Research Article

Communicating Cutting Edge Research on Physiological Networks: A Three-Step Method

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Medical knowledge and practice are usually structured and implemented by dividing the various organs and systems of the human body. This makes it easier to provide healthcare services and education, and to distribute tasks and responsibilities among different professionals. However, this approach has its limitations, as it overlooks the interactions between different systems that often transcend these divisions. Moreover, it neglects the systemic properties and behavior of the whole organism.

Calmecac is a transdisciplinary research group at the National Autonomous University of Mexico (UNAM), founded in 2019, with the goal of enhancing human health by viewing the human body as a complex system. The group carries out innovative research on physiological networks, exploring how human physiological systems and organs are interconnected.

To share its main findings with various audiences, Calmecac hired a science communicator who followed a three-step method:

1. A thorough immersion into Calmecac's research, including involvement in experimental activities.

2. The identification and concise explanation of the main concepts and results to be communicated.

3. The integration of three essential elements of discursive strategies (credibility, legitimacy, and attention capture) in the creation of science communication materials: a popular science article and a series of TikTok videos.

The next stage of this research will consist of evaluating the effectiveness of these videos in transmitting scientific information using four memory tasks: recall, identify, remember, and contextualize (RIRC Method). The study will also aim to ascertain if the information best remembered by participants matches well with the features related to the three elements of discursive strategies.

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Introduction

How is our brain connected to the rest of our body? What is the effect of obesity on human health? How much exercise do we need every day? These and other questions are related to human physiology, an area in which human beings have been interested for thousands of years. To study human physiology, there are two main approaches: the holistic and the reductionist one. According to the first one, our body is an indivisible entity, and therefore, it can only be understood by studying it in an integral manner. The holistic approach has been present since ancient times, for instance, in the Egyptian medical treatise, *Papiro Ebers* (1500 B.C.), and in the studies of Hippocrates (440-360 B.C.), Galeno (129-201), and Avicenna (980-1037) (Lartigue et al., in press). According to all of these studies, the functioning of our body depends on the interconnections between our organs and systems.

The reductionist approach, in contrast, assumes that the whole is the sum of its parts, and that it can be understood by analyzing them separately. In medicine, it is represented by specialization, whereby a substantial amount of research on individual organs and systems has been carried out. Although it has existed throughout history, the work of French mathematician and philosopher René Descartes enhanced its importance in science. He visualized the human body as a machine to be studied through its components.

Specialization has influenced the way doctors diagnose sicknesses and prescribe medicines. Partly thanks to specialization, our life expectancy has more than doubled in the past two centuries (Oeppen and Vaupel 2002). However, it has some limits that can be overcome by considering the human body as an integral entity, in which all organs and systems continuously interact. According to this perspective, a network is used as a metaphor for the human body instead of a machine (Ahn et al. 2006). These interactions give rise to emergent properties, such as conscience. It is not the individual functioning of neurons that produces it but rather the interactions among millions of them.

In 2019, the Calmecac group was created at the National Autonomous University of Mexico (UNAM). It is a transdisciplinary research group that studies human physiology with a holistic approach. Researchers of Calmecac build physiological networks in order to try to understand the coordinated activity of human organs and systems. One of its main assumptions is that an adequate health condition requires a balance between the capacity of our body to adapt to external and internal changes (adaptability) and its capacity to keep physiological variables (heart rate, body temperature, insulin and glucose levels, body weight, etc.) under control (robustness) (Rivera et al. 2018).

The study of physiological networks is an emergent field of research. One of its pioneers is Dr. Plamen Ivanov, from Boston University. For instance, by constructing physiological networks, his group has studied brain and muscle activity in order to understand the processes of loss of muscle tone during REM sleep. They have also studied synchronization of different muscle fiber types to respond to fatigue during maximum exercise (García-Retortillo et al. 2023). Another outstanding researcher in this field is Dr. Natalia Balagué, from Barcelona University. Her group discovered that heart rate and breathing rhythm are highly coupled during exercise (Balagué et al. 2020).

