from the brain and spinal cord (central nervous system), one that is directly impacted by external stimuli, is one of the most important to be educated on. This starts in the school systems, in curriculum at both secondary and collegiate level academics. Though this research of the enteric nervous system, the gut microbiome that inhabits it, and how it connects to the brain began as early as 1998 (6), it is still not usually included in textbooks. Knowing that 70% of textbooks have new editions released every 3-4 years (15), it would be very beneficial to future generations for the recent research to be included in prospective editions of widely used textbooks and curriculum.

One way I found the communication lacking in my research is that the availability of info about the gut microbiome and mental illness is geared more toward people in the microbiology and nutrition fields... not mental health and psychology. There is a strong intersection between nutrition and psychology which is established within both communities. Nutritional deficiencies can impact mental health and cognitive function,

such as sleep, brain fog/alertness, memory, and mood (5). Understanding the connection between nutrients and mental health can help clinicians develop treatment plans that include both nutritional and psychological interventions. The intersection between nutritional science and psychology is a rich and complex field that requires collaboration and communication between experts from both disciplines to educate the public, especially those with mental illness.

Another social science lens needed to fully illustrate mental illness is socioeconomics. Factors such as poverty, violence, and social isolation contribute to increased risk of mental illness. For example, people living in poverty may experience chronic stress and lack access to resources that support mental health, such as healthcare and social support networks. Poverty leads to the consumption of cheap, high carbohydrates and fat food, which in turn spike energy levels. The lack of nutritionally dense foods in the diet long-term leads to nutrient deficiencies. Several vitamins and minerals must be obtained from the external environment, such as magnesium, vitamin D and B12, iron, and omega 3 fatty acids are correlated with brain dysfunction (5). Eating a diet high in carbohydrates and fats and low in nutrients long-term can also lead to obesity. Studies have shown that adults with significant excess weight have a 55% higher risk of developing depression in their lifetime (57). If an individual is struggling with obesity, they may be limited in traveling, exercise, and other activities. This may lead to social isolation, which is associated with depression, anxiety, and panic disorders (43). Additionally, exposure to violence and trauma can lead to conditions such as post-traumatic stress disorder (PTSD), depression, and anxiety. For example, poverty is correlated with higher rates of child abuse. Childhood abuse, whether it be emotional,

physical, sexual, or neglect, is associated with decreased myelination of neurons, neuroplasticity, and dysfunctional neurotransmission (26). These changes in the brain, in combination with higher risk of social isolation and self-esteem issues, may lead to depression and the development of other mental illnesses later in life.

There were several limitations of the study present. Without them, the validity of the conclusions would increase even further. Statistical analysis, such as an ANOVA test, was not utilized for this study due to time and training restraints. Performing statistical analysis would have strengthened the conclusions by providing quantifiable answer of statistical significance. Another limitation of this research is that there is an immeasurable way that Instagram, and other social media sites, rank search results. Most followed accounts may appear first, or content that best fits the usage history. Data was collected using my existing Instagram account that was created over 5 years ago. Therefore, search results may have been catered to what an algorithm best predicted I would want to see based on past interactions. Prioritized results could vary between each person. That being said, the search bar was not the only pathway through which accounts were selected.

Based on the findings, there are several areas that need to be further investigated and explored. This study specifically focused on the social media platform Instagram and its effectiveness at scientific information and research communication. Instagram was found to be the most used social media platform by the age group of interest, Generation Z. However, there are several exponentially growing platforms that would be beneficial to analyze, namely TikTok. Facebook is a less recent platform than others, but it is highly

used among previous generations. An aspect of Facebook that is unique is that "sharing" or reposting content is very common. Since that is a quantifiable value, it would be very engaging to investigate and measure the spread of misinformation as well as where it comes from. Another variable that would be worthwhile to investigate is the comprehensibility of the information that is present on social media. Though many accounts involved in this study contained accurate information and facts about the connection between the gut microbiome and the brain, it still needs to be comprehensible and readable for someone without a scientific background.

Following this study, I have several suggestions for the future in order to increase the amount that social media specifically and adequately addresses the connection between the gut microbiome and depression and anxiety. It is imperative that information about enteric NS and gut microbiome are incorporated into curriculum at both secondary and college levels of education. At an even more basic level, children in K-12 should be exposed to the enteric nervous system, particularly through health and nutrition education. When explaining the impacts of diet and nutrition on the body, the brain and mental health should be included in terms comprehensible to them. In addition to education, school systems need to implement this nutrition, brain, and mental health connection by providing lunches that help establish a healthy gut microbiome. Diets with plenty of vegetables, legumes, fruits, and natural probiotics (such as yogurt) are recommended. Fruits and vegetables are high in fiber, which can only be digested by certain bacteria in the gut and will stimulate their growth. Individuals should also be encouraged to use antibiotics only when necessary, as they can cause rapid decrease in bacterial diversity and abundance. Another recommendation for the future is that

scientists and doctors need to become better equipped to educate in a manner that is comprehensible for an audience that is not in their field of study. One way to ensure this is for future scientists and doctors to be required to take a social media literacy class as a part of their training. Though it might be unrealistic, it would be ideal for there to be a part of every research project budget that is dedicated to hiring someone who is well versed in modern communication through social media.

In a modern world where technology develops and changes at an alarming rate and the differences between generations are more intense than ever, there is a clear gap in communication and media literacy between the youth population and previous generations that practice in the field of science. There is no clear answer to who would be the most successful at closing this gap, or how they might begin to do so. Regardless, it is imperative that we start working toward narrowing the boundary between the public and the scientific and medical community.

CONCLUSION

Based on my hypothesis and the accounts used to collect data, scientists and medical professionals need to adapt their methods of communication to cater to communities that are largely affected by their research findings. Generation Z is one of the most recent generations and has been shown to have higher rates of mental illness diagnosis. The study determined *that social media does not specifically and adequately address the connection between the gut microbiome and depression and anxiety.* However, there are many more factors that impact the development of mental illnesses and enable them to be as harmful as they are. The research of the gut microbiome is beneficial because it is a possible alternative of treating and preventing mental illnesses that doesn't involve harsh prescription drugs. Viewing mental illness through the lenses of biology, society, media, and socioeconomics allows for a more complete, multi-faceted approach to addressing them.

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AUTHOR'S BIOGRAPHY

Grace LaFrance is a biology major in the College of Natural Sciences, Forestry and Agriculture at the University of Maine. She will graduate in May of 2023 with a Bachelor of Science degree with a pre-medicine concentration. During her undergraduate education she worked as a Maine Learning Assistant and as a Concierge at Eastern Maine Medical Center in Bangor, Maine, and was also a member of the Outing Club. In her last semester and during the thesis process, she lived and studied abroad in San Ramón, Costa Rica. Grace is eager to start the next chapter of her life and continue learning about the world and herself. She plans to further her education and attend graduate school in the hopes of working in the healthcare or psychology fields.