University of Brasília

Institute of Psychology

Graduate Program in Social, Work, and

Organizational Psychology (PPG-PSTO)

Doctoral Dissertation

Introducing a Multilevel Analytic Model of Science Communication: Applications to COVID-19, Genetically Modified Foods, and Vaccine Hesitancy

Andressa Alves Bonafé Pontes

Supervisor: Prof. Dr. Ronaldo Pilati

Brasília - DF

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Doctoral dissertation presented to the Post-Graduate Program of Social, Work, and Organizational Psychology of the University of Brasília as a partial requirement for the degree of Doctor in Social, Work, and Organizational Psychology. Supervisor: Prof. Dr. Ronaldo Pilati

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“Science is not finished until it’s communicated”

Sir Mar Walport - UK Government Chief Scientist Adviser

Summary

Acknowledgements

I would like to express my deepest gratitude to my advisor, whose wise guidance, generosity, and calm presence were indispensable throughout this journey. He was remarkably understanding of the many unexpected turns along the way, and his experience, support, and trust in my ideas made this work not only possible, but enjoyable.

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To my husband, thank you for supporting me through every one of my wild ideas and endeavors.

And to my children who inspire me and remind me what matters in life.

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General Abstract

Public responses to science are shaped by a complex interplay of psychological, social, and contextual factors. In the face of global challenges deeply rooted in science - such as pandemics, climate change, and vaccine hesitancy - effective science communication is essential for guiding decision-making at both individual and institutional levels. Grounded in social psychology, this dissertation advances the understanding of how people engage with scientific information by proposing and applying a Multilevel Analytic Model (MAM) that integrates individual, group, and contextual determinants of message reception and impact. It is composed of six manuscripts that reflect the theoretical development and empirical application of this model. Manuscript 1 investigates how Brazilian participants evaluate the accuracy of information shared in politically-oriented WhatsApp groups, highlighting the role of political orientation, trust in sources, and open-minded thinking. Manuscript 2 introduces the MAM and discusses its conceptual and methodological foundations. Manuscript 3 applies the model to the case of genetically modified foods, testing an informational intervention and identifying key predictors of belief change. Manuscripts 4 and 5 address the lack of culturally appropriate instruments by adapting and validating the Actively Open-minded Thinking about Evidence (AOT-E) scale and the Scientific Reasoning Scale (SRS) for Brazilian Portuguese. Finally, Manuscript 6 presents a multi-country study on dengue vaccine acceptance, testing a psychological distance intervention and examining the interplay of micro- and macro-level predictors such as scientific reasoning and cultural tightness. Together, these studies advance theoretical, methodological, and empirical knowledge in science communication, offering a comprehensive and context-sensitive understanding of how scientific messages are processed in Brazil and beyond.

Keywords: science communication; science skepticism; models of science communication; genetically modified foods; scientific reasoning.

Apresentando um Modelo Analítico Multinível de Comunicação Científica: Aplicações à COVID-19, aos Alimentos Geneticamente Modificados e à Hesitação Vacinal

Resumo Geral

As respostas do público à ciência são moldadas por uma complexa interação de fatores psicológicos, sociais e contextuais. Diante de desafios globais profundamente enraizados na ciência - como pandemias, mudanças climáticas e hesitação vacinal - a comunicação científica eficaz é essencial para orientar a tomada de decisão tanto em nível individual quanto institucional. Fundamentada na psicologia social, esta tese avança na compreensão de como as pessoas se envolvem com informações científicas ao propor e aplicar um Modelo Analítico Multinível (MAM) que integra determinantes individuais, grupais e contextuais da recepção e do impacto das mensagens. Ela é composta por seis manuscritos que refletem o desenvolvimento teórico e a aplicação empírica deste modelo. O Manuscrito 1 investiga como participantes brasileiros avaliam a veracidade de informações compartilhadas em grupos de WhatsApp com orientação política, destacando o papel da orientação política, da confiança nas fontes e do pensamento aberto. O Manuscrito 2 apresenta o MAM e discute seus fundamentos conceituais e metodológicos. O Manuscrito 3 aplica o modelo ao caso dos alimentos geneticamente modificados, testando uma intervenção informacional e identificando os principais preditores de mudança de crença. Os Manuscritos 4 e 5 abordam a carência de instrumentos culturalmente apropriados, adaptando e validando para o português brasileiro as escalas de Pensamento Ativamente Aberto sobre Evidências (AOT-E) e de Raciocínio Científico (SRS). Por fim, o Manuscrito 6 apresenta um estudo multinacional sobre aceitação da vacina contra a dengue, testando uma intervenção baseada na redução da distância psicológica e examinando a interação de preditores em níveis micro e macro, como raciocínio científico e rigidez cultural. Em conjunto, esses estudos avançam o conhecimento teórico, metodológico e empírico na área de comunicação científica, oferecendo uma compreensão abrangente e sensível ao contexto sobre como as mensagens científicas são processadas no Brasil e em outros países.

Palavras-chave: comunicação científica; ceticismo científico; modelos de comunicação científica; alimentos geneticamente modificados; raciocínio científico.

General Introduction

Science-related topics are among the most heated of current debates. Vaccine skepticism, climate change, and genetic modification are just a few examples of how diverse and polarizing these issues can be. Ideally, science findings should inform decision-making, both at the individual and institutional levels. Empirical evidence should guide the way, however tentatively, to a better world. In reality, nonetheless, there seems to be a persistent gap between the way scientists view the world and how the public perceives it. In the words of Dan Kahan (2015, p. 1), “never have human societies known so much about mitigating the dangers they face but agreed so little about what they collectively know.” Time and time again, the science message gets lost along the way, leaving the scientific quest unfinished.

The science of science communication aims to change this scenario by providing empirical evidence on how to effectively promote “scientific awareness, understanding, literacy, and culture” (Burns et al., 2003, p. 190). This complex and ambitious task is interdisciplinary by nature and brings together a growing number of scholars from various areas of knowledge, from sociology and media studies to philosophy and rhetoric. Through innovative collaborations, researchers and practitioners, policymakers and citizens demonstrate the great potential of having a scientific approach to communicating science.

Internationally, the field of science communication has grown exponentially in recent years. A systematic mapping of science communication publications between 1980 and 2020 revealed that 83% of articles had been published after 2011 and 75% of those after 2016 (Judd & McKinnon, 2021). Besides the acceleration in the rate of publication, the emergence of specialized journals such as *Public Understanding of Science*, *Science Communication*, and *JCOM – Journal of Science Communication* further attests to the consolidation of the field.

Despite this remarkable growth, the geographic concentration of research output remains flagrant, to the virtual exclusion of developing countries. There is a pronounced dominance of authors from Western, English-speaking countries, with US and UK authors accounting for three-fifths of the "major works" in over 50 years of science communication research (Trench & Bucchi, 2015). Studies point to increasing internationalization, a trend that remains, however, largely restricted to the Northern hemisphere. A review of the publications in the journal *Public Understanding of Science* between 1992 and 2010 showed that even though the range of countries covered each year increased from around 10 to 20-25, only one-sixth of empirical reports came from Asia, Africa, and Latin America (Martin & Howard, 2012). More recent data confirm the persistence of regional disparities, despite an increase in the number of submitting countries. Between 2016 and 2021, researchers from just 15 countries accounted for 75% of submissions to the journal, with scholars from the United States strengthening their dominance and contributions from Africa and the Global South remaining marginal, both in volume and acceptance rates (Peters, 2022).

In this highly inequitable scenario, Brazil stands out as a promising exception. The country ranked 10th in the overall number of publications in a systematic analysis of the three most prominent science communication journals between 1979 and 2016. Despite performing best among developing countries, Brazil's contributions represented only 1.6% of the total number of publications versus 39% and 15.8% from the US and UK, respectively (Guenther & Joubert, 2017). This blatant imbalance reiterates the importance of intensifying the efforts to diversify science communication research, making space for under-represented voices from all parts of the world (Massarani, 2015).

The present dissertation aims to contribute to these efforts by focusing on the science communication landscape in Brazil and, to a lesser extent, other developing countries. To do so, we build upon the theoretical framework and methodological tools of social psychology, which are particularly well-suited for understanding the multiple levels of analysis and myriad potential interactions involved in science communication. Specifically, the overarching goal of this project is to propose a multilevel analytic model (MAM) of the effects of science communication and provide empirical evidence of its application.

Throughout its history, social psychology has proven its ability to tackle complex issues that involve a variety of multidirectional relationships, such as science communication. By contemplating the individual perspective without paying any less attention to group- and macro-level processes, the discipline allows for a better understanding of real-world dynamics. A consolidated theoretical framework, with well-delineated concepts, helps elucidate multifaceted issues, creating a common vocabulary to facilitate future research. Moreover, a tradition of methodological rigor, which includes the development and validation of psychometric instruments, opens the way to promising and reliable research designs. Experimental research in science communication can greatly benefit from the assets of social psychology, especially in Brazil, where this type of investigation is relatively uncommon.

This dissertation is composed of six manuscripts, two of which have already been published and one currently under review. They are presented in chronological order, reflecting not only the rationale behind the development of the proposed theoretical model, but also the practical needs that emerged through its empirical applications. Together, these manuscripts trace the evolution of a research effort that was shaped by urgent real-world events, the demands of theory-building, and the challenges of measurement and cross-cultural application.

Manuscript 1 was developed in 2020, in direct response to the COVID-19 pandemic and the alarming spread of misinformation in Brazil. Motivated by the prominent role of WhatsApp in Brazilian communication, we investigated how participants assessed the accuracy of scientific information when it appeared in politically-oriented group chats. The findings highlighted the influence of micro-level variables (such as political orientation, trust in media sources, and open-minded thinking) in shaping truth discernment about science-related topics. These results reiterated that the communication of scientific information is a far more complex and multifaceted phenomenon than it may first appear. The urgency of the pandemic brought to light a fundamental question: why are some scientific messages readily accepted while others are met with resistance?

This inquiry served as the foundation for the development of Manuscript 2, which offers a conceptual contribution by discussing the challenges of studying science communication and proposing the MAM. This model builds on existing frameworks while offering an integrative perspective that accounts for the interplay of individual, group, and contextual factors. Manuscript 3 presents the first empirical application of the MAM to a controversial scientific topic, genetically modified (GM) foods. It tests an informational intervention and identifies key variables associated with participants' beliefs, offering insight into how scientific messages are processed in real-world contexts.

This early application of the MAM also revealed a significant methodological gap: the need for valid, reliable tools to measure individual-level predictors of science communication in Brazil. In response, we developed Manuscript 4 and Manuscript 5, which detail the adaptation and validation of the Actively Open-minded Thinking about Evidence (AOT-E) and the Scientific Reasoning Scale (SRS) to Brazilian Portuguese, respectively. These instruments expand the range of validated measures available for science communication research in non-English-speaking contexts and enable more rigorous and culturally sensitive investigations.

Finally, Manuscript 6 returns to empirical application, this time focusing on a topic of pressing global relevance: the rapid surge in dengue fever cases. This multi-country study investigates psychological and contextual determinants of dengue vaccine acceptance across eight countries. It tests the effectiveness of a "decreasing psychological distance" intervention and applies the MAM to explore the interplay between micro- and macro-level predictors of vaccine skepticism and intention, including cultural tightness, scientific reasoning, and perceived proximity to science.

Together, these studies advance theoretical, methodological, and empirical knowledge in science communication. By proposing and applying a multilevel framework, adapting key psychometric tools, and investigating high-impact, real-world issues, this dissertation contributes to a more nuanced and context-sensitive understanding of how science is communicated and received in Brazil and beyond.

Manuscript 1

COVID-19 as infodemic: The impact of political orientation and open-mindedness on the discernment of misinformation in WhatsApp

This first manuscript presents an initial investigation into the psychological and contextual factors that influenced the discernment of science-related information during the COVID-19 pandemic, with a specific focus on the Brazilian WhatsApp environment. Conducted at a time when scientific communication was both urgent and contested, this study examined how political orientation, trust in information sources, and individual thinking dispositions relate to truth discernment. The findings revealed that open-minded thinking and trust in the World Health Organization (WHO) and traditional media were associated with greater accuracy in identifying misinformation, while political orientation to the right and confidence in social media were linked to greater susceptibility to false claims. Although anchored in the specific context of the pandemic, these results underscored broader patterns of how individual and sociopolitical variables interact in shaping responses to scientific content.

This study laid the groundwork for the subsequent development of a multilevel analytic model (as described in Manuscript 2) by underscoring the importance of considering both individual-level traits and broader sociocultural forces in science communication. Its findings inform and connect with the following manuscripts, which expand the investigation beyond COVID-19 to other contested scientific domains, such as genetically modified foods and vaccine hesitancy. In parallel, this initial investigation also highlighted critical methodological gaps, particularly the need for robust, validated instruments to assess constructs like scientific reasoning and open-minded thinking across diverse sociocultural contexts. By combining psychometric validation efforts with empirical applications, the dissertation builds on this opening manuscript to advance a more integrative framework for understanding how cognitive, ideological, and contextual variables jointly shape public responses to science across distinct domains.

For the full text, please refer to: Bonafé-Pontes, A., Couto, C., Kakinohana, R., Travain, M., Schimidt, L., & Pilati, R. (2021). COVID-19 as infodemic: The impact of political orientation and open-mindedness on the discernment of misinformation in WhatsApp. Judgment and Decision Making, 16(6), 22. https://doi.org/10.1017/S193029750000855X.

Manuscript 2

Science Communication Through a Multilevel Lens: Toward an Integrative Social Psychological Framework

The present Manuscript introduces the theoretical investigation that gave rise to our proposed multilevel analytic model (MAM) of the effects of science communication, which serves as a guidepost for the empirical studies presented in subsequent chapters. We start by presenting the relevant concepts and challenges involved in researching the communication of scientific findings. Then, we outline and discuss some of the models of science communication that exist in the literature before going into detail on the various components of the MAM, its potential, and limitations.

Definitions and Challenges in Science Communication

In 2019, the World Health Organization (WHO) included the growing hesitancy towards vaccination among the top ten health threats in the globe (World Health Organization, 2019), a fact that has gained renewed urgency in the context of the Covid-19 pandemic. Addressing the lack of confidence in the early days of coronavirus vaccines, Heidi J. Larson, director of the Vaccine Confidence Project, pointed out that the success of vaccination efforts hinges on much more than technical or logistical aspects. The author underlined that in a “scientific rush to develop, manufacture and deliver vaccines more rapidly than ever in history, countries around the world have failed to engage the public” (Larson, 2021, para. 19). This mismatch between scientific findings and public opinion illustrates the core challenge of science communication. Larson further points out that “Covid vaccines [should not] be seen as something taken because the government says so, but because they have meaning in people’s lives” (Larson, 2021, para. 17).

The production and negotiation of meanings are at the heart of any communication effort, which cannot be separated from the social, cultural, and political context in which it occurs (Schirato & Yell, 1997). In the specific case of science communication, these meanings can encompass “one or more of the following personal responses to science (...): Awareness, Enjoyment, Interest, Opinion-forming, and Understanding" (Burns et al., 2003, p. 183).

As exemplified by the recent surge in vaccine skepticism, effectively communicating science is a complex and challenging endeavor. In Brazil, social challenges include high levels of functional illiteracy, which affects up to 38% of those between 15 and 64 years old (Lourenço, 2020). From a global perspective, mistrust in science and the rapid spread of misinformation pose major challenges (Oreskes, 2019). Moreover, increasing political polarization presents additional hurdles to science communication, particularly when public opinion on scientific topics is organized around political divides (National Academy of Sciences, 2018).

The science of science communication aims to shed light on potential ways to overcome these challenges by applying "an empirical approach to defining and understanding audiences, designing messages, mapping communication landscapes, and - most important - evaluating the effectiveness of communication efforts" (Kahan et al., 2017, p.1).

Beyond the contextual challenges presented above, scientists of science communication face considerable methodological complexities that ensue from the very nature of their object of research. The scope of science communication is incredibly broad, encompassing the most diverse topics, from evolution and climate change to nanotechnology and genetic modification. There is also great diversity in the means of communication, which follow the fast pace of technological changes. Science museums, public events, books, and social media are just a few examples of the domains in which science communication can happen. Applying an empirical approach to such a complex scenario is not an easy task. Over the years, researchers of science communication have proposed models to guide and inform this ambitious endeavor. The next section presents some of these models and discusses their contributions and limitations.