Through its research, Calmecac has been able to distinguish different physiological systems in the human body, as well as to identify specificities of different population groups, such as male and female sexes, between young and elderly people, and between homeless and housed young males. The scientific relevance of the academic works of this group is notorious. Since the establishment of Calmecac, a total of 16 articles has been published in high-impact indexed journals, the members of the group have attended 14 conferences, and over 20 undergraduate and graduate students have participated in different research projects.

Given that this group produces cutting-edge research and that most of its findings can have an important impact on health care, the members of Calmecac were interested in disseminating them among different publics. Therefore, a science communicator was hired (first author of this article). The products of the collaboration between the science communicator and members of the team are a science dissemination article, as well as a series of short clips for a TikTok channel, specially created for Calmecac.

Even though music and entertainment are the most searched categories on the internet, science videos have also become top trending [Dubovi & Tabak, 2021]. There is a wide variety of formats for online science videos: monologues, animations, documentaries, making them hard to classify (Ferreira et al., 2023). There is also a wide variety of apps for video sharing, such as Instagram, YouTube, Facebook, and TikTok.

Although TikTok has only been available since 2017, it is one of the most downloaded apps of the last decade, becoming a central element of popular culture (Schellewald, 2021). It has over 900 million users who spend more than 50 minutes per day on it. This platform is not only used for entertainment, but it is also important for science communication. Regarding the field of medicine, specifically, it was abundantly used to disseminate information about the COVID-19 pandemic (Comp, 2020). Likewise, the hashtags “doctor” and “MedEd” have both received over four million views, and some videos

produced by a doctor about COVID and lung injury were viewed more than four million times (Comp, 2020).

This article describes the three-step method used to disseminate Calmecac's main research concepts and findings. The specific materials produced were a science communication article, as well as a series of twelve short videos. The videos are being uploaded every two weeks to the group´s TikTok channel. In the intervening weeks between the main videos, short but attractive animations are being uploaded in order to increase the visibility of the account.

While some institutes of UNAM have TikTok accounts, as far as we know, ours is the only one belonging to a transdisciplinary research group of the university. Consequently, we believe it may constitute a showcase for this kind of research at UNAM.

For the creation of both kinds of science communication material, we tried to include the three fundamental elements of discursive strategies mentioned by Charaudeau (1993), i.e., credibility, legitimacy, and attention capture. Credibility regards the fact that someone can be believed or trusted; legitimacy refers to the quality of deserving to be heard (Charaudeau, 2011), while attention capture refers to the fact that individuals notice salient or surprising stimuli that they are not looking for (Maquestiaux, 2017).

Method

The first step of this process was a deep dive of the science communicator into Calmecac's field of research and practices. Consequently, she read all the articles published by the group in indexed journals in the last five years. Also, several days per week, she participated in the activities involved in the measurement of physiological signals of voluntary individuals. The results from these measurements are used to construct the physiological networks, among other purposes. Finally, she attended the group´s weekly meetings, in which research advances were presented and very specific questions were addressed by the group members.

The above-mentioned activities allowed the science communicator to carry out the second step of the process: to identify (1) the main concepts used in this field of research and the concepts related to them. Each concept was defined, as can be seen in Table 1. Likewise, it was possible to determine (2) the most important findings of Calmecac, which had been published in scientific indexed journals (Table 2).

Concept	Definition	Related concepts	Definition
Physiology	Study of how the human body's systems and functions work together.		
Holism	Approach according to which the functioning of the human body can only be understood by studying it holistically.		
Reductionism	Approach according to which the functioning of the human body can be understood by analyzing each component separately.	Medical specialization	Reductionism applied to medicine: studying each organ and system of the human body separately.
Complex system	A system that exhibits self-organized and emergent properties, and has a fractal organization	System	Made up of interacting components
		Self-organization	Adjusting their elements to respond to external changes.
		Fractality	Property of being similar to themselves on many scales.
		Emergent properties	Behaviors that the components of an entity do not have on their own, and emerge only when they interact in a wider whole.
Homeostasis	A balance between robustness and adaptability	Robustness	Tight control of each physiological variable of the organism.
		Adaptability	Capacity to adapt to internal or external changes.
Physiological variables	Parameters that can be measured and that allow the regulation of the functioning of a living organism.	Time series	Sequences of observations over regularly spaced time intervals.

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Concept	Definition	Related concepts	Definition
		Point recordings of variables	A single value of each variable is obtained for a given time.
Physiological signals	Electrical signals sent by the body's organs and systems.		
Physiological networks	Networks that are constructed to understand the interactions between organs and body systems.		
Regulatory systems	Systems that carry out processes to maintain physiological variables within healthy intervals.	Regulated variable	Variables contained within a narrow range of values around a certain setpoint, such as blood pressure and core temperature.
		Effector variables	Variables that adapt to perturbations to ensure the stability of regulated variables.

Table 1.

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1. All the organs and systems in the human body continuously interact, including the brain.
2. The physiological networks of men and women are different: women's are more robust and men's are more adaptable.
3. Because of the difference in their physiological networks, men get more seriously ill than women, but women take longer to recover.
4. Age plays an important role in the regulation of physiological networks. As we get older, these networks become more robust, so they lose their ability to adapt to changes in the environment. However, this change in physiological networks (becoming more robust) occurs in adolescence in women and at age 50 in men.
5. It is more difficult for women to lose weight than for men because the physiological networks of women are more robust than those of men.
6. A sudden increase in glucose causes an increase in blood pressure and a change in heart rate.
7. Homeless young men suffer cardiovascular deterioration because their heart rate variability is more random than that of housed young men.
8. When breathing is controlled at a certain rate, all physiological signals are brought into resonance, including those of the brain, and this can benefit health.
9. Physiological signals change when an individual carries out activities that he enjoys or does with ease (e.g., drawing, listening to music, writing a poem) and when activities cause difficulty or displeasure (e.g., solving a mathematical operation).

Table 2. Main published findings of Calmecac group

Given the complexity of the concepts used in this field of research, it was decided that the first science communication stage would be addressed to an audience with at least middle school education. As Calmecac is part of UNAM, which is the biggest university in Mexico (over 370,000 middle, undergraduate, and post-students), we thought that reaching its student audience would be an ambitious enough first objective. With this public in mind, we decided to use two different media: a science communication journal of UNAM, whose main audience is the university´s students, and a social network popular among young people. We believed that TikTok met our requirements. As of

January 2023, this social media was most popular among users between 18 and 24 years old (https://www.statista.com/topics/6077/tiktok/#topicOverview).

Science communication article

The article (Annex 1) was conceived as a general material on which specific research would be anchored, those that would be disseminated through the TikTok videos. Therefore, the aim of our article was to convey the concept of physiological networks, the most important one of the Calmecac group, around which most of its work revolves. For this purpose, it was necessary to first address the holistic approach on which it is based. We thought that it was essential to demonstrate the necessity of analyzing the human body in its integrity, and for this purpose, we used, as an example, our body´s response to a dangerous situation.

We considered it relevant to also tackle reductionism, the counterpart of the holistic approach, as we believed that it has led to great advances in medicine, such as the doubling of human life expectancy in the last century. Consequently, we briefly described the history of both approaches, treating them as complementary.

Subsequently, we tried to contextualize Calmecac's work by briefly explaining the objectives and main results of other research groups around the world that study physiological networks. We then addressed Calmecac's understanding of physiological networks, closely linked to the method used to construct them. It was certainly the most challenging part of the article, as the construction of these networks is a complicated mathematical procedure and they comprise many variables very likely unknown by non-physicians (e.g., estimated glomerular filtration rate, cytopenia, prothrombin, creatinine kinase). We therefore selected some widely known variables (heart rate, blood pressure, glucose, body weight, total water volume, cholesterol) and managed to explain the construction of networks without mentioning the mathematical and statistical procedures (correlations, principal component analysis).