Models of Science Communication

The Information Deficit Model

Though its origins are not precisely defined, science journalist David Dickson (2005) states that the first references to a deficit model date back to the social science literature of the 1980s. It appears, however, that the term's original goal was not to describe the dynamics of science communication but rather to "characterize a widely held belief that underlies much of what is carried out in the name of such activity" (Dickson, 2005, para. 9).

As currently understood, the information deficit model (IDM) argues that the public's skepticism towards science is due to a lack of knowledge. In other words, the public's resistance to scientific and technological developments is explained by inadequate access to quality information and a lack of scientific literacy (McDivitt, 2016). Consequently, such a model argues that the dissemination of information, combined with the development of the ability to understand it, would be enough to change attitudes and behaviors related to science (Hornsey, 2020). The IDM thus advocates a process of communication in which scientific knowledge is transmitted from scientists to the lay public. It assumes that facts speak for themselves and are interpreted by the public in very similar ways (Nisbet & Scheufele, 2009). As pointed out by Gross (1994), it operates as a one-way flow based on public deficiency and scientific sufficiency.

Several studies have shown that there is, in fact, a sizable knowledge gap when it comes to science. In Brazil, data from the *Indicador de Letramento Científico* (ILC, in English Scientific Literacy Indicator), from 2014, indicated that only 5% of the participants had proficient knowledge, while 64% had low literacy (GIFE, 2014). Results from the 2018 edition of the Program for International Student Assessment (PISA) showed that 55% of 15-year-old Brazilian students did not have a basic level of science. The country ranked last in South America, tied with Argentina and Peru (INEP, 2019).

The mere existence of a scientific knowledge deficit does not mean, however, that its reduction would necessarily lead to more positive attitudes towards science, or to the intensification of behaviors based on scientific evidence. In fact, there is no consensus in the literature in this regard (Scheufele, 2013). On the one hand, studies have found that greater knowledge is related to more positive attitudes towards genetically modified foods (Calabrese et al., 2021; McPhetres et al., 2019; Rutjens et al., 2021). On the other hand, attempts to change anti-vaccine and skeptical attitudes towards global warming have had little success when based solely on an informative approach (Brulle et al., 2012; Nyhan et al., 2014). In some instances, presenting information on certain polarized topics actually poses the risk of backlash and increased disbelief among certain groups (Kahan, 2012).

Contextual Model

Criticism of the deficit model gave rise to research that is interested in how social and psychological aspects affect the processing of scientific information. Generally referred to as "contextual model", this view of science communication proposes that individuals are not empty containers, ready to receive information, and that previous experiences and present circumstances work as filters to the scientific message (Brossard & Lewenstein, 2010). Gross (1994) underlines that, unlike the deficit model, which assumes a single direction and asymmetry in the communicative process, the contextual approach proposes a two-way street and draws attention to the interaction with the public. It also argues that communication goes beyond the cognitive aspect, being influenced by several contextual elements, including social, cultural, ethical, and political issues. It is thus not restricted to the state of scientific knowledge but encompasses the entirety of the communication environment, which is understood "as the sum total of social processes that individuals use to align their decisions with the best available scientific information" (Kahan, 2017, p. 7).

Cultural Cognition of Risk

The contextual approach gave rise to important lines of research, among which is the cultural cognition of risk, whose most well-known champion is Dan Kahan. This literature is largely based on Douglas and Wildavsky's (1982) proposition that individuals assess risk in a way that reflects and reinforces their worldviews and preferences about how society should be organized (a phenomenon called cultural cognition of risk). The perception of risk is hypothesized to be at the core of how people relate to science communication, a relationship that is determined by whether they hold an individualistic, hierarchical, communitarian, or egalitarian worldview (Kahan, 2012).

This hypothesis has been corroborated in a series of experimental studies. Kahan et al. (2010) found that cultural cognition (i.e., "the tendency of individuals to form beliefs about societal dangers that reflect and reinforce their commitments to particular visions of the ideal society" [Kahan, 2013, p.1]) explains differences in perceived risks and benefits of the HPV vaccine. Kahan et al. (2011), in turn, found an important alignment between cultural cognition and the perception of scientific consensus regarding different topics of scientific communication (e.g., participants with individualistic and hierarchical tendencies perceived less consensus regarding climate change than those with communitarian and egalitarian views). In the words of the authors, "(...) cultural cognition strongly motivates individuals - of all worldviews - to recognize such information as sound in a selective pattern that reinforces their cultural predispositions. To overcome this effect, communicators must attend to the cultural meaning as well as the scientific content of information." (Kahan et al., 2011, p. 30-31).

Several mechanisms are involved in the cultural cognition of risk, including identity protection, biased assimilation, the polarization of groups, cultural credibility, cultural availability, and affirmation of cultural identity (Kahan, 2012). Biased assimilation, for example, was demonstrated by Kahan et al. (2009) in a study on nanotechnology, in which exposure to the same type of information had an inverse effect on risk perception by groups with different worldviews (i.e., individualistic, hierarchical, communitarian, or egalitarian), causing polarization.

When considered within the context of social psychology, and particularly cultural psychology and cross-cultural social psychology, the cultural cognition of risk proposition creates conceptual confusion. This line of research does not seem to understand culture merely as “groups of people who exist within a shared context, where they are exposed to similar institutions, engage in similar practices, and communicate with one another regularly” (Heine, 2010, p. 1423). It seems rather to conflate the concepts of *culture*, *worldviews*, and *values*, which are often used interchangeably. There is, therefore, considerable ambiguity as to the intended level of analysis of the cultural cognition thesis. Several studies which compare cultures traditionally focus on the macro, or aggregate level, and analyze common patterns in responses from members of the same group. Given the inherent complexity of studying culture, social psychologists have focused on certain dimensions, notably individualism and collectivism (Hofstede, 1980), tightness and looseness (Gelfand et al., 2011), and value priorities (Schwartz, 1992), which are often studied in large-scale, multinational initiatives. Despite using the term “cultural”, Kahan’s proposition diverges from these traditional lines of research. Rather than focusing on the macro, it oscillates between the meso and the individual levels of analysis, often confusing culture and political orientation.

Critics of the cultural cognition thesis, notoriously van der Linden, characterize the theory as a “strange loop” of self-referential arguments in which “core theoretical properties (culture, group, political affiliation, etc.) are never exogenously defined” (van der Linden, 2015, p. 3). Circular reasoning fallacies come together with an overgeneralization of findings that have not yet been satisfactorily replicated in cross-cultural studies and should, therefore, be understood as specific to American political groups with opposing views on certain science topics.

Motivated Rejection of Science

Another important line of research within the contextual approach brings together studies that consider motivated reasoning as a central variable in science communication. In the words of Kunda

(1990, p. 480), “motivation may affect reasoning through reliance on a biased set of cognitive processes—that is, strategies for accessing, constructing, and evaluating beliefs”. Similarly, to the cultural cognition approach, the motivated rejection of science literature argues that people tend to be resistant to scientific information that threatens their core beliefs. These studies, however, go beyond the influence of different perceptions of risk and include a variety of other potential motivators, such as values, ideology, political orientation, religion, conspiracy thinking, etc. As summed up by Lewandowsky and Oberauer (2016, p. 219), “science is rejected on the basis of motivated identity-protective cognition that cannot be understood without consideration of the broader societal and political context.”

Recent studies of science skepticism are good examples of this line of research. Overall, research shows that “different ideological predictors are related to the acceptance of different scientific findings” (Rutjens et al, 2018, p. 384). Rutjens et al. (2021) carried out a 24-country study that confirmed the multiplicity of skepticism predictors across domains, showing, for instance, that while climate change skepticism is mainly associated with political conservatism, this is not the case for genetic modification and evolution skepticism, which were primarily linked to scientific literacy and religious orthodoxy, respectively. Kerr and Wilson (2021) agree that skepticism is heterogeneous across domains but suggest that there may be an overarching influence of attitudes towards authoritarianism and group-based dominance. Similarly, Lewandowsky et al. (2013) argue that conspiracy thinking may have a widespread influence, predicting opposition to information related to vaccination, climate change, and genetically modified foods.

Aiming to illustrate the heterogeneity of potential motivations of science resistance, Hornsey and Fielding (2017, p. 459) propose the notion of “attitude roots”, which encompass the “underlying fears, ideologies, worldviews, and identity needs that sustain and motivate specific “surface” [antiscience] attitudes”. The authors argue that understanding what lies under the surface is key to developing more effective science communication (Hornsey, 2020). Specifically, they propose a “jiu jitsu” model of persuasion that identifies and addresses the roots of skepticism. “Rather than taking on people’s surface attitudes directly (which causes people to tune out or rebel), the goal of jiu jitsu persuasion is to identify the underlying motivation, and then to tailor the message so that it aligns with that motivation” (Hornsey & Fielding, 2017, p. 469).

Though highly didactic, Hornsey and Fielding (2017)’s attempt to create a transtheoretical model is oversimplified. While easy to understand, the “tree model” creates theoretical confusion, as it uses the term “attitude” without a clear definition. Attitudes represent “an evaluative integration of cognitions and affects experienced in relation to an object” (Crano & Prislin, 2006, p. 347) and, though potentially related, are conceptually different from *beliefs*, *values*, *worldviews*, and *ideology*. In the proposed model, both “surface” and “underground” elements go beyond the attitudinal realm and into these other concepts. In addition to the conceptual confusion, one could question the comprehensiveness of the proposed model, specifically what it does not consider. Despite referring to various “attitudes”, Hornsey and Fielding (2017) fail to include attitudes toward science itself, regardless of the subject matter at hand. By ignoring people’s views on the scientific method and enterprise *per se*, the authors seem to assume that an individual’s opinions on various scientific topics are unrelated to their perception of science in general (or scientists, for that matter).

Other Models of Science Communication

Despite the undeniable contributions of studies based on the contextual model, this view of science communication has faced its share of opposition. Critics accuse the contextual model of being merely a more sophisticated version of the information deficit approach and remaining constricted to the goal of spreading the interests of a scientific elite (Brossard & Lewenstein, 2010; Wynne, 1995). The model is said to revolve around the supposed inadequacy in the way individuals respond to scientific information, opening the way to manipulation, which could be used to achieve goals other than an enhanced understanding of science (Lewenstein, 2003).

In response to these criticisms, alternative propositions have emerged, such as the lay expertise and public participation models, which emphasize the contribution and participation of the population in the construction of knowledge. These approaches break up with the linear, top-down view of the relationship between science and society, encouraging an open dialogue with an equal stance.

The lay expertise model assumes that local knowledge (e.g., community practices, historical legacies, etc.) can be as important as technical or scientific expertise. It advocates for science communication efforts that work with the population to harness their existing knowledge and expertise. It further acknowledges that scientific issues are not exclusively scientific and challenges the relationship between science and society, arguing that lay people should not be restricted to the receiving end of information (Irwin, 2009). Though bringing important contributions in terms of empowerment and trust-building, the lay expertise model has been criticized for "equalizing expert, lay-expert, and non-expert knowledge" (Secko et al., 2013, p. 8).

The public participation model aims to actively engage stakeholders, making the scientific process more interactive. With a clear focus on democratization, this approach encourages a pluralistic and inclusive debate of science issues (Secko et al., 2013). In practical terms, this includes a variety of techniques, such as "consensus conferences, citizen juries, deliberative technology assessments, science shops, deliberative polling", etc. (Lewenstein, 2003, p.5). Critics of this approach argue that it favors political goals rather than public understanding and that it focuses excessively on the scientific process rather than content (Brossard & Lewenstein, 2010).

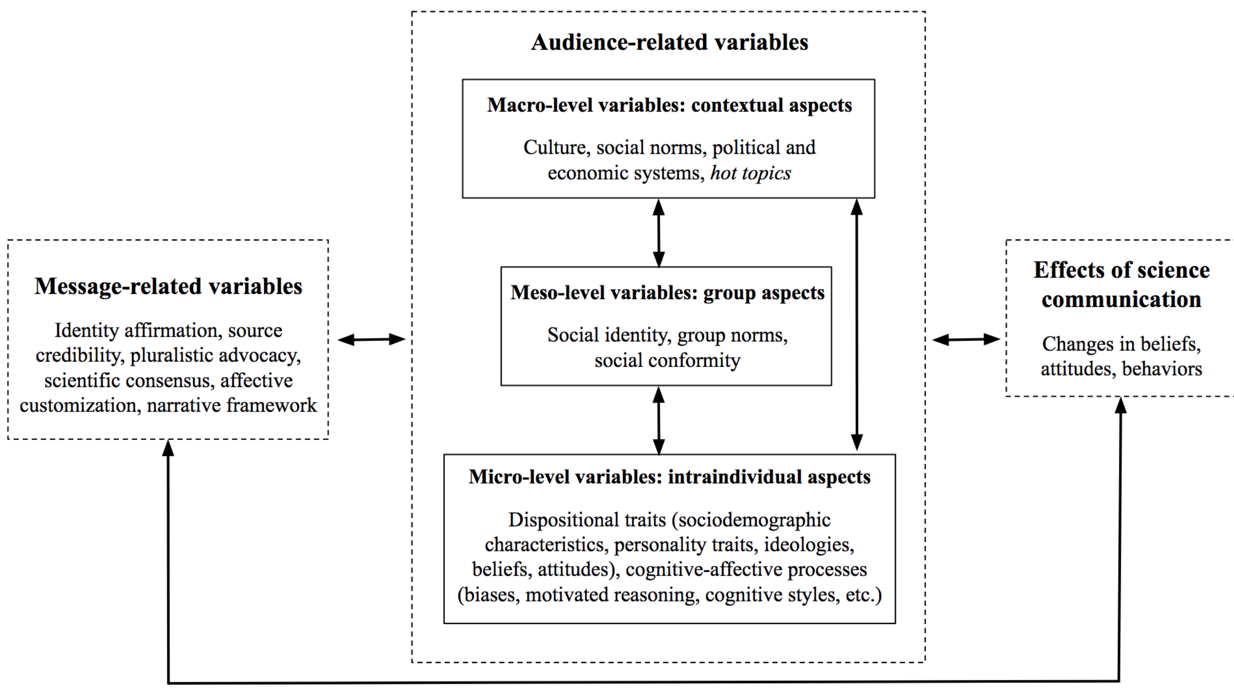
A Multilevel Analytic Model of the Effects of Science Communication

Building upon the literature presented so far, and particularly the contributions and shortcomings of the different models discussed in previous sections, we propose a multilevel analytic model (MAM) of the effects of science communication. We believe that the analytical approach will contribute to the existing literature by helping identify, organize, and establish relationships between different categories of variables. Different from prior propositions, it intends to be more than a framework for interpretation of phenomena but also serve as a guidepost to future research.

Figure 1 presents the proposed model along with examples of variables within each category. It is worth noting that these examples are merely illustrative and in no way constitute an exhaustive list.

Figure 1

Multilevel Analytic Model of the Effects of Science Communication



It is our view that the effectiveness of science communication, specifically its ability to change beliefs, attitudes and behaviors, is determined by four categories of variables, namely, those related to the message and those related to the audience at the macro, meso, and micro levels. Although this dissertation focuses on how these categories influence the effects of science communication, it is important to recognize that this relationship is not unidirectional. Rather, changes in beliefs, attitudes, and behaviors may, over time, shape the design and content of messages, as well as modify audience-related variables, thereby constituting a dynamic and interdependent system.

Audience-Related Variables

Before going into the specifics of the three levels of audience-related variables it is important to underline their interdependency. Though divided for didactic purposes, these levels cannot be understood in isolation from one another. Rather, as illustrated by the double-sided arrows that connect them, each group of variables is informed by the others in a series of complex, multidirectional relationships. Echoing van de Vijver and Matsumoto (2011)'s perspective on cross-cultural research, we believe that data related to the effects of science communication are inherently nested. Observations pertaining to one level of analysis (e.g., individuals) are nested within those related to another level (i.e., group), which themselves are nested within an even broader category (i.e., context). The objective of a multilevel model is precisely to shed light on this network of relationships, unveiling the joint effects of individual-, group-, and context-related variables and acknowledging how different levels of analysis are key to understanding the responses to science communication.

Macro-Level: Contextual Aspects of Science Communication

The inclusion of a macro-level category in the MAM ensues from the need to explicitly acknowledge the importance of context in science communication. By context, we mean a plethora of variables concerning, for instance, the cultural, social, political, economic situation in which the communication takes place. Throughout history, there have been numerous examples of how the context influences the spread of scientific messages. Between the late 1950s and the mid-1970s, efforts by the USSR and the US to achieve superior spaceflight capabilities, created unparalleled interest in scientific and technological developments related to astronomy and aerospace engineering. In a survey of over 800 researchers who had published in the journal *Nature* between 2006 and 2009, half of the respondents stated that the Apollo missions had inspired them to pursue science and 90% of them believed that it still motivates younger generations to study science (Monastersky, 2009).