We then pointed out the main findings of several research projects of this group, most of which make use of physiological networks. As we expressed before, the findings of these research projects were the subject of the TikTok videos. For instance, we mentioned one research project that identifies differences between female and male physiological networks; another one that specified the differential effect of COVID in men and women, and one more in which the differences between physiological networks in young and older persons were explained.

As can be seen in Table 1, another concept closely linked to this group's field of research is "complexity", given the fact that the human body is perceived by Calmecac as a complex system, in other words, a self-organized system, with emergent properties, fractal behavior, and nonlinear interactions between its elements. However, we decided to omit complexity from our science communication article, given that it is a complicated subject that gives place to important reflections and, therefore, from our point of view, would divert attention from physiological networks. Complexity will be addressed in a future paper.

TikTok videos

The first step was to visit several popular science TikTok accounts to identify some features that could benefit our own materials. We chose accounts with videos that were mainly concentrated on theoretical content and did not show spectacular experiments. The reason for this is that we wanted to convey scientific and medical theories on which Calmecac research is based, as well as the group's experiments, neither of which is visually spectacular, as are some videos of scientific TikTok channels. Therefore, we selected the following channels: *Instituteofhumananatomy* (10.4 million followers), *Evanthorizon* (2.6 million followers), *Neurolab* (450 k followers), *Todoesrelativo* (319 k followers), *Andre Isaacs* (44 k followers), and *Learnwithsherlock* (89 k followers). We watched about ten videos of each one of them.

As a result of this activity, we decided to keep our videos short (less than two minutes long), to use the same indoor location in most of them, decorated in a simple way, and to start with a catchphrase, which needed to be very short, as different TikTok tutorials mention that the audience decides in the first three to five seconds whether to keep watching the video or not.

Additionally, we considered it important for our TikTok account to have an identity, in terms of its visual style (production and postproduction stages), its structure, and the use of language and sound.

Video recording style

Provided that Calmecac is part of UNAM, a university with a formal institutional image, we believed we needed to create entertaining content but not detrimental to its image. Therefore, we avoided informal language, such as using slang and, obviously, swear words. We watched content published on TikTok by different institutes of UNAM and confirmed that none of them used this kind of language.

The location we chose was the Calmecac's laboratory, in which the measurements of physiological signals take place. Based on previous work (Lartigue, 2020), in which it was noted that the use of decorative elements that refer to scientific credibility is important in this kind of video, a poster created by Calmecac for a scientific conference was placed in the background. Also, we decided to use only two colors in the shots in order to avoid distracting the audience from the content of the video: white (speaker´s clothing and background wall) and blue (window shades and poster).

Recordings were done using mainly medium shots and only a few close-ups. A certain distance from the camera allowed us to have the speakers reading the texts from a screen behind the camera without it being too obvious.

Speakers

Because the target audience of our TikTok videos is young people, we believed that it would be better if the speakers belonged to the same age group. Considering gender equality, half of the videos were presented by a young woman and the other half by a young man. On the other hand, given that differences in female and male physiological networks are some of the main findings of Calmecac, it was fundamental to find a way to present them while respecting gender sensitivity. Therefore, we decided that the female speaker would present those videos. Talking on behalf of other women, she could say that it is important to acknowledge differences between male and female organisms in order to emphasize the need for specific medical treatments for the latter.

An initial amount of 12 videos was produced. In the first one, the Calmecac group was introduced, presenting the professional background of its members, the fact that it is a transdisciplinary group, as well as some of its main findings. We decided to keep our videos short (less than 2 minutes), inspired by popular science TikTok accounts (e.g., *Neurolab, Sherlock, Andre Isaacs*), with the purpose of avoiding to lose our audience´s attention.

Visual effects

We did not want to saturate the internauts with too many visual elements, but rather to only include those that would help them understand difficult concepts, or to occasionally reinforce with images what was being said. Only if we felt that a lack of images in long time intervals could lead to boredom did we include one or two images to capture their attention.

With the purpose of contributing to the identity of Calmecac's TikTok account, we tried to use the same style of images, the great majority of them being illustrations, and just a small number of pictures. Also, we cropped the illustrations using *inkscape* in order to make them more attractive. Additionally, whenever possible, we inserted excerpts from footage recorded during the measurements of physiological signals.

Video structure

Once again, to contribute to the identity of our account, we tried to keep the same structure in all the videos. Table 3 presents the elements of this structure, together with some examples extracted from the videos.

Structure element	Examples
1. SShort catch phrase	“Being homeless constitutes a cardiovascular risk”
2. Brief mention of the research addressed in the video	“Calmecac studied the variation in heart rate in young homeless men”
3. An explanation of the scientific concepts and processes (no more than two) related to this finding	“Heart rate is an indicator of a person's health, as it tells us how well the heart, arteries and veins, as well as other body systems are functioning....”
4. Short description of research procedure, findings, and implications.	“Calmecac group's study showed that, in young men living on the street, the difference between the duration of one heartbeat and the next is completely random. Such a random variation represents a risk for the cardiovascular system and can perhaps be explained by the fact that young men living in this situation face conditions of high risk of cardiovascular disease.”
5. Summary	“In summary, heart rate variability is an indicator of health...”
6. Conclusion	“In Mexico, close to 6,000 people live on the streets, the vast majority of whom are men. If we want a fairer country, we need to prevent conditions that seriously affect health, such as living on the street.”

Table 3. Predominant structure used for videos created to disseminate the research carried out by the Calmecac group of UNAM.

Depending on the subject addressed and on the particular communication needs, for some videos, we made some adaptations to this structure. For instance, in a couple of videos, the catch phrase (first element) coincided with the mention of the research addressed (second element). Likewise, in three videos, the explanation of concepts needed to be extensive because of their complexity. Therefore, the summary was omitted to avoid the videos being too long.

We produced 12 videos about the following topics:

- A description of the Calmecac group, emphasizing the importance of constituting a transdisciplinary group to holistically approach the topic of health
- An explanation of physiological networks, comparing them to spiderwebs
- The need for gender-specific medical treatments, based on the differences in the physiological networks of men and women
- The reason why men become more severely ill with COVID than women, but take less time than women to recover
- The resonance that occurs between physiological signals when breathing is controlled at a certain frequency
- The difference between the physiological networks of children and old people, and the ages at which the networks become more robust for each sex
- An increase in blood pressure when a sugary drink is ingested, as a test of the group's focus on the interconnection between organs and systems
- The importance of measuring physiological networks
- The health impact of highly random heart rate variability in Mexican homeless young men
- The reason why women have a harder time losing weight than men
- The physiological response of our bodies to infections in terms of physiological networks
- Our physiological responses to watching a film due to the interconnections of our organs

Credibility, Legitimacy, and Attracting the Public´s Attention

As a third general step of the science communication process, we made sure of including features related to the three elements of discursive strategies pointed out by Charaudeau (1993). Table 4 presents some of these features and to which of the elements they relate, according to the classification presented in Lartigue (2022). For instance, features that could make the concepts easier to understand, such as metaphors and examples, were considered as being related to "legitimacy," given that if the message is understood by internauts, we believe that it is more likely that they will find the videos worth watching or the article worth reading. Similarly, we consider that the speakers´ characteristics and their conversational tone of voice would contribute to this discursive element.

In contrast, we believe that the speakers´ clothing, the inclusion of UNAM´s name (in videos and in the article), together with the presence of a conference poster, would all contribute to increasing the

credibility of the science communication material.

On the other hand, there were some elements that we classified as relating simultaneously to two discursive elements. For instance, the use of illustrations, could help to make the videos more dynamic and attractive, while at the same time, helping the audience to understand the message (“legitimacy”). Also, the use of graphs may serve the latter purpose, while portraying an image of “serious” research (“credibility).