More recent examples include both isolated events that have sparked science-related discussions (creating what we call *hot topics*) and more general trends in the public opinion. The first category includes, for instance, the Fukushima nuclear disaster in 2011, while the second encompasses a growing concern about sustainability fueled by high-profile activists such as Greta Thunberg.

Perhaps the most telling example of how contextual variables influence science communication is the Covid-19 pandemic. The epidemiological context generated one of the most expressive surges in scientific publication ever (Brainard, 2020), which surpassed the 100-thousand mark by December 2020 (Else, 2020). This torrent of science communication was not restricted to traditional, peer-reviewed channels. Public interest led to a growing use of social media and messaging applications for the discussion of scientific issues, generating major challenges, among which fake news, conspiracy theories, echo chambers, etc. (Bonafé-Pontes, 2021; Van Bavel et al., 2020).

Beyond major events or crises, cultural perspectives deeply influence how science is communicated and understood. Different societies hold distinct assumptions about knowledge and relationships, for instance, while Western traditions often depict humans as separate from nature, Indigenous frameworks emphasize interconnectedness (Medin & Bang, 2014). These orientations affect not only the interpretation of scientific messages but also the forms through which they are most effectively conveyed. As Davies et al. (2019) argue, science communication should be recognized as a cultural practice shaped by collective identities and storytelling traditions. Empirical evidence supports this view - in a study of online science videos, Finkler et al. (2024) found that students from high-context cultures responded more positively to narrative formats that emphasized emotional connection and communal values, compared to those from low-context cultures who preferred rational, individualistic messaging. The literature also points to the influence of widely used cultural frameworks, such as individualism versus collectivism (Triandis, 1995) and cultural tightness versus looseness (Gelfand et al., 2006), on communication styles (Gudykunst et al., 2006) and science-related behaviors (Gelfand et al., 2021; Ng & Tan, 2023), suggesting a promising avenue for future research.

Macro-level variables also include measurable structural conditions that influence how science is produced, communicated, and received. National investment in science and technology varies dramatically across countries, revealing stark global disparities. While Israel and South Korea are notable outliers, investing around 6% and over 5% of their GDP in R&D respectively, the majority of countries fall well below these levels. In fact, approximately half of the world's economies invest under 0.5%. This uneven distribution limits both the capacity for scientific innovation and the infrastructure for effective science communication in many regions (Bonaglia et al., 2024). Similarly, income inequality, educational attainment, and trust in scientific institutions can vary widely and hinder equitable access to scientific knowledge and resources. Political contexts also play a decisive role in shaping both science communication and scientific activity itself. Massarani and Moreira (2016) present several examples of how political shifts affected science production and communication throughout the history of Brazil. The authors underline, for instance, that “in the 1970s, dictatorship severely hit sectors of the scientific community, forcing many people into exile, including scientists and students” (Massarani & Moreira, 2016, p. 88).

Though the existing literature on science communication acknowledges the importance of macro-level variables, these are hardly ever the focus of research. They are most often referred to in the introduction of articles, to justify the relevance of certain topics. Important exceptions include studies that investigate the history of science communication and its cultural aspect (e.g., Medin & Bang, 2014; Orthia et al., 2021; Hanauska, 2019; among others). It is our hope that by including a specific category of macro-level variables, the MAM will encourage a more careful consideration of contextual influences and inspire innovative study designs, including longitudinal research.

Meso-Level: Group Processes and Science Communication

The meso-level category encompasses variables that capture the influence of groups on how individuals perceive scientific communication, including social identity, group norms, and social conformity. In social psychology, groups are understood as three or more people that interact and are interdependent, meaning that their needs and goals are intertwined (for seminal work on group dynamics, see Ashforth & Mael, 1989; Cartwright & Zander, 1968; Lewin, 1948; Tajfel, 1978; Tajfel & Turner, 1979; Turner, 1984). Researchers argue that people have a fundamental need to belong, and that social acceptance is generally associated with well-being (DeWall & Richman, 2011). Baumeister and Leary (1995, p.497)'s belongingness hypothesis summarizes this necessity by stating that "human beings have a pervasive drive to form and maintain (...) lasting, positive, and significant interpersonal relationships".

Group dynamics can influence individuals through a variety of processes, including cohesion and conformity to group norms (Kiesler et al., 1969), social facilitation (Zajonc, 1965), deindividuation (Lea et a., 2001), polarization (Isenberg, 1986), etc.. Perhaps more importantly, being part of a group often affects the very way in which individuals see themselves, becoming a component of their identity. In the words of Stets and Burke (2000, p. 226) "having a particular social identity means being at one with a certain group, being like others in the group, and seeing things from the group's perspective". In this sense, Lewandowsky and Oberauer (2016)'s hypothesis of motivated science skepticism based on identity-protective cognition becomes particularly relevant.

Writing about the pervasive effect of social identity on cognition, Van Bavel et al. (2014) underscores that group belonging is part of human evolution and that collective representations of the world, the so-called "group mind", structure a variety of cognitive processes. The authors review a wide range of social, cognitive, and neuroscience research that sheds light on the impact of social identity on several information-processing mechanisms, from person memory (Van Bavel & Cunningham, 2012) to distance (Xiao & Van Bavel, 2012) and mind perception (Hackel et al., 2014). Given such extensive evidence of the importance of group-level variables, it is paramount to investigate their influence on the effects of science communication.

The most preeminent examples of group-related variables in science communication research are related to politics and religion. It is worth noting, however, that most studies have been negligent in differentiating the meso and micro levels of analysis. The wide majority of authors focus solely on the individual aspect, namely, religiosity and political orientation, while neglecting the undeniable connection to the group aspect (which would be more accurately captured by religious and political affiliation).

Politics and religion are particularly good illustrators of how the different levels of audience-related variables are nested within each other, in a series of complex, multidirectional relationships. For instance, the micro-level aspect of political orientation is at once informed and reinforced by the meso-level variable political affiliation and vice-versa. In other words, an individual of certain political orientation is likely to seek socialization with people of similar views by affiliating to a political group. Mechanisms of social identity and conformity come into play, helping strengthen their political orientation. Similar dynamics could easily be at play for religiosity and religious affiliation.

Jensen et al. (2019) demonstrated the advantages of a multilevel approach by explicitly differentiating the effect of micro and meso-level variables on evolution skepticism. Overall, the authors found that self-reported religiosity and acceptance of the evolutionary theory were inversely related. They found, however, that this relationship varied across religious affiliations. For instance, while there was a linear correlation among Southern Baptists, those of Jewish affiliation had similarly high levels of acceptance when reporting low and medium religiosity (though it dropped for those reporting high religiosity).

The role of political affiliation has also been explored by researchers of science communication. Hornsey et al. (2016) carried out a meta-analysis of 25 polls and 171 academic studies across 56 nations and concluded that political affiliation is among the most important predictors of resistance to climate change. The authors summarize their findings saying that “the data suggest that “evidence” around climate change is searched, remembered, and assimilated in a way that dovetails with people's own political loyalties" (Hornsey et al., 2016, p. 625). A later investigation of 24 countries suggests, however, that this relationship is stronger and more consistent in the United States than elsewhere (Hornsey et al., 2018a). This finding encourages further research to understand national particularities, an area in which the study of relationships between meso- and macro-level variables may be especially enlightening.

Micro-Level: Intraindividual Aspects of Science Communication

This category of variables encompasses both dispositional traits and cognitive-affective processes. The first group of variables is defined as "a frame of reference through which a person appraises and reacts to a situation using consistent and stable ways of thinking, feeling and behaving" (Chiu & Francesco, 2003, p. 284). Examples include personality traits, ideologies, beliefs, attitudes, and sociodemographic characteristics. The second group pertains to the way individuals process information and encompasses both automated and deliberate thinking (Evans, 2008). Examples include biases, motivated reasoning, cognitive styles, etc.

The previous sections on existing models of science communication (the contextual model, in particular) have given an overview of recent findings on intraindividual variables, therefore, we present here a summary proposed by Hornsey and Fielding (2017). Based on exhaustive literature search and analysis, the authors organize the most relevant variables into six themes. One of them, social identity, is related to the meso-level category discussed above and has thus been excluded from our report.

The five remaining themes can be described as follows: (a) Ideologies, values, and worldviews include hierarchical, individualistic, egalitarian, and communitarian orientations, as discussed in the section on cultural cognition of risk. Also relevant are variables such as social dominance orientation, which is associated with resistance to scientific findings perceived to threaten the dominance of privileged groups (Milfont et al., 2013); free-market ideology, which is linked to the rejection of findings that could justify government regulation (Hornsey et al., 2016); and belief in a just world, which can support skepticism toward evidence that challenges the *status quo* (Feygina et al., 2010). (b) Conspiratorial ideation reflects the belief that scientific claims are part of a coordinated deception by powerful actors with hidden agendas (Lewandowsky et al., 2013a). (c) Vested interests refer to situations in which scientific findings imply personal sacrifices—such as giving up high-carbon habits—and therefore meet resistance (Corner & Hahn, 2009). (d) Personal identity expression involves the rejection of scientific messages as a way to protect or affirm one's sense of self (Lewandowsky & Oberauer, 2016). Finally, (e) fears and phobias can also motivate skepticism, either as a form of avoidance or rationalization (Jung et al., 2015).

It is worth noting that this list of variables, though helpful and didactic, leaves ample room for greater conceptual rigor. In particular, the confusion between *ideologies, values,* and *worldviews* persists. Furthermore, there is room for expansion, as the summary fails to consider individual differences in how people relate to science itself. These include both scientific knowledge and attitudes towards science and scientists. The former has been widely measured in the literature by true-or-false questions that aim at assessing the individual's literacy regarding either science in general or specific topics. As discussed in the section on the knowledge deficit model, literacy has proven a poor predictor of science acceptance, with the exclusion of genetically modified foods (Rutjens et al., 2021).

Attitudes towards science have been measured in the literature by a variety of instruments with different conceptual underpinnings. These include faith in science (Farias et al., 2013), deference to scientific authority (Brossard & Nisbet, 2006), perceived corruption of science (Rutjens et al., 2021), and general attitude towards science, which encompasses measurements of beliefs, affects, and behaviors (Novaes et al., 2019). This lack of consistency within the literature leaves ample room for progress, as the use of such disparate approaches may hinder the consolidation of findings.

The variables presented above are by no means the only ones that could be included in the micro-level category. Other examples are sociodemographic variables and cognitive styles, such as analytical and open-minded thinking.

Message-Related Variables

The inclusion of message-related variables within the model is based on the hypothesis that it is possible to create communication that is open and less prone to biases (Kahan, 2010). This proposition is in line with the previously discussed notion of "jiu jitsu" persuasion (Hornsey & Fielding, 2017) and could be understood as part of an effort to "tailor" messages to their audiences. Chapman et al. (2017, p. 852) exemplify this strategy by arguing that a better understanding of individual responses can help "design messages that best meet different individuals' particular emotional, informational and decision-making needs".

Even though science communication researchers have explored message-related variables, studies are scarcer, and literature is less robust than the one focusing on the audience. The following paragraphs exemplify some of the variables that have been investigated:

Identity Affirmation. When discussing alternatives for dealing with cultural cognition and different perceptions of risk, Kahan et al. (2011) underline that people are more open to information that affirms their values. For instance, when discussing potential responses to climate change, the authors point out that messages advocating the use of nuclear energy should be better received by people with individualistic and hierarchical worldviews than those that advocate economic restrictions.

Source Credibility. Lupia (2013) argues that source credibility is particularly important in contexts of politicization of the scientific debate. The author presents a series of studies that demonstrate the importance of perceived common interests and expertise of the scientist.

Pluralistic Advocacy. In an experimental study on the perception of risks related to the HPV vaccine, Kahan (2012) found that when participants were exposed to arguments from a plurality of advocates (both culturally aligned and with different worldviews), polarization was reduced. In the words of Kahan et al. (2011, p. 31) individuals “attend more open-mindedly to such information [inconsistent with their predispositions], and are much more likely to accept it, if they perceive that there are experts of diverse values on both sides of the debate”.

Scientific Consensus. In a series of studies, Lewandowsky et al. (2013b) demonstrated the importance of perceived consensus to shape public opinion. Positive correlations between perceived consensus and belief in scientific claims were verified across various topics (e.g., HIV, smoking, obesity). Studies suggest that messages that underscore the scientific consensus tend to be more effective (Ding et al., 2011; Lewandowsky et al., 2013b)

Affective Customization. Chapman et al. (2017) advocate the use of rigorous affective science methods to customize the emotional content of messages. Despite recognizing the practical difficulties of such a proposal, they argue that its chances of success will be considerably greater than massified approaches.

Narrative Framework. Kahan et al. (2011) emphasize that the assimilation of information is commonly accompanied by attempts to relate it to pre-existing narrative schemes or templates that will give it meaning (e.g., existence of villains and heroes, moral questions, etc.). The authors suggest that shaping messages to evoke such narratives can be an effective communication strategy. The empirical study of such effectiveness is challenging, but tools such as the “Narrative Policy Framework” can facilitate the identification of structure and content, as well as their impact on individual attitudes (Jones & McBeth, 2010).

It is important to note that although the variables discussed in this section are presented as message-level factors, they are deeply interwoven with variables at other levels of analysis. For instance, identity affirmation is closely related to group dynamics and social identity (meso-level), source credibility involves perceptions shaped by social trust and institutional confidence (macro-level), and the effectiveness of pluralistic advocacy hinges on individual predispositions and values (micro-level). These overlaps underscore the interactive nature of the model proposed in this dissertation. Rather than operating in isolation or following a linear causal pathway, the categories of variables influence one another in dynamic and reciprocal ways. Over time, message strategies may reshape audience-level dispositions, just as cultural, social, and political contexts can inform the framing and perceived legitimacy of messages. This interdependence reinforces the need for science communication research to adopt integrative frameworks that account for the constant interplay among cognitive, contextual, and communicative dimensions.

The examples listed above exemplify the diversity of potential approaches to increase the effectiveness of science communication by manipulating message-related variables. Including such a category of variables in the MAM aims to encourage a more systematic investigation of these strategies and others.

Concluding Remarks

The present Manuscript presented the central concepts and relevant challenges involved in the research of science communication. It discussed the contributions and limitations of existing models, namely, the information deficit model, the contextual model (with focus on the cultural cognition of risk and motivated rejection of science), and alternative approaches, such as the lay-expertise and public engagement models.

We subsequently presented our proposition of a multilevel analytic model (MAM) of the effects of science communication and went into detail about the four categories of variables included. We argued that this model will go beyond mere description of the dynamics of science communication, serving as a guidepost to identify, organize, and explore the multitude of variables involved in this complex phenomenon. Its main goal is thus to guide interdisciplinary research while building upon the conceptual and methodological contributions of social psychology. In particular, by acknowledging different levels of analysis and drawing attention to multidirectional, intricate relationships between them, the model aims to foster a more comprehensive approach to the effects of science communication.

Manuscript 3

Person, Process, Product: How the Focus of Intervention Impacts Beliefs about GM Foods

The present work was conceived as an attempt to test a multilevel analytical model (MAM) of the effects of science communication and gather empirical data about its application to a particularly controversial scientific topic, namely, genetically modified (GM) foods. This is an especially relevant issue in Brazil, the world's fourth-largest grain producer in 2021 (Embrapa, 2021). The country is also the second-largest producer of biotech crops in the globe, with nearly 53 million hectares dedicated to GM crops, including corn, soybean, and cotton (Ventura, 2021).

Despite its central role in the country's economy and its widespread presence in Brazilian households, GM foods are surrounded by confusion and misinformation. In 2016, a public opinion survey showed that 44% of participants thought that GM foods were poorly tested, 33% believed they were harmful, and 30% stated that they caused allergies. The study further revealed the lack of basic knowledge about genetic modification among Brazilians: 73% of respondents admitted to being "worried about consuming DNA molecules," a statement that makes no sense given that all living beings have DNA (Alves, 2016).