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Features of videos	Type of features	Example/Description	Element of discursive strategy
Young Speakers	Visual	Female and male speakers of the target audience´s age	Legitimacy
	Linguistic	Use of day-to-day language using the tone of a friendly talk	Legitimacy
Catch phrases	Linguistic	"Don´t fool yourself, your signals give you away", "We have discovered why men become more severely ill with COVID but women take longer to recover"	Attracting the public´s attention
Illustrations	Visual	Physiological networks, organs, bacteria and viruses, unhealthy diet, among many others.	Attracting the public´s attention/ Legitimacy
Film excerpts	Visual	Physiological signal measurements at Calmecac's laboratory	Credibility
Graphs	Visual	Electroencephalogram, Increase of glucose concentration, Relationship between heart rate and blood pressure.	Credibility/Legitimacy
Use of metaphors	Linguistic	Human body as a machine	Legitimacy
	Visual	Robustness: a physically strong woman Adaptability: a man wearing clothing that is adequate for bad weather	
	Linguistic and visual	Physiological networks as spiderwebs Physiological networks as cities Physiological networks as molecular model kits	
Use of examples	Linguistic	Examples of time series and point recordings, of body responses that prove the connections between our organs, of holistic approaches in medicine, among many others	Legitimacy

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Features of videos	Type of features	Example/Description	Element of discursive strategy
	Linguistic and visual	Unhealthy food, connection between body organs,	
Humor	Linguistic	Catch phrase "Don´t fool yourself, the signals give you away"	Attracting the public´s attention
	Visual	Superimposition of a person's face or body on the speaker's face or body, insertion of image of scissors cutting the brain-body connection	
Identity	Visual	Logo of Calmecac	Credibility
	Linguistic	Mentioning of "Calmecac from UNAM"	
	Auditive	Jingle at the end of the video	
Trustworthiness	Visual	Use of doctor's gown with logo of UNAM, Poster of one Calmecac's researches	Credibility
Local references	Linguistic	Excerpt of Mexican song.	Legitimacy
	Linguistic/ Visual	Mention of Mexican food, together with images of it.	

Table 4. Features included in the twelve videos produced to convey information about Calmecac's research and their relation to the three elements of discursive strategies.

Video posting

We are uploading one video every two weeks. However, in order to increase posting frequency and thus gain visibility, we are alternating these twelve videos with short animations about the messages that Calmecac would like to reinforce, for instance, the interactions between our organs.

The first video, describing the transdisciplinary research group of Calmecac, was released on December 7, 2023. At the end of the second day, it had 1603 views and 76 likes. Also, by the same time, the TikTok account had received 352 likes.

Second stage: assessing the effectiveness of videos to convey scientific information

In a second stage of this project, we will assess the effectiveness of our videos to convey scientific information. For this purpose, we will use the RIRC method (Negrete & Lartigue, 2010) to evaluate retention and comprehension of the information provided by the videos by using four independent memory tasks: recall, identify, retell, and contextualize, the acronym corresponding to the first letter of each task.

Likewise, we will try to determine if the information conveyed in an effective manner corresponds to the features included in Table 4. For instance, if what the audience best recalls is part of a funny section, or if the illustrations, the graphs, or perhaps the metaphors, contribute to increase retention of information.

Conclusion

There is an increasing need for researchers to communicate their knowledge and findings to various audiences [Maynard, 2021]. This is the case of the members of Calmecac, a transdisciplinary group of UNAM, that has developed the research field of physiological networks. In order to convey the main findings of their research to different audiences, a three-step science communication method was implemented: (1) a deep dive into Calmecac's research concepts and findings, (2) the identification of the main concepts and messages to be conveyed, and (3) the inclusion of the three elements of discursive strategies (credibility, legitimacy, and attention capture) in the design of the science communication materials: a science popularization article and a series of TikTok videos.

In the near future, we will assess the effectiveness of our videos to convey scientific information by using four memory tasks. We will also try to determine if the information conveyed in an effective manner corresponds to the features related to the three elements of discursive strategies.

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