The resistance to GM foods among Brazilians echoes a worldwide phenomenon. Between 2019 and 2020, the Pew Research Center interviewed people across 20 countries and concluded that nearly half of them considered GM foods generally unsafe to eat. A 20-public median of 48% said that GM foods were unsafe while a median of only 13% affirmed their safety for consumption (Kennedy & Thigpen, 2020).

This perceived unsafety is at odds with the scientific consensus, according to which GM foods consumption poses no health threat. In 2016, the United States National Academies of Science, Engineering and Medicine issued a report based on the careful examination of evidence accumulated over two decades. The committee found no adverse health effects that could be directly attributed to GM foods consumption. In their own words:

> Studies with animals and research on the chemical composition of GE [genetically engineered] foods currently on the market reveal no differences that would implicate a higher risk to human health and safety than from eating their non-GE counterparts. Though long-term epidemiological studies have not directly addressed GE food consumption, available epidemiological data do not show associations between any disease or chronic conditions and the consumption of GE foods (National Academies, 2016, paragraph 7).

In 2019, an expert panel in Japan reached similar conclusions about gene-edited foods (Normile, 2019). Similarly, the Brazilian Agricultural Research Corporation (Embrapa) reiterates the safety of GM foods and underlines the role of strict biosafety regulations:

> Before reaching the consumer, every GMO is exhaustingly analyzed through strict laboratory and field tests. (...) Brazilian Law 11.105/05, which regulates the activities with GMOs and biotechnology activities in general, is among the strictest laws *of* the world. This legislation determines that, from initial discovery [to] the stage of being a commercial product, a GMO has to go through many studies, which take approximately 10 years of research. Such studies aim at ensuring the food and environmental safety of the end product (Embrapa, n.d., paragraph 13).

The gap between public opinion and scientific consensus makes GM foods a particularly interesting topic from a science communication standpoint. It seems that despite decades of research, scientists have been unable to shape attitudes or even promote an adequate understanding of genetic modification. We hope that a multilevel analytic approach will help shed light on this issue, not only allowing for a clearer overview of the existing literature but also serving as a guidepost for new studies such as the one reported here.

It is worth noting that even though the proposed MAM includes four categories of audience- and message-related variables, its applications are by no means required to cover all of them. On the contrary, its position is that different studies, either for methodological or theoretical reasons, will address specific categories and thus help incrementally build a new body of research. The present study inaugurates these efforts by focusing solely on intraindividual and message-related variables and their relationship with GM foods beliefs. Our choice is justified by the existing literature on the topic and our overarching goal of verifying the replicability of previous findings in a Brazilian sample.

Most of the research on science communication related to GM foods focuses on the micro-level and, particularly, dispositional factors. Specifically, resistance to GM foods has been associated with lower scientific literacy (Rutjens et al., 2018; Rutjens et al., 2021; Rutjens and Van der Lee, 2020) and lack of domain-specific knowledge (Calabrese et al., 2021; Fernbach et al., 2019; McPhetres et al., 2019). On the contrary, GM foods acceptance has been positively associated with faith (Rutjens et al., 2021) and trust (Drummond & Fischhoff, 2017a) in science, and deference to scientific authority (Kim & Fang, 2020).

It is interesting to point out that the strong relationship between science literacy and acceptance of GM foods is somewhat unique to this topic of science communication. In a comparative study across 24 countries, Rutjens et al. (2021) found that while scientific literacy was the main predictor of GM skepticism, this was not the case for other domains. Climate change skepticism, for instance, was primarily associated with political conservatism, while evolution skepticism was mainly linked to religious orthodoxy. Compared to other science topics, it seems that genetic modification is less susceptible to political, ideological, and religious variables (Drummond & Fischhoff, 2017a).

It would be interesting to investigate whether this positive relationship between GM foods acceptance and science-related variables expands to a more general open-mindedness about evidence. In other words, whether the people's openness to change their views according to new evidence, an important trait of science, though not necessarily linked to the scientific domain, would be a predictor of favorable GM foods beliefs. Actively open-minded thinking about evidence (AOT-E, Pennycook et al., 2020) has been linked to a greater ability to discern true information about Covid-19, an especially relevant topic of science communication (Bonafé-Pontes et al., 2021).

Another intraindividual variable that has repeatedly come up in the literature as a predictor of GM foods resistance is conspiracy ideation. Both Lewandoswki et al. (2013) and Rutjens and Van der Lee (2020) found positive associations between conspiracy thinking and GM foods skepticism. Though not yet broadly explored, healthy eating interests have also been found to moderate the relationship between the perception and consumption of GM foods (Kim & Fang, 2020).

Overall, the existing literature fails to find connections between political orientation and religiosity, and GM foods beliefs (Rutjens et al., 2021; Rutjens & Van der Lee, 2020). It is conceivable, however, that this could be different in a Brazilian sample. The present study aims to explore potential associations that might be unique to a politically polarized country whose right-wing movement is known for his support of the agribusiness sector (Itta, 2022). Similarly, we could envision a negative association between GM foods acceptance and religiosity, given the considerable support from evangelicals to the right-wing, agribusiness-oriented policies (Ionova, 2022).

As for message-related variables, the science communication literature presents sparse evidence about the effectiveness of different strategies. In a series of experimental studies, Dixon (2016) found that messages emphasizing the scientific consensus about the safety of GM foods successfully increased consensus estimation, though audiences' GM foods beliefs were affected differently according to their prior views on the topic. McPhetres et al. (2019) implemented a five-week longitudinal design that demonstrated the effectiveness of teaching participants about the science of GM foods. The authors found more positive attitudes, greater willingness to eat, and lowered risk perceptions of GM foods for participants that learned about the basic science behind GM technology.

Aiming to shed light on the types of informative messages that are the most effective in changing GM foods beliefs, the present study investigates how the focus of an intervention impacts its effectiveness. It builds upon the qualitative study of confidence in science by Brounéus et al. (2019), which identified four overarching themes that can either promote or lower confidence in research, namely, person (the individual who performs the research, i.e., the researcher), process (how the research is performed), product (the results and their usefulness), and presentation (how the research is communicated). We decided to focus on the three content-related aspects, i.e., person, process, and product. In doing so, we follow de Bruin and Bostrom's (2013) proposed steps to developing science communication, particularly the iterative design of communication content and randomized testing of its effectiveness. Numerous studies have comparatively evaluated science communication interventions (e.g., Abu-Akel et al., 2021; Ruzi et al., 2021; van der Bles et al., 2020; among many others). However, to the best of our knowledge, the themes identified by Brounéus et al. (2019) have not yet been experimentally investigated.

Given all that has been discussed so far, the present work aims to (a) test the replicability in a Brazilian sample of findings pertaining to the effect of scientific and domain-specific literacy, attitudes towards science, and conspiracy thinking on GM foods beliefs and (b) explore associations between GM foods beliefs and open-minded thinking about evidence, healthy eating habits, religiosity, and political orientation. Furthermore, it aims to (c) assess whether informative messages will impact GM foods beliefs and (d) investigate potential variations according to the texts' focus (i.e., person, process, product).

Method

This study's intended sample size, variables, design, hypotheses, and planned analyses were preregistered on AsPredicted (https://aspredicted.org/ks2im.pdf) prior to any data being collected. All data and materials are available at our Supplementary Materials page (https://osf.io/nys5p/).

Participants

A total of 787 participants responded to an online questionnaire, which was advertised on paid social media posts. Data was collected in March 2022. Sixteen participants were duplicates and 53 failed the attention checks. After exclusions, the final sample amounted to 718 participants (mean age = 42.71, *SD* = 15.4; 36% female, 63% male, 1% other). The sample size had been determined *a pr*iori (*n* = 700) using parameters that included an effect size (f) of 0.15; error probability of 0.05; and power of 0.95. Informed consent was obtained from all participants. The study followed the ethical guidelines of research with human subjects.

Materials and Procedure

Experimental Conditions

In this between subjects' design, participants were randomly assigned to one of three experimental conditions. In all three conditions, they were asked to read a short text about GM foods (see Appendix A). The specific topic of the text, however, varied across conditions. The first condition focused on "person" and described the academic and professional accomplishments of a preeminent Brazilian researcher of GM foods; the second condition pertained to "process" and described the recombinant DNA, an important technology in GM foods development; finally, the third condition focused on "product" and presented the example of insect-resistant corn, a common GM crop in Brazil.

All three textual stimuli started with two identical paragraphs, the first featured a definition of genetically modified organisms, while the second presented a brief statement about the scientific perspective on the safety of commercially available GM foods. The third paragraph varied across conditions to contemplate the above-mentioned topics (i.e., person, process, product). All texts had similar numbers of words (ranging from 154 to 159). Levels of difficulty, engagement, and technicality were assessed in a pilot data collection.

Dependent Variable

GM food beliefs were measured both at the start of the study (pre) and right after the experimental intervention (post). We purposefully spaced out the pre- and post-intervention measurements to minimize correlations due to the mere repetition of items. Participants answered six items on a slider scale that ranged from 0, “totally disagree”, to 100, “totally agree”. Statements were adapted from Dixon (2016) and included “GM foods are safe to eat”, “I support the sale of genetically modified foods”, and “GM ingredients in foods can cause illness in people” (reverse item). Both measurements had unifactorial structure and good reliability (ω = .94 and factor loadings ranging from .75 to .93 for the pre-test and ω = .93 and factor loadings ranging from .66 to .91 for the post-test).

Pre- and post-intervention scores were calculated - the higher the score, the more favorable beliefs about GM foods. Our dependent variable was the change in beliefs after the experimental intervention (i.e., post scores minus pre scores).

Covariate Measures

For all the scales described below, items were measured in slider scales that ranged from 0, “totally disagree”, to 100, “totally agree”, unless said otherwise.

Healthy Eating Habits. Participants responded to six items pertaining to their eating habits. Examples included “I believe that a healthy diet leads to a better quality of life” and “Due to practicality, fast foods and processed foods are good options” (reverse item). This scale presented a unifactorial structure and good reliability (ω = .77; factor loadings between .44 and .80).

Reduced Attitude Towards Science Scale (ATSS). Developed by Novaes et al. (2019) the original ATSS has 42 items and a bidimensional structure that contemplates (1) beliefs and affects and (2) personal initiative. Given the length of the scale, we applied a reduced version that included the ten items with the highest factor loading (above .7). “Science is essential to human development” and “I like to read about science” are examples of items in the reduced ATSS. Similar to the original study, the scale presented bidimensional structure and good reliability (ω = .78; factor loadings between .47 and .85).

Scientific Literacy. Nine true/false items were used to measure participants' scientific knowledge. These items were translated into Brazilian Portuguese from Kahan et al. (2012) and Rutjens et al. (2018). Examples include "The center of the Earth is very hot" and "All human-made chemicals can cause cancer". This scale presented a unifactorial structure and good reliability (ω = .82; factor loadings between .34 and .77).

GMO Literacy. Participants responded to eight true-false items about GMOs. This is a translated and reduced version of Calabrese et al. (2021)'s GM literacy scale, which originally has 23 items. Examples include "Genetically modified organisms are always bigger than normal" and "Genetically modified crops are sterile". This scale presented a unifactorial structure and acceptable reliability (ω = .74). However, low factor loadings (ranging between .03 and .84) may be cause for concern.

Confidence in Knowledge. Participants indicated their level of agreement with the following sentences "I feel confident in my knowledge about science" and "I feel confident in my knowledge about GMOs". Considered together, these items presented acceptable reliability (ω = .71; factor loadings of .75 for both items).

Actively Open-Minded Thinking about Evidence Scale (AOT-E). Conceived as a variation of the Actively Open-Minded Thinking Scale (Stanovich & West, 2007), the AOT-E contains 8 items (e.g., "A person should always consider new possibilities") and measures respondents' openness to changing their beliefs according to new evidence (Pennycook et al., 2020). It was translated to Portuguese and validated for application in Brazilian samples (Bonafe-Pontes & Pilati, 2025). Its current application shows a unifactorial structure and acceptable reliability (ω = .71; factor loadings between .44 and .71).

General Conspiracy Belief Scale. Developed by Rezende et al. (2021), the scale is composed of 15 items, including "New drugs and technologies are routinely tested in people without their knowledge" and "Secret organizations are in contact with extraterrestrials but keep it a secret". Though inspired by Brotherton et al. (2013)'s Generic Conspiracist Beliefs Scale, this instrument was created specifically for Brazilian samples and was thus considered a better fit for our purposes. In our study, the scale showed good reliability ω = .91 (factor loadings between .40 and .90).

Political Orientation and Religiosity. Participants were asked to indicate their position in the political spectrum and their level of religiosity on two slider scales that ranged from "extremely to the left" and "not religious at all" (0) to "extremely to the right" and "extremely religious" (100), respectively.

Sociodemographic Questions. Participants were asked questions regarding their gender, age, state of residence, and level of education.

The scales were presented in the order shown above. GM foods beliefs were measured after the healthy eating habits items and again after the experimental intervention, which was presented after the scientific/GMO literacy/confidence block.

Attention Check

Following the best practices in research, we included two screener questions. The first instructed participants to select *"Completely Disagree"* to indicate that they were effectively paying attention to the task. The second asked participants to identify the topic of the text presented in the experimental task.

Results

Statistical analyses were performed in IBM SPSS (version 23), Factor (version 12.01.02), and JASP (version 0.15). We began by performing exploratory analyses, including non-parametric correlations, which are reported in Table 1. It is worth noting that our findings largely corroborate the existing literature, including positive associations between GM foods acceptance (i.e., scores in the initial application of the GM foods beliefs scale) and a more favorable attitude towards science, and greater

Table 1

Correlations (Kendall's τ)

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. GM foods_Pre	325.44	214.55														
2. GM foods_Post	404.99	195.22	.67**													
3. GM foods_Difference	79.55	120.14	-.35**	.00												
4. Healthy eating	473.36	102.85	-.24**	-.22**	.04											
5. ATSS	833.31	158.01	.15**	.13**	-.07**	.09**										
6. Confidence in knowledge	135.96	51.03	.23**	.15**	-.24**	.07**	.26**									
7. Scientific literacy	6.75	1.93	.25**	.17**	-.18**	-.10**	.27**	.22**								
8. GMO literacy	4.69	1.46	.20**	.16**	-.13**	-00	.18**	.23**	.23**							
9. AOT-E	650.64	128.37	.11**	.14**	-.02	.03	.26**	.09**	.25**	.11**						
10. Conspiracy beliefs	623.97	348.60	-.24**	-.25**	.04	.12**	-.17**	-.12**	-.25**	-.10**	-.17**					
11. Political orientation	48.13	28.55	.16**	.14**	-.06**	-.07**	-.13**	.02	-.11**	.03	-.16**	.04				
12. Religiosity	37.19	34.42	-.07**	-.05*	.05*	.06*	-.19**	-.06**	-.30**	-.03	-.29**	.15**	.24**			
13. Age	42.72	15.40	-.15**	-.15**	.04	.22**	-.01	.05	-.12**	.04	-.04	.09**	.03	.08**	-.13**	
14. Education	5.57	1.27	.00	-.02	-.03	.04	.16**	.10**	.22**	.10**	.10**	-.14**	-.10**	-.09**	-.03	.14**

Note. N = 718. ** Correlation is significant at the .01 level (2-tailed). * Correlation is significant at the .05 level (2-tailed).

GMO and scientific literacy. Similarly, expected negative associations were found between GM foods acceptance and conspiracy beliefs. As for the exploratory variables, the hypothesized negative correlation between healthy eating habits and GM foods acceptance was indeed verified. Similarly, the expected positive correlation between open-mindedness and GM foods acceptance was also present. Contrary to previous studies but aligned with our expectations for the Brazilian sample, we found a positive correlation between GM foods acceptance and political orientation to the right. However, there was a small but negative correlation with religiosity.

We proceeded to investigate differences in GM foods beliefs before and after the experimental intervention. On average, participants had more favorable GM foods beliefs after the intervention (M = 404.99, SD = 195.22) than they had before (M = 325.44, SD = 214.54). A paired samples t-test with bootstrapping confirmed that this difference was statistically significant ($t(717) = 17.74$, $p < .001$).

We subsequently compared these differences across experimental groups with the goal of determining whether any of the intervention focuses (person, process, or product) had been more or less effective in increasing GM foods acceptance. Means and standard deviations for each condition are reported in Table 2. Given the distribution of our data, we performed Welch's ANOVA, which showed that even though the mean difference (post- minus pre-intervention GM foods beliefs score) was slightly smaller for participants that read about "process", overall these means were not statistically different across experimental groups ($F(2,476.41) = 1.10$, $p = .33$).

Table 2

Mean Difference in GM Foods Beliefs (Post Minus Pre Scores)

Group	*n*	Mean	SD
People	239	83.33	117.85
Process	241	70.26	119.39
Product	238	85.16	123.10

We further explored the influence of covariate measures on GM foods beliefs pre- and post-intervention by running two linear regression models. As reported in Table 3, the first model had as dependent variable GM foods beliefs pre-intervention. All the listed variables were entered at once, using the forced entry method. Results largely corroborated what was found in the exploratory correlational analyses, except for religiosity and attitude towards science scores, which lost their statistical significance. Overall, the model was capable of explaining a considerable portion of the variance for the dependent variable (adjusted R^2 = .36).

Table 3

Linear Regression - GM Foods Beliefs Pre-Intervention

	B	95% CI for *B*		*SE B*	β	*p*
		LL	*UL*			
(Constant)	162.287	39.563	285.011	62.508		.010
Healthy eating	-.598	-.727	-.470	.066	-.287	<.001
ATSS	.048	-.050	.146	.050	.035	.336
Scientific literacy	14.584	6.469	22.700	4.134	.132	<.001
GMO literacy	13.317	3.779	22.854	4.858	.091	.006
Confidence in knowledge	.898	.620	1.176	.142	.214	<.001
AOT-E	.160	.041	.280	.061	.096	.009
Conspiracy beliefs	-.118	-.158	-.078	.020	-.192	<.001
Political orientation	1.809	1.325	2.292	.246	.240	<.001
Religiosity	.151	-.286	.587	.222	.024	.498

Note. CI = confidence interval; LL = lower limit; UL = upper limit; R^2 = .370; Adjusted R^2 = .362.

The second linear regression model is reported in Table 4 and had the difference in GM foods beliefs pre- and post-intervention as the dependent variable (i.e., scores post-intervention minus scores pre-intervention). We also utilized the forced entry method. In this instance, the only statistically significant predictors were scientific and GMO-related literacy and confidence in one’s own scientific knowledge, all of which had negative coefficients. Compared with the previous regression, there was an important reduction in explanatory power for this dependent variable (adjusted R^2 = .165).

Table 4

Linear Regression - Difference in GM Foods Beliefs Before and After Intervention

Variable	*B*	95% CI for *B*		*SE B*	β	*p*
		LL	*UL*			
(Constant)	212.355	133.723	290.986	40.050		<.001
Healthy eating	.057	-.026	.139	.042	.049	.177
ATSS	.034	-.029	.097	.032	.045	.284
Scientific literacy	-12.562	-17.762	-7.363	2.648	-.202	<.001
GMO literacy	-5.935	-12.046	.176	3.113	-.072	.057
Confidence in knowledge	-.708	-.886	-.529	.091	-.301	<.001
AOT-E	.070	-.007	.146	.039	.074	.075
Conspiracy beliefs	-.024	-.049	.002	.013	-.069	.071
Political orientation	-.300	-.610	.009	.158	-.071	.057
Religiosity	.123	-.157	.402	.142	.035	.389

Note. CI = confidence interval; LL = lower limit; UL = upper limit; R^2 = .176; Adjusted R^2 = .165.

Discussion

Despite the widespread presence of GM crops in Brazil, there is still considerable resistance and confusion about the topic (Alves, 2016). Our research contributes to a better understanding of beliefs about GM foods among Brazilians and pioneers the use of an experimental design to investigate the effectiveness of science communication related to GM foods in the country. It further advances the use of the MAM of the effects of science communication and specifically the study of micro-level variables related to the audiences along with those pertaining to the message.

Considering the effects of the experimental intervention, our results reiterate the findings of McPhetres et al. (2019). Regardless of the message's focus, it seems that giving people information about GM foods increases positive beliefs about the topic. The fact that, on average, an increase was found throughout the sample provides some evidence for the deficit model, according to which the lack of scientific information or understanding drives negative attitudes towards science (McDivitt, 2016). It seems that people's attitudes towards GM foods could be addressed with more widespread access to information, which could help dispel confusion and misunderstandings that may be at the root of skepticism.

The regression results pertaining to the difference in beliefs pre- and post-intervention corroborate this conclusion. Participants' scientific and GMO-related literacy, as well as how confident they were in their knowledge, negatively predicted changes to their beliefs. We could argue that the more literate the individual, the less affected by informative messages because their original beliefs were favorable to begin with (as shown by the pre-intervention regression results). In deficit model terms, literate participants have a much narrower gap to fill than those with poor scientific knowledge, at least when it comes to GM foods.

Such a conclusion, however, should not be generalized to other science communication topics. As mentioned in Chapter 1, several studies have demonstrated that the deficit model is overly simplistic and unable to account for the relationship between knowledge and attitudes or beliefs, particularly for politically polarized issues, such as climate change (Kahan, 2010; Simis et al., 2016; Suldovsky, 2017). In their 24-country comparative study, Rutjens et al. (2021) underline the heterogeneous nature of science skepticism. In the authors' words, "levels of science skepticism are heterogeneous across countries, but predictors of science skepticism are heterogeneous across domains" (Rutjens et al., 2021, abstract). We believe that domain-related heterogeneity extends to the effectiveness of science communication approaches and that the difference in the public's response to experimental interventions related to GM foods and, for instance, climate change, attests to this condition.

Discussing the predictor variables for GM beliefs prior to the intervention is particularly helpful when it comes to painting a general picture of what influences these beliefs among Brazilians and how these dynamics relate to the existing literature. Considering MAM's micro-level variables, our results build upon the existing literature, shedding light on some important nuances. We chose to assess participants' attitudes towards science using a scale that had been built specifically for Brazilian samples. We expected to see a similar pattern of positive association with favorable GM foods beliefs as was found in international studies that used measures of faith and trust in science (Drummond & Fischhoff, 2017a; Rutjens et al., 2021). This was only partially the case. Even though there were statistically significant positive correlations between ATSS and both pre- and post-intervention GM scores, this variable lost its relevance in the regression models. This happened once literacy and open-mindedness were accounted for, which leads us to believe that rather than a positive attitude towards science and scientists, what actually matters is people's scientific knowledge and their willingness to abide by one of science's main principles, which is openness to new evidence. Potentially high levels of social desirability could also help explain this variable's lack of discriminatory power.

As for general scientific and GM-specific literacy scores, our results replicate those of the existing literature. Similar to McPhetres et al. (2019) and Calabrese et al. (2021) we find that domain-specific knowledge is a particularly interesting predictor of GM foods acceptance, as its significance corroborates the prior discussion of the effectiveness of informative messages on this topic of science communication.

Negative associations between conspiracy beliefs and GM foods beliefs are also like those found in previous research. Our use of a Brazilian conspiracy ideation scale attests to the robustness of this effect across various contexts (Lewandoswki et al., 2013; Rutjens & Van der Lee, 2020). Our study further advances the understanding of healthy eating interests and their relationship with GM foods beliefs. While Kim and Fang (2020) found a moderation, our model shows healthy eating scores as a statistically significant predictor of unfavorable GM foods beliefs (though with a relatively small coefficient). We believe that increasing public awareness about the use of pesticides and the growing demand for organic foods may fuel this association (Portela, 2022). In this sense, informative messages that dispel confusion related to this topic may be particularly relevant.

As far as political orientation and religiosity, our study partially corroborates previous ones. Even though an initial negative correlation was found between religiosity and GM foods beliefs, this effect was not present in the regression model, echoing the findings of Rutjens et al. 2018.

However, our models show that political orientation to the right is a statistically significant predictor of favorable GM foods beliefs, a divergence from the existing literature, which finds no association between political orientation and GM foods skepticism (Rutjens et al., 2021; Rutjens & Van der Lee, 2020). This finding may reflect the political landscape at the time the study was conducted. During that period, the Administration placed strong emphasis on the agribusiness sector, which had become closely associated with support for then-President Jair Bolsonaro. Given the agricultural industry's interest in the multiplication of GM crops, and its strong sway over the country's economic and political scene, it is possible that those that position themselves to the right of the political spectrum may be more accepting of GMOs. Political polarization has also enhanced the opposition between agribusiness and environmentalists, which could explain a left-wing resistance to GM foods.

It is important to recognize the limitations of our study. For starters, the characteristics of our sample were not fully representative of the Brazilian population, with a pronounced overrepresentation of highly educated individuals. This is a direct consequence of doing research in countries where sampling tools are not widely available. Even though social media allows us to reach people from very diverse backgrounds, paid advertisement algorithms make sampling biases almost impossible to avoid.

Another limitation is the use of somewhat simplistic stimuli that may not adequately represent what real-life science communication messages would look like. Aiming to control confounding variables, we decided to utilize simple texts with no images or videos. As people become ever more reliant on the Internet, and especially social media, text-only communication loses salience. In that sense, we believe that our results could have been magnified if our intervention had included more attention-grabbing elements.

We also sought to control for confounding variables by repeating our GM foods beliefs measure pre- and post-intervention. As expected, there was a high correlation between scores before and after reading our science communication message. A potential limitation would be participants recalling their previous answers and simply reproducing them in the post-intervention measurements. We attempted to reduce this trend by spacing the two measurements out within the questionnaire flow and by presenting items randomly. Utilizing similar but non-identical items could have been a more effective approach and we urge future research to consider this strategy.

Despite its limitations, our study is an important contribution to the nascent field of experimental science communication research in Brazil. It also contributes to the international literature by confirming and adding nuance to the understanding of communication pertaining to GM foods and by pioneering the study of person, process, and product as potential focuses for interventions. Finally, it contributes to future research by demonstrating how to use the MAM as a tool to investigate various categories of variables within the complex field of science communication.

Manuscript 4

Actively Open-Minded Thinking About Evidence (AOT-E) Scale: Adaptation and Evidence of Validity in a Brazilian Sample

The development of Manuscript 4 represents a critical methodological step in the advancement of this dissertation's goals. As highlighted by the early applications of the Multilevel Analytic Model (MAM), particularly in Manuscript 3, a major challenge in the study of science communication in Brazil was the absence of psychometric tools capable of capturing key individual-level dispositions. Constructs such as actively open-minded thinking had emerged as central predictors of science-related beliefs and behaviors, yet their systematic investigation remained limited by the lack of culturally and linguistically validated measures. By adapting and testing the Actively Open-Minded Thinking About Evidence (AOT-E; Pennycook et al., 2020) scale for use with Brazilian populations, Manuscript 4 addresses this gap directly, offering a tool with strong psychometric properties and clear theoretical relevance.

Moreover, this contribution expands the global science communication literature by offering data from an understudied context. Most research in this field has historically centered on North American and European samples, leaving significant blind spots in our understanding of how cognitive dispositions operate across different sociocultural environments. The adaptation of the AOT-E scale allows for more accurate, culturally sensitive assessments and opens the way for future research. In doing so, this manuscript strengthens the multilevel model's empirical foundation and reinforces the dissertation's overarching goal: to advance a more inclusive, theory-driven, and methodologically rigorous approach to science communication.

For the full text, please refer to: Bonafé-Pontes, A., Bastos, R. C., & Pilati, R. (2025). Actively Open-Minded Thinking About Evidence (AOT-E) Scale: Adaptation and Evidence of Validity in a Brazilian Sample. *Judgement and Decision Making*, *20*(e3), 1–15. https://doi.org/doi:10.1017/jdm.2024.37.

Manuscript 5

Adaptation of the Scientific Reasoning Scale in Brazil

Manuscript 5 also marks an important methodological advancement in this dissertation's overarching objective to model how individuals engage with scientific information across varying contexts. As the need for valid, theoretically grounded instruments became increasingly clear in prior studies, geared our efforts toward expanding the available tools beyond measures of general literacy or attitudes. Scientific reasoning, conceptualized as the ability to critically evaluate the quality of evidence (Drummond & Fischoff, 2017b), emerged as a construct of high explanatory potential but limited empirical exploration in understudied populations. By adapting and validating the Scientific Reasoning Scale (SRS) for Brazilian Portuguese, this manuscript fills a crucial gap, offering a reliable and context-sensitive measure for assessing a skill that is foundational to science comprehension and scientifically-informed decision-making.

This contribution not only strengthens the internal consistency of the multilevel analytic model proposed in this thesis but also extends its applicability to culturally diverse contexts. Brazil presents a particularly urgent case for this investigation, given its ongoing challenges with scientific misinformation, public health crises, and educational disparities. The adapted SRS provides a psychometrically sound tool to examine how individuals process evidence-based claims, paving the way for its use in future research, educational interventions, and public policy evaluations. Moreover, this manuscript reinforces the dissertation's commitment to methodological rigor and internationalization by addressing the chronic underrepresentation of non-WEIRD populations in science communication research and expanding the global reach of validated psychological measures.

This manuscript has been submitted for publication.

Manuscript 6

How Perceived Psychological Distance Affects Attitudes Towards Dengue Vaccines

Dengue fever is a rapidly growing global health threat, with nearly half of the world's population at risk and up to 400 million infections occurring annually (WHO, 2024a). Caused by the dengue virus and transmitted by *Aedes* mosquitoes, the disease is most prevalent in tropical and subtropical regions, especially in urban and semi-urban settings. While many cases are mild or asymptomatic, severe dengue can lead to life-threatening complications, including organ failure and internal bleeding. In 2024, dengue cases reached unprecedented levels worldwide, with over 14 million reported infections and more than 10,000 deaths across 90 countries (ECDC, 2025, WHO, 2024b). The Americas were particularly hard-hit, accounting for approximately 90% of the global cases - with Brazil, Argentina, Colombia, and Mexico bearing the heaviest burden. This surge represents a nearly threefold increase in the number of cases in the region compared to the previous year, underscoring the escalating crisis posed by dengue fever. (Reuters, 2024).

Beyond the Americas, Asia, the Western Pacific, and Africa are also heavily impacted by dengue fever, with cases rising at alarming rates. In Asia, dengue remains a major public health crisis, with Indonesia, Bangladesh, and the Philippines experiencing severe outbreaks in 2024, leading to thousands of hospitalizations and deaths. The Western Pacific Region, including Cambodia, Malaysia, Vietnam, and Singapore, continues to face persistent dengue transmission, exacerbated by rapid urbanization and favorable climate conditions for mosquito breeding. Meanwhile, in Africa, despite a history of underreporting, dengue is becoming an increasing threat, particularly in sub-Saharan regions, where changing climate patterns and limited vector control measures have contributed to growing outbreaks (WHO, 2024b).

Unfortunately, there is no specific antiviral treatment for dengue, making early detection and supportive medical care crucial in reducing fatalities. Prevention efforts rely heavily on vector control, including the elimination of mosquito breeding sites, the use of insect repellents, and the implementation of protective measures such as window screens and bed nets. According to the World Health Organization (WHO, 2024b), the dramatic rise in cases of dengue fever is linked to climate change, which has expanded the habitats of *Aedes* mosquitoes, along with rapid urbanization and inadequate sanitation, which provide ideal breeding conditions. The escalating incidence of dengue highlights the urgent need for strengthened public health initiatives, improved vector surveillance, and continued investment in vaccine development to curb the spread of the disease.

Dengue Vaccines: an Overview

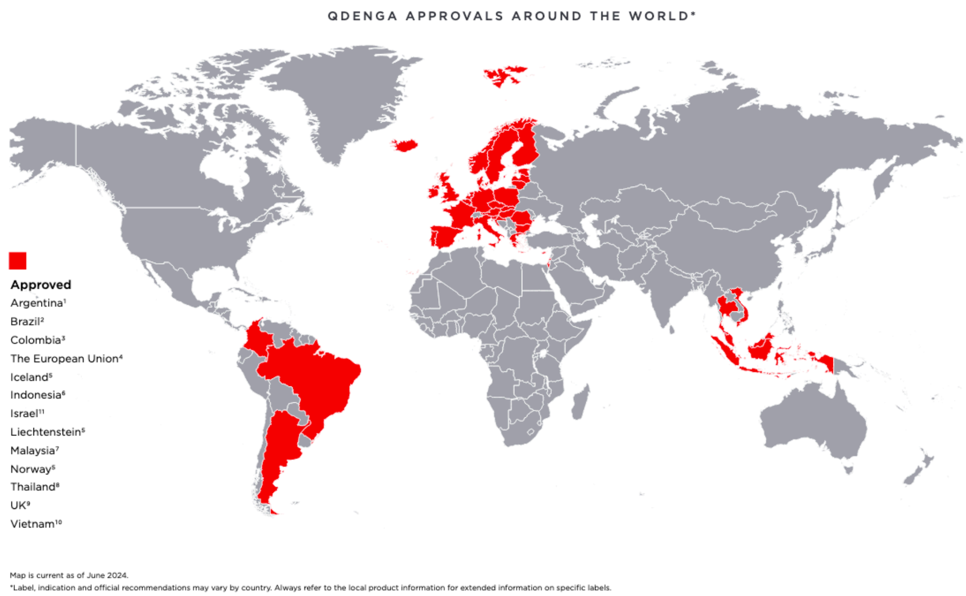
Given the growing burden of dengue, vaccination has emerged as a critical preventive strategy. Currently, two dengue vaccines have been licensed: Dengvaxia® (CYD-TDV), developed by Sanofi Pasteur, and Qdenga® (TAK-003), produced by Takeda. Dengvaxia®, the first vaccine to receive regulatory approval, is a live recombinant tetravalent vaccine administered in a three-dose series at six-month intervals (Sanofi, n.d.). It is recommended for individuals aged 9–45 or 9–60 years, depending on country-specific regulations, and is restricted to those with prior dengue virus infection, as confirmed by pre-vaccination screening (WHO, 2025). Due to this requirement, its widespread implementation has been limited despite its approval for use in the US, EU, and in some Asian and Latin American countries (Sanofi, n.d.).

Unfortunately, Dengvaxia®'s initial rollout faced several challenges and caused significant controversy because, at the outset, the vaccine was not restricted to seropositive people. The Dengvaxia® public vaccination program in the Philippines, launched in 2016, was the first of its kind and initially viewed as a promising avenue for dengue prevention. However, in November 2017, Sanofi Pasteur, the vaccine's manufacturer, disclosed that Dengvaxia® posed a risk of severe dengue in individuals who had not previously been exposed to the virus. This announcement led to the abrupt suspension of the vaccination program after nearly 800,000 children had already received at least one dose (The Guardian, 2017). The situation escalated further as political actors and media outlets sensationalized the issue, fostering widespread fear and misinformation. Government investigations, including televised autopsies, linked the vaccine to child fatalities, despite limited scientific evidence supporting direct causality (Mabale et. al, 2024). Research has shown that public confidence in vaccines declined dramatically, leading to decreased immunization rates for other vaccine-preventable diseases, such as measles (Larson et al., 2018). In 2018, measles vaccination coverage in the Philippines plummeted to 55%, compared to 88% in 2014, and was followed by a severe outbreak of the disease (Dyer, 2019). The Dengvaxia® controversy exemplifies the profound impact of vaccine-related misinformation and underscores the critical need for effective risk communication strategies and transparent public health policies to maintain vaccine confidence.

Qdenga®, the second licensed dengue vaccine, is a live-attenuated formulation based on the DENV2 strain and includes all four serotypes (Takeda, n.d.). It follows a two-dose regimen with a three-month interval and is recommended by the WHO for children aged 6–16 years in regions with high dengue transmission intensity (Takeda's official recommendation is much broader, including people from 4 to 60 years of age). As of February 2025, WHO also advises against the programmatic use of TAK-003 in low-to-moderate transmission settings until further data on its efficacy-risk profile, particularly against DENV3 and DENV4 in seronegative individuals, become available. However, in dengue-endemic countries, individuals with comorbidities may be considered for vaccination outside the organization's recommended age range if a substantial burden of severe dengue has been documented (WHO, 2025). As of July 2024, Qdenga® was available in over 20 countries, as shown in Figure 1 (Takeda, 2024).

Figure 1

Qdenga Approvals Around the World



Throughout the globe, ongoing efforts are focused on developing new dengue vaccines to expand preventive options. Live attenuated vaccines specifically have been a key area of research due to their ability to provide immunity against all four dengue virus serotypes. One of the most promising candidates is the Butantan-DV vaccine, developed by the Butantan Institute in collaboration with the U.S. National Institutes of Health (NIH). Unlike existing dengue vaccines, Butantan-DV is designed as a single-dose immunization, simplifying administration and potentially increasing coverage. Phase III clinical trials have demonstrated an efficacy of 79.6%, regardless of prior dengue exposure, making it a strong candidate for widespread use in endemic regions. The Brazilian government is working toward integrating this vaccine into national immunization programs, aiming to make it more accessible to at-risk populations (Butantan, n.d.).

Beyond Butantan-DV, other vaccine platforms are under development, including purified inactivated vaccines (PIVs), recombinant subunit vaccines, and DNA-based approaches. Institutions such as GlaxoSmithKline, the Walter Reed Army Institute of Research, and Merck & Co. are leading these efforts, each focusing on different strategies to enhance safety, efficacy, and durability of immune responses (Pintado Silva & Fernandez-Sesma, 2023).

Models for Understanding Vaccine Hesitancy

While significant advancements have been made in developing dengue vaccines, addressing vaccine hesitancy is crucial to ensure successful immunization programs. Vaccine hesitancy, understood as the reluctance or refusal to receive vaccines despite their availability, represents a major challenge to global health initiatives (MacDonald & SAGE Working Group on Vaccine Hesitancy, 2015). In 2019, the World Health Organization (WHO) recognized vaccine hesitancy as one of the ten greatest threats to global health. (WHO, n.d.). This growing skepticism has contributed to a resurgence of vaccine-preventable diseases worldwide. For instance, in 2023, there were 14.5 million children globally who missed out on any vaccination, termed "zero-dose children." Additionally, coverage for the first dose of the measles vaccine was 83% in 2023, a decline from 86% in 2019 (WHO, 2024c). Such declines in immunization rates have led to outbreaks; the WHO reported 10.3 million measles cases and 107,500 deaths in 2023, with significant increases in regions like Africa, the Middle East, and Asia (Associated Press, 2025).

Investing solely in vaccine development is insufficient without considering public acceptance. Several models have been developed to understand and address vaccine hesitancy, each focusing on different determinants of vaccination behavior (for a comprehensive review, see Tostrud et al., 2022). Built upon the assumption that existing beliefs shape future behaviors, the Health Belief Model (HBM) is one of the most widely used frameworks. It posits that individuals' likelihood of adopting a health behavior, such as vaccination, depends on their perceived susceptibility to the disease, perceived severity of its consequences, perceived benefits of vaccination, and perceived barriers to receiving the vaccine (Becker et al., 1974; Rosenstock, 1974). Additional factors, such as cues to action and self-efficacy, further influence decision-making (Rosenstock et al., 1988). The HBM has been extensively applied across different contexts and has been effective in predicting vaccine attitudes and behaviors (recent examples include Ventonen et al., 2024; Stark et al., 2024; Limbu et al., 2022; Zampetakis & Melas, 2021).

Another influential framework is the Theory of Planned Behavior (TPB), which assumes that an individual's intention to act is a predictor of their actual behavior (Ajzen, 1985; 1991). It suggests that vaccination intentions are shaped by attitudes toward the vaccine, subjective norms (social pressures and expectations), and perceived behavioral control (the extent to which individuals feel capable of getting vaccinated). Overall, the TPB suggests that an individual's attitudes, social norms, and perceived behavioral control are positively linked to their intention to act, ultimately leading to improved health behavior outcomes. (Tostrud et al., 2022). This model has been used to assess vaccine hesitancy in various settings, including general and childhood vaccinations (Caso et al., 2022; Dubé et al., 2018; Hu et al., 2019; etc.), influenza (Schmid et al., 2017), HPV (Shah et al., 2021), and COVID-19 vaccines (Breslin et al., 2021; Rountree & Prentice, 2022; among many others).

The 3C model, developed by the WHO’s Strategic Advisory Group of Experts (SAGE) on Immunization, simplifies vaccine hesitancy into three core factors: confidence (trust in vaccines, healthcare providers, and policymakers), complacency (low perceived risk of vaccine-preventable diseases), and convenience (availability and accessibility of vaccines) (SAGE Working Group on Vaccine Hesitancy, 2014). This model aims to provide a practical approach to understand and address vaccine hesitancy in different populations, accounting for the complexity and contextual variance of the phenomenon. More recently, the 5C model expanded on this framework by adding two additional antecedents of vaccine acceptance: calculation (the extent to which individuals engage in information-seeking and risk assessment) and collective responsibility (the willingness to vaccinate for community protection) (Betsch et al., 2018). Lastly, the 5A model proposes a new taxonomy for the determinants of vaccine uptake, which includes barriers and facilitators, namely: access, affordability, awareness, acceptance, and activation (Thomson et al., 2016).

Post-COVID-19 Vaccine Hesitancy Findings

While these models offer a strong and comprehensive theoretical foundation, the COVID-19 pandemic has driven a new wave of large-scale, correlational research aimed at identifying specific variables that enhance our understanding of vaccine skepticism. In a study conducted across 23 countries, Lazarus et al. (2022) found significant correlations between vaccine hesitancy and negative perceptions regarding risk, trust, safety, and efficacy. Trust in the science behind vaccine research and production seems to play a particularly crucial role both at the individual (Marinthe et al., 2024; Palamenghi et al., 2020; Reiss, 2022) and societal levels. Analyzing data from 120,000 respondents in 126 countries, Sturgis et al. (2021) concluded that people tend to have greater confidence in vaccines in countries where trust in science is high, a phenomenon that goes above and beyond individual-level beliefs. Moreover, strong societal consensus on the reliability of science amplifies this effect, strengthening the link between trust in science and vaccine confidence.

In a study of nearly 6 thousand individuals across 24 countries, Rutjens et al. (2021) found that vaccine skepticism was positively associated with spirituality and negatively associated with scientific literacy. Similarly, Candio et al. (2023) analyzed survey data from over 15,500 in 13 countries and found that factors influencing moderate hesitancy were different from those driving extreme hesitancy. A lack of trust in healthcare providers emerged as a key driver of extreme vaccine refusal, while factors such as age, gender (with women showing greater hesitancy), and political ideology played significant roles in moderate hesitancy, though varying across countries. Additionally, concerns over vaccine safety and side effects were the most cited reasons for hesitancy. The authors conclude that different intervention strategies may be needed to target different levels of hesitancy, while addressing deep-seated mistrust in healthcare institutions remains a complex challenge.

Jennings et al. (2023) also investigated the role of trust in shaping vaccine hesitancy across diverse populations. Utilizing both original survey data from seven countries (France, Germany, Spain, Argentina, Croatia, Brazil, and India) and a global survey covering 113 countries, drawn from the Wellcome Global Monitor, the study employs multilevel regression models to analyze the impact of different forms of trust - including generalized trust, trust in political institutions, trust in health institutions, and conspiracy mentality - on vaccine acceptance and hesitancy. Findings indicate that trust in health institutions is the strongest and most consistent predictor of vaccine acceptance, while conspiracy mentality emerges as the most significant driver of vaccine hesitancy. Generalized distrust in government also correlates with higher hesitancy, whereas trust in political institutions has a more variable effect. Additionally, consumption of traditional media (television, newspapers, radio) is associated with greater vaccine willingness, while higher engagement with online political content predicts greater hesitancy. The study underscores the dynamic role of different types of trust in shaping vaccination behaviors and suggests that addressing vaccine hesitancy requires restoring confidence in health authorities and combating misinformation.

Darbandi et al. (2024) also examined the prevalence of vaccine hesitancy and acceptance, as well as the underlying factors influencing these attitudes. The researchers conducted a systematic review of 59 cross-sectional studies across 27 countries, covering populations from Asia, the Americas, Europe, Africa, and Oceania. Findings revealed wide variation in vaccine acceptance, ranging from 13% to 96%, while hesitancy ranged from 0% to 57.5%. The main factors driving vaccine acceptance were confidence in the healthcare system and a heightened perception of the risks posed by COVID-19 infection. Conversely, hesitancy was most commonly driven by concerns over vaccine safety, the rapid development process, fear of adverse effects (such as infertility or death), and conspiracy theories suggesting the vaccine contained microchips. Additionally, socio-demographic factors such as higher income, male gender, older age, marriage, the presence of vaccinated children, higher education, and health insurance coverage were associated with greater vaccine acceptance.

These findings expand on a previous multicultural investigation of the psychological roots of anti-vaccination attitudes. After studying data from over 5,300 respondents in 24 countries, Hornsey et al. (2018a), found that resistance to vaccination was most prevalent among individuals who exhibited high levels of conspiratorial thinking, strong reactance—indicating a low tolerance for perceived restrictions on personal freedom—, heightened disgust sensitivity toward blood and needles, and a strong preference for individualistic and hierarchical worldviews, which reflect beliefs about the extent of societal control over individuals and the desirability of social hierarchies.

Though the studies presented above analyze data from multiple countries, attempts to interpret vaccine-related attitudes and behaviors through a cultural lens are scarce. One interesting exception is the concept of cultural tightness and looseness (CLT; Gelfand et al., 2006; Gelfand et al., 2011), which aims to capture the degree to which social norms are clearly established, widely upheld, and consistently enforced within a society. It reflects how strongly a culture values conformity to social expectations and how it responds to deviations. In tight cultures, norms are rigidly enforced, and non-conformity tends to be sanctioned, whereas loose cultures are more flexible, allowing greater tolerance for diversity and individual expression. Ng and Tan (2023) explored the relationship between cultural tightness and willingness to receive the COVID-19 vaccine in 12 countries. Findings revealed a negative correlation between cultural tightness and vaccine acceptance, suggesting that individuals in tighter cultures were paradoxically less willing to receive the vaccine. Further analysis indicated that vaccine willingness was positively associated with the prevalence of COVID-19 cases, implying that in societies where the virus was well-controlled, individuals perceived a lower risk of infection and were thus more hesitant to get vaccinated. The authors suggest that while cultural tightness may have contributed to effective pandemic control (Gelfand et al., 2021), it may have reduced the perceived urgency of vaccination. They highlight the need for culturally tight societies to leverage their strengths in coordination and societal cooperation to promote vaccination.

Jones et al. (2022) had similar findings when examining COVID-19 vaccination rates across U.S. states and counties. The authors suggest that cultural tightness does not inherently promote or discourage vaccination but rather reinforces the prevailing social norms within a given community. They argue that individuals in tight cultures rely more on societal expectations rather than expert recommendations when making vaccination decisions. Consequently, if vaccine hesitancy becomes a dominant norm within a tight culture, individuals are more likely to conform to it. In contrast, individuals in looser cultures, who exhibit greater independence in decision-making, are more inclined to follow expert guidance. Shi et al. (2024) provide complementary evidence from a study of eight Asian countries, showing that the influence of perceived and collective norms on vaccination intention is stronger in tighter cultures. While their findings suggest that tightness can enhance norm-based behavior, they also report a direct positive association between cultural tightness and vaccine intention, indicating that tighter cultures in their sample were, on average, more supportive of vaccination.

While vaccine acceptance has been widely studied, research on dengue vaccines remains limited. Most studies have small, local samples and therefore draw somewhat limited conclusions (for examples, see Ali et al., 2021; Harapan et al., 2016; Rosado-Santiago et al., 2024; Scott et al., 2023; and Valido et al., 2018). Shafie et al. (2023) carried out a more comprehensive, multi-country investigation into willingness to vaccinate against dengue, utilizing the Capability, Opportunity, Motivation for Behavior change (COM-B) framework to evaluate the underlying factors influencing these behaviors. The research included data from nationally representative samples from seven countries across Latin America and the Asia Pacific region (namely, Argentina, Brazil, Colombia, Mexico, Indonesia, Malaysia, and Singapore). Patterns of willingness to receive a dengue vaccine closely aligned with perceptions of dengue risk and the perceived benefits of vaccination. Globally, more than half of respondents expressed a strong willingness to vaccinate against dengue. However, this willingness varied significantly by region, with Latin America showing higher acceptance (60%) than the Asia Pacific region (41%). Brazilian participants had the highest willingness, with 66% of respondents stating they were certain or nearly certain to get vaccinated, while Singapore had the lowest at 25%. Overall, vaccine willingness remained high across most surveyed countries, except for Singapore and Malaysia, and to a smaller degree, Argentina.

Shafie et al. (2023) also found that, globally, the primary motivations for vaccine willingness were protection against dengue and overall health protection. In contrast, concerns about vaccine safety and efficacy were the leading reasons for hesitancy, with 6% of respondents mentioning fear of side effects and 4% believing vaccines were ineffective. Willingness to vaccinate was generally consistent across sociodemographic factors. However, individuals aged 31 to 50 years showed higher vaccine acceptance compared to other age groups, as did respondents with children, who were more likely to express willingness to vaccinate than those without children. Conclusions from a COM-B analysis had a high degree of consistency across countries. Financial accessibility emerged as a critical opportunity factor, with vaccine acceptance increasing when vaccines were free or subsidized. Social opportunity, including recommendations from healthcare professionals, governments, and community leaders, also played a key role in promoting vaccination. Motivational factors included trust in healthcare professionals and the healthcare system, which positively correlated with vaccine acceptance, while distrust and misinformation—such as the belief that dengue risks were exaggerated—led to hesitancy, especially in Argentina and Brazil. Incentives, whether financial or non-financial, were also powerful motivators for vaccination. Furthermore, vaccine hesitancy was higher among individuals with lower education levels, highlighting the need for educational programs to address misconceptions about vaccine safety and effectiveness.

In a systematic review and meta-analysis of 19 studies from the Americas and Asia, Orellano et al. (2023) analyzed cross-sectional and cohort data to determine vaccine acceptance rates and the average monetary value individuals were willing to pay for dengue immunization. The pooled vaccine acceptance rate was 88.3% (95% CI: 81.0%–93.0%), though significant heterogeneity was observed across studies and continents, with rates found to be higher in the Americas compared to Asia. Willingness to pay for a dengue vaccine averaged $46.7 per recipient (95% CI: $25.9–$67.5).

Behavioral Science Interventions

Given the relative novelty of dengue vaccines, they are likely to encounter some degree of public resistance, especially in the post-COVID-19 era. To address this challenge, behavioral science interventions could offer valuable strategies for shaping beliefs and encouraging vaccine acceptance. Exploring these approaches can help mitigate hesitancy and promote informed decision-making regarding dengue immunization. To that end, inspiration can be drawn from recent studies on science skepticism.

Vlasceanu et al. (2024) conducted a large-scale global study aimed at investigating the effectiveness of various behavioral science interventions in promoting changes in climate change beliefs and behaviors. With a sample of 59,440 participants across 63 countries, the authors compared 11 expert-crowdsourced interventions, targeting four key climate-related outcomes: belief in climate change, policy support, willingness to share climate-related information, and effortful pro-environmental behavior (tree planting). The researchers found that different interventions had varying degrees of success, with the most effective strategies differing across outcomes. Notably, decreasing psychological distance was identified as the most effective strategy for strengthening climate change beliefs.

Research has suggested that many individuals view climate change as a remote and uncertain phenomenon, involving potential future events that may occur in faraway locations and primarily affect people unlike themselves (Spence et al., 2011). Though further efforts are necessary to account for the diversity and complexity of psychological distance in the context of climate change (Keller et al., 2022), studies have indicated that framing climate communications to minimize said distance is a promising approach for enhancing public engagement (Jones et al., 2016; Loy & Spence, 2020). Vlasceanu et al.

(2024)'s findings corroborate this view. The "Decreasing Psychological Distance" intervention, which emphasized the local, social, and temporal proximity of climate change, resulted in a 2.3% increase in climate change belief, making it the most effective among the tested strategies in strengthening such beliefs. While the authors underline that additional measures may be needed to translate belief changes into sustained behavioral action, it is interesting to consider the connection between psychological distance and beliefs regarding scientific topics.

Većkalov et al. (2024) contributed to this pursuit with the creation of the Psychological Distance to Science (PYSDISC) Scale. The authors proposed an innovative approach that hypothesized PYSDISC as a domain-general precursor of science skepticism. They aimed to go beyond domain-specific explanations traditionally found in the literature (such as demographics, ideology, and scientific knowledge), positing that PSYDISC could act as a general predictor and thus provide a more comprehensive way to understand and address science skepticism.

According to Većkalov et al. (2024, p.19), PSYDISC “refers to perceptions of science in terms of its tangibility and relevance for the individual” and “to how one evaluates science from the perspective of the self.” Rooted in *Construal Level Theory* (CLT; Liberman & Trope, 2014, Trope & Liberman, 2010), PSYDISC spans four dimensions: temporal (how science is perceived in relation to the present), spatial (its perceived relevance to one's local community), social (how relatable and approachable scientists are), and hypothetical (the perceived tangibility and practical implications of science).

In a series of six studies across two countries, Većkalov et al. (2024) developed and validated a novel instrument to measure PSYDISC. In addition to exploratory and confirmatory factor analyses, they tested the scale's convergent/divergent validity, finding negative correlations with measures of faith in science, pro-science attitudes, as well as science knowledge, understanding, interest, and funding support. Tests of predictive validity corroborated the authors’ overarching hypothesis, with PSYDISC consistently predicting skepticism across a variety of domains, including climate change, vaccination, evolution, GM foods, and genetic editing. This was true even after controlling other potential explanatory variables, such as sociodemographic factors, religiosity, spirituality, conspiracy beliefs, political orientation, science knowledge, science understanding, and other science attitude scales. Interestingly, PSYDISC was also capable of predicting actual science-based behavior, specifically, COVID-19 vaccination.

These findings underline the importance of the perceived psychological distance as both a predictor of science skepticism (both in general and across specific domains, including vaccine hesitancy) and as an area opportunity when considering interventions to foster vaccine acceptance.

An Operationalization of the Multilevel Analytic Model

This study builds directly upon the Multilevel Analytic Model (MAM) proposed in the present dissertation, which emphasizes the multidirectional interactions among message-related variables, audience characteristics across micro, meso, and macro levels, and the effects of science communication itself. The model assumes that science communication outcomes are not determined by any single factor but rather emerge from the dynamic interplay of individual, social, and contextual influences. In this section, we detail how the variables examined in this study map onto the levels of the MAM, providing a conceptual bridge between the theoretical framework and the empirical investigation of vaccine hesitancy.

At the micro level, we consider individual cognitive and dispositional variables that shape how people engage with scientific information. These include scientific reasoning and open-mindedness, both of which are measured by instruments that have been previously validated in the Brazilian context (as detailed in Manuscripts 4 and 5). These constructs are conceptually aligned with literature on epistemic cognition and have been associated with decreased susceptibility to misinformation and greater acceptance of evidence-based claims. We also examine conspiratorial thinking, religiosity, and political orientation, which may reflect underlying worldviews that predispose individuals to accept or reject scientific consensus. Together, these variables capture a broad range of intraindividual tendencies relevant to vaccine skepticism.

At the meso level, the focus shifts to social and group-related dynamics. Unfortunately, this category is not explicitly present in the current study. However, measures of political orientation and religiosity could hint at shared ideological and identity-based group affiliations, which should be further studied in the future.

Most notably, the present study incorporates macro-level variables to account for sociocultural variation across countries. In addition to testing theoretical constructs, our inclusion of eight culturally and geographically diverse countries—spanning Latin America and Southeast Asia—was designed to capture cross-national differences that may shape how individuals respond to vaccine communication. This approach allows us to operationalize “country” not simply as a demographic descriptor, but as a meaningful contextual factor reflecting broader societal norms, values, and institutions. Among these macro-level variables, we focus in particular on cultural tightness-looseness, a construct that captures the strength of social norms and tolerance for deviance, as a primary explanatory dimension. This variable has been shown to influence both general behavioral tendencies and responses to collective threats, such as public health crises.

The present study also engages with the message component of the MAM through its use of an experimental intervention designed to reduce psychological distance. Building on previous research suggesting that greater perceived proximity to scientific issues enhances engagement and trust (Vlasceanu et al., 2024), the intervention aimed to increase the salience of dengue by emphasizing its personal and social relevance. In doing so, we operationalized message-level influence through the framing of scientific information, a core mechanism in science communication. Although the intervention was uniformly presented across countries, its effectiveness was expected to vary depending on individual predispositions and cultural context, in line with the model's emphasis on interaction across levels. This experimental manipulation thus represents a concrete instantiation of message-level input in the MAM framework.

Finally, the present study also addresses the effects of science communication, which constitutes a distinct category in the MAM. Specifically, we measured two key outcomes: vaccine skepticism and intention to vaccinate. These variables reflect attitudinal and behavioral dimensions of engagement with scientific content and serve as indicators of the communication process's success or failure. By modeling these outcomes as a function of micro- and macro-level variables, while also examining the impact of an experimentally manipulated message, the study exemplifies the model's commitment to integrative, multidimensional analysis. This focus on communication effects ensures that the MAM is not only descriptive but also evaluative, allowing researchers to assess how structural, cognitive, and communicative factors jointly shape public responses to science.

The Present Study: Objectives

First and foremost, the present study sought to advance research on a largely unexplored topic. While vaccine acceptance has been extensively studied, the specific case of dengue vaccines remains underexamined. Given the widespread prevalence and urgency of dengue, which affects a substantial portion of the global population, addressing this gap is both timely and necessary.

More specifically, this study had two complementary objectives. First, it aimed to evaluate the effectiveness of a "decreasing psychological distance" intervention in promoting (a) greater vaccine intention and (b) reduced vaccine skepticism. Second, it sought to examine the influence of both micro- and macro-level factors on these vaccine-related metrics thus testing the applicability of the proposed multilevel model of science communication, as described above. At the individual level, we expected to replicate findings from international literature, identifying positive associations between scientific reasoning, open-minded thinking about evidence, and education. Conversely, we anticipated negative correlations with perceived psychological distance to science, conspiracy thinking, religiosity, and right-leaning political orientation. At the contextual level, we adopted an exploratory approach to examining the role of cultural tightness. Based on the understanding that tightness primarily reinforces prevailing social norms, whether they support or undermine vaccination (Jones et al., 2022), we did not advance a directional hypothesis. Instead, we sought to explore how perceived cultural tightness related to vaccine skepticism and intention across diverse national contexts.

Additionally, we aimed to explore the relationships between sociodemographic characteristics, familiarity with dengue vaccines, and prior dengue experience in shaping vaccine intention and skepticism. We expected familiarity and personal experience with dengue to be positively correlated with vaccine acceptance, with the latter effect mediated by the severity of prior symptoms.

Method

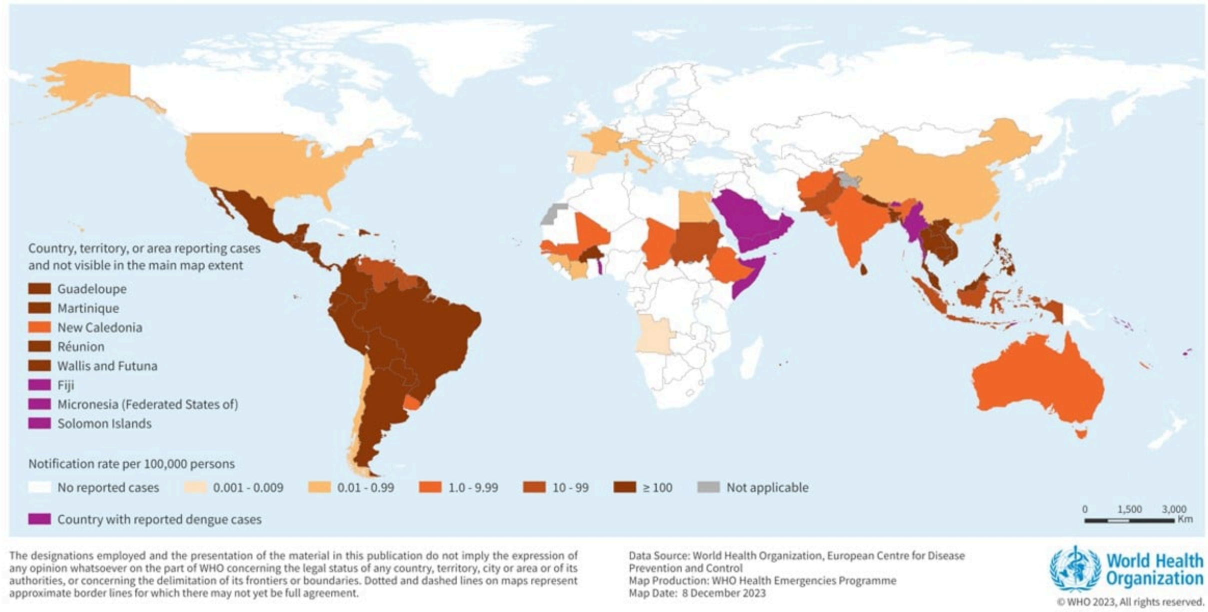
This study's intended sample size, variables, design, hypotheses, and planned analyses were preregistered on AsPredicted (https://aspredicted.org/ji7nm.pdf) prior to any data being collected. All data and materials are available at the Open Science Framework (https://osf.io/nxwcm/).

Participants

Country selection was based on two criteria. Firstly, we chose countries with the highest incidence of reported dengue fever cases according to the World Health Organization (WHO). Figure 2 (WHO, 2023) portraits the distribution of reported cases of dengue fever around the globe, according to the most recent available data as of December 2023. Secondly, our selection was limited to those nations in which we had the means to collect data, either through collaboration with other researchers or through data collection platforms.

Figure 2

Countries/Territories/Areas Reporting Autochthonous Dengue Cases (November 2022- November 2023)



Participants were recruited either through the Besample platform or paid advertising on Facebook. Data was collected between September, 2024 and February, 2025. Table 1 presents the initial sample, exclusions (duplicates, failed attention checks), the resulting sample, and its demographic characteristics per country. It is worth noting that each national sample, with the exception of Thailand, surpasses the target sample size (*N* = 189) determined by a priori power analysis.

Table 1

Sample Characteristics Per Country

Country	Initial sample	Exclusions	Resulting sample	Percentage of female	Mean age [SD]	Percentage with some college education or more
Argentina	214	13	201	52.7	33.24 [10.93]	69.2
Brazil	228	27	201	49.8	34.22 [9.98]	78.1
Colombia	223	25	198	53.5	31.81 [10.96]	92.9

Malaysia	236	36	200	48.5	30.67 [8.37]	84.5
Mexico	237	12	223	46.6	34.43 [9.60]	97.3
Philippines	218	25	193	49.7	33.56 [10.11]	93.3
Thailand	245	80	165	61.8	21.68 [10.14]	86.1
Vietnam	251	58	193	49.2	27.77 [7.97]	65.8

Note. SD = standard deviation.

Measures

Surveys were administered in the official language of each participating country, except in Malaysia, where the English version was used. All translations were produced and reviewed in collaboration with native speakers to ensure linguistic accuracy and cultural appropriateness.

Before introducing each individual measure, it is important to note that measurement invariance analyses were conducted across countries to assess the comparability of the scales used in this study. As detailed in Appendix B (Tables C1-C5), none of the instruments met the standard criteria for metric or scalar invariance, as indicated by changes in fit indices that exceeded accepted thresholds (ΔCFI > .01 and/or ΔRMSEA > .015; Chen, 2007; Khademi et al., 2023). Although some configural models demonstrated acceptable or even excellent absolute fit, the decline in model fit across increasingly constrained models suggests that item loadings and intercepts are not equivalent across national samples (Davidov et al., 2014; de Van de Schoot et al., 2012; Leitgöb et al., 2023). In spite of these limitations, we decided to move forward with our analyses - a decision that is further addressed in the discussion section. However, these results highlight the need for caution in interpreting cross-cultural comparisons and suggest that further refinement or cultural adaptation of these measures may be necessary for truly comparable use across countries.

Familiarity With Dengue Vaccines

After reading a brief informational text about dengue vaccines (see Appendix B), participants were asked whether they had heard of these vaccines before. They then provided information on their vaccination status, including whether they had been vaccinated, the number of doses received, and the specific vaccine administered. Additionally, they were asked if anyone they knew had been vaccinated. We created a composite score by adding up responses to these items, each assigned a different weight based on its level of proximity to personal experience. Participants received one point if they had heard of the vaccine, two points if they knew someone who had received it, and three points if they had been vaccinated themselves. The final score ranged from 0 to 6, with higher values indicating greater familiarity and direct exposure to the vaccine.

Vaccine Intention

After being exposed to either the experimental or the control condition (described below), participants were asked if they intended to be vaccinated against dengue. If the response was negative, they were asked to report all the reasons that applied: financial cost, difficulty accessing the vaccine, possible side effects, doubts about the efficacy of the vaccine, fear of needles, not considering themselves as part of a high-risk group, not believing in vaccines, and other.

Skepticism Towards Dengue Vaccines Scale

We adapted the Skepticism Towards Covid-19 Vaccines Scale, by Zarzeczna et al. (2023), to make it applicable to the dengue epidemic. The scale consists of 9 items, including “I believe that the development of dengue vaccines has been rushed, so that the vaccines are not safe to the public” and “I believe that vaccines are a safe and reliable way to help prevent the spread of dengue” (reversed). An exploratory factor analysis (EFA) of the entire sample revealed a unifactorial structure with good reliability (ω = .80; factor loadings between .29 and .75), a result that aligns with the scale’s original application, which was also unidimensional. Items were measured on a slider scale ranging from 0 (totally disagree) to 100 (totally agree).

Psychological Distance to Science (PSYDISC) Scale

Developed by Većkalov et al. (2022), the PSYDISC scale focuses on four aspects of the individual's relationship with science. It measures the degree to which science is perceived as a concrete endeavor carried out by people like themselves (social), with immediate effects in the present (temporal) and within their surroundings (spatial), as well as its relevance and applicability in real-world contexts (hypothetical distance). The scale has 16 items, such as “Science is mainly focused on the distant future”, “Scientists are very different from me", and “Science provides accurate information about the world we live in” (reversed). Consistent with the original application, the scale exhibited a four-factor structure with adequate reliability when analyzed across the full sample (ω ranging between .67 to .85; factor loadings ranging from .41 to .92). Items were measured on a slider scale ranging from 0 (totally disagree) to 100 (totally agree).

Scientific Reasoning Scale (SRS)

Created by Drummond and Fischhoff (2017), the SRS has 11 items, each presenting a brief scientific scenario followed by a true-or-false statement. The scale aims to evaluate scientific reasoning skills, which are defined as the abilities required to assess scientific findings based on the factors that determine their quality. Specifically, it evaluates participants’ ability to reason about concepts such as confounding variables, causality, control groups, and ecological validity. Aligning with its original application, the scale exhibited a unidimensional structure and adequate reliability when analyzed across the entire sample (ω = .71; factor loadings ranging from .38 to .61). We did, however, decide to eliminate items 1, 3, and 7 due to extremely low factor loadings (ranging from .01 to .18).

Actively Open-Minded Thinking About Evidence Scale (AOT-E)

The AOT-E has 8 items designed to measure whether people are open to changing their beliefs according to evidence (Pennycook et al., 2020). Items include "A person should always consider new possibilities" and “Beliefs should always be revised in response to new information or evidence.” Consistent with the original application, an EFA conducted on the full sample indicated a unifactorial solution with adequate reliability (ω = .76; factor loadings between .29 and .70). Items were measured on a slider scale ranging from 0 (totally disagree) to 100 (totally agree).

Single-Item Conspiracy Belief Scale

Developed by Lantian et al. (2016) this single-item scale is designed to assess an individual's overall inclination to believe in conspiracy theories. After presenting a few examples of controversial occurrences, it states “I think that the official version of the events given by the authorities very often hides the truth”. Participants were asked to respond on a slider scale ranging from 0 (totally disagree) to 100 (totally agree). It is worth noting that the original scale listed examples that took place exclusively in the United States. (i.e., 09/11 attacks, the death of Lady Diana, the assassination of John F. Kennedy). Given the diverse nature of our sample, we replaced them with more general subjects that are often at the center of conspiracy theories, namely, experiments with new drugs and technologies, spread of viruses and diseases, deaths of well-known public figures, terrorist attacks, and extraterrestrial activities.

Cultural Tightness–Looseness Scale (CTLS)

Developed by Gelfand et al. (2011), the CTLS evaluates individuals' perceptions of cultural tightness. It serves as a broad measure of the extent to which social norms are widespread, well-defined, and consistently enforced within a nation. It comprises six items, including "There are many social norms that people are supposed to abide by in this country” and “In this country, if someone acts in an inappropriate way, others will strongly disapprove.” When considering the full sample, the scale demonstrated a unidimensional structure, aligning with findings from the original application (ω = .63;

factor loadings between .50 and .71). Items were measured on a slider scale ranging from 0 (totally disagree) to 100 (totally agree).

Political Orientation and Religiosity

Participants reported their position on the political spectrum and their level of religiosity using two slider scales. The scales ranged from 0 to 100, with the political spectrum labeled as “extremely to the left” (0) to “extremely to the right” (100) and religiosity labeled as “not religious at all” (0) to “extremely religious” (100). Due to the unique socio-political context in Vietnam, we did not collect data on political orientation in that country.

Sociodemographic Questions

Participants were asked to report their gender, age, country and state of residence, and level of education.

Experience with Dengue

Participants’ experience with dengue was calculated using a weighted composite score that captured both social and personal exposure, adjusted by the perceived severity of symptoms. For social exposure, participants reported how many people they knew who had contracted dengue, scored from 0 to 4. This score was multiplied by their self-reported severity of symptoms experienced by those individuals (0–100 scale, rescaled by 0.1). For personal exposure, participants indicated how many times they had contracted dengue, scored from 0 to 3, and this was multiplied by their own symptom severity (0–100 scale, rescaled by 0.1), and again multiplied by 2 to give greater weight to direct personal experience. The final experience score represented the sum of these two weighted components.

Attention Checks

Following the best research practices (Gummer et al., 2021), we included two screening questions that instructed participants to select either “totally disagree” or “totally agree” to indicate that they were effectively paying attention to the task.

Procedures

Within each national sample, participants were randomly assigned to either the experimental or control conditions, as described below.

Decreasing Psychological Distance Intervention

Following the model proposed by Vlasceanu et al. (2024), participants were asked to read a paragraph about the impact of dengue fever (see Appendix B). It included information on the number of people living in areas that are at risk for the disease, the ten-fold increase in reported cases between 2000 and 2019, the potential symptoms involved, and the number of dengue-related deaths in 2023. Participants were then presented with data (i.e. number of dengue cases in 2024) related to their specific country of residence. They were asked to select which aspects of personal life and the society can be affected by dengue fever from a list including: individual health, relationships, productivity, well-being, public health, economy, and environment. After making their selections, participants were shown the correct answers, which included all possible options. Lastly, they were asked to write a brief paragraph about how dengue fever could affect them and their communities.

Control Condition

This condition followed exactly the same format as the intervention described above. However, rather than focusing on dengue fever, the content centered on the Paris 2024 Olympic and Paralympic Games (see Appendix B).

Participants completed an online questionnaire using Qualtrics. Instruments were presented in the order listed above (except for the intervention/control condition, which followed the familiarity with dengue vaccines section, and the attention checks, which were randomly distributed throughout the questionnaire). Statistical analyses were performed in SPSS Version 30.0.0.0, JASP 0.17.1, and Factor 12.04.01.

Results

We began by conducting an exploratory analysis of descriptive statistics across key variables, including vaccine familiarity, vaccination status, skepticism, intention to vaccinate, dengue-related experiences, reasons for vaccine hesitancy, and perceived cultural tightness across countries. Tables 2-5 report these results.

Table 2 summarizes participants' personal and social experiences with dengue. It reports the percentage of individuals who had dengue once or more than once, as well as those who knew at least one or more than five people who had the disease. Mean severity ratings for dengue symptoms experienced personally and by others are also presented, with standard deviations in brackets. Data are shown for the overall sample and by country. Notably, Brazil and Thailand consistently show the highest and lowest levels, respectively, across variables related to personal and social experience with dengue fever.

Table 2

Dengue Experience (Personal and Others)

Sample	History of dengue once (%)	History of dengue more than once (%)	Reported ≥1 dengue case in social circle (%)	Reported >5 dengue cases in social circle (%)	Mean severity of symptoms self [*SD*]	Mean severity of symptoms others [*SD*]
Total	18.30	4.60	77.00	11.70	62.49 [23.16]	64.28 [21.34]
Argentina	14.90	3.50	75.60	15.50	70.16 [20.13]	65.11 [17.74]
Brazil	24.90	9.50	89.60	24.80	56.84 [21.24]	60.98 [21.51]
Colombia	11.10	4.00	70.20	6.50	55.77 [27.57]	61.01 [27.46]
Malaysia	22.00	4.00	86.00	6.00	60.10 [24.12]	64.17 [20.35]
Mexico	18.80	3.10	72.20	12.20	60.39 [25.02]	65.16 [20.35]
Philippines	19.70	4.20	86.00	13.90	65.96 [25.12]	67.95 [19.36]
Thailand	9.70	.60	63.00	1.80	71.88 [18.02]	63.64 [24.60]
Vietnam	23.80	7.20	71.50	10.30	66.08 [19.66]	66.17 [18.99]

Note. SD = standard deviation.

Table 3 displays descriptive statistics on participants' familiarity with dengue vaccines, vaccination status, skepticism toward dengue vaccines, and intention to vaccinate among the unvaccinated. Data are presented for the overall sample and by country. Familiarity with dengue vaccines was highest in Argentina (91.5%) and the Philippines (91.2%), and lowest in Mexico (46.6%). Vaccination rates also varied widely, with Vietnam reporting the highest proportion of vaccinated participants (49.7%) and Mexico the lowest (12.1%). Skepticism scores showed less variability across countries. The Philippines had the highest mean skepticism (*M* = 44.68, *SD* = 15.79), while Brazil had the lowest (*M* = 32.00, *SD* = 18.40). Still, all means fell within a relatively narrow range. Intention to vaccinate among unvaccinated individuals was highest in Brazil (73.5%) and Vietnam (68.8%), while the lowest intentions were reported in Thailand (21.6%) and the Philippines (48.8%).

Table 3

Familiarity, History of Vaccination, Skepticism, and Intention to Vaccinate

Sample	Familiarity with dengue vaccines (%)	Vaccinated (%)	Mean Skepticism [*SD*]	Intention to vaccinate (%)*
Total	73.60	22.30	38.20 [16.85]	53.60
Argentina	91.50	14.90	36.98 [19.16]	51.20
Brazil	73.10	17.90	32.00 [18.40]	73.50
Colombia	67.20	21.70	36.83 [14.69]	52.90
Malaysia	59.50	17.50	41.77 [15.90]	48.70
Mexico	46.60	12.10	36.29 [17.39]	55.30
Philippines	91.20	15.00	44.68 [15.79]	47.40
Thailand	76.40	32.70	41.60 [14.27]	17.50
Vietnam	87.60	49.70	36.45 [14.76]	68.80

Note. *Of unvaccinated participants. *SD* = standard deviation.

Table 4 lists the self-reported reasons for not intending to receive the dengue vaccine (n = 632), broken down by country. Frequencies are presented as percentages of the unwilling or unsure subsample. Response options include practical barriers (e.g., cost, access), health concerns (e.g., side effects, efficacy), and personal beliefs. Across all countries, the most frequently cited reason was concern about possible side effects (54.3%), followed by the perception of not being at high risk (43.0%) and doubts about the vaccine's efficacy (36.9%). When examining the data by country, a broadly similar pattern emerged, with concerns about side effects consistently ranking among the top reasons, particularly in the Philippines (77.0%) and Thailand (61.3%). However, some differences were notable. Financial cost was a major barrier in countries like Argentina (44.7%) and Thailand (57.7%), but much less so in Brazil (8.7%) and Colombia (14.30%). Additionally, while the perception of low personal risk was a common factor in many countries, it was especially high in Colombia (58.3%) and Vietnam (53.8%). These findings suggest that although health concerns dominate across contexts, practical and perceptual barriers vary substantially between countries.

Table 4

Reasons for not intending to vaccinate or being unsure about - Frequencies

Country	Financial cost	Access to the vaccine	Possible side effects	Doubts about the efficacy	Fear of needles	Believes not to be at high risk	Does not believe in vaccines
All countries	31.60%	19.30%	54.30%	36.90%	10.10%	43.00%	6.00%
Argentina	44.70%	21.20%	58.80%	35.30%	3.50%	34.10%	3.50%
Brazil	8.70%	10.90%	52.20%	37.00%	0.00%	34.80%	8.70%
Colombia	14.30%	14.30%	32.10%	23.80%	8.30%	58.30%	6.00%
Malaysia	39.80%	19.30%	63.30%	48.90%	10.20%	48.90%	5.70%
Mexico	22.80%	25.00%	34.80%	34.80%	8.70%	43.50%	4.30%
Philippines	20.70%	12.60%	77.00%	51.70%	12.60%	26.40%	5.70%
Thailand	57.70%	21.60%	61.30%	34.20%	13.50%	45.90%	9.00%
Vietnam	20.50%	30.80%	48.70%	20.50%	28.20%	53.80%	5.10%

Note. Frequencies for those that reported not intending to vaccinate or being unsure about it. All countries n = 632. Argentina n = 85. Brazil n = 46. Colombia n = 84. Malaysia n = 88. Mexico n = 92. Philippines n = 87. Thailand n = 111. Vietnam n = 39.

Table 5 presents mean perceived cultural tightness scores by country, along with data from previous studies. A clear pattern emerges across regions: participants from Asian countries (Malaysia, the Philippines, Thailand, and Vietnam) reported higher tightness scores compared to those from Latin American countries (Argentina, Brazil, Colombia, and Mexico). Vietnam showed the highest average score (M = 68.92, SD = 11.21), while Brazil reported the lowest (M = 51.98, SD = 15.38). Even though absolute values are not directly comparable and relative country positioning may vary slightly, previous studies (Gelfand et al., 2011; Gelfand et al., 2021; Uz, 2014) reveal a broad replication of this regional pattern, with Asian countries ranking higher on tightness than Latin American ones.

Table 5

Tightness Scores

Country	Mean Tightness [*SD*][a]	Gelfand et. al (2011) Tightness Score[a]	Uz (2014) Cultural Tightness and Looseness[b]	Gelfand et al. (2021) Cultural Tightness[a]
Argentina	52.26 [14.34]	–	75	-.53
Brazil	51.98 [15.38]	3.5	–	-.38
Colombia	59.66 [13.99]	–	–	-.58
Malaysia	67.87 [11.13]	11.8	–	.22
Mexico	55.82 [14.96]	7.2	74.7	-.35
Philippines	65.02 [12.12]	–	31.5	–
Thailand	67.58 [13.75]	–	–	.25
Vietnam	68.92 [11.21]	–	35.9	.39

Note. SD = standard deviation.

[a] Higher scores = greater tightness. [b] Higher scores = greater looseness.

Aiming to get an initial understanding of the potential effects of sociocultural characteristics on our dependent variables, we performed Welch's ANOVAs for both vaccine skepticism and vaccine intention (considering only the unvaccinated who responded either yes or no). In both instances, results confirmed the existence of significant differences across national samples (for skepticism, $F(7, 667.37) = 11.64$, $p < .001$; for vaccine intention, $F(7, 283.04) = 4.58$, $p < .001$.

We subsequently conducted a preliminary investigation of the effect of the intervention on our dependent variables (i.e., vaccine intention and vaccine skepticism) as well as on the perceived psychological distance to science (PSYDISC). Independent samples t-tests showed that participants in the intervention condition reported slightly lower levels of vaccine skepticism (M = 37.40, SD = 16.92) compared to those in the control condition (M = 39.06, SD = 16.73), $t(1572) = 1.97$, $p = .02$, $d = .10$. Similarly, when considering solely participants that responded either yes or no, those that were exposed to our intervention reported slightly higher intention to vaccinate (M = .82, SD = 0.38) when compared to those in the control group (M = .77, SD = 0.42), $t(1176) = 2.16$, $p = .02$, $d = -.13$. No significant differences were found for PSYDISC between conditions, $t(1572) = 0.75$, $p = .45$, $d = .04$.

To explore potential country-level differences in the effects of the intervention, we conducted independent samples t-tests separately for each national sample. Among all countries and across the three variables of interest (i.e., vaccine intention, vaccine skepticism, and perceived psychological distance to science) significant between-group differences were observed for vaccine skepticism in Colombia and Vietnam, and for vaccine intention in Colombia, Malaysia, and Thailand. In Colombia, participants in the intervention group reported significantly lower skepticism (M = 33.78, SD = 12.62) than those in the control group (M = 40.13, SD = 16.06), $t(196) = 3.11$, $p = .001$, $d = .44$. In Vietnam, the intervention group also showed reduced skepticism (M = 33.98, SD = 14.26) compared to controls (M = 39.06, SD = 14.90), $t(191) = 2.42$, $p = .008$, $d = .35$.

For vaccine intention, participants in the intervention condition were more likely to express willingness to vaccinate in Colombia (M = .84, SD = .37) than in the control group (M = .66, SD = .48), $t(150) = -2.57$, $p = .006$, $d = -.42$. A similar pattern emerged in Malaysia, with higher intention scores in the intervention group (M = .89, SD = .31) than in the control group (M = .72, SD = .46), $t(138) = -2.67$, $p = .004$, $d = -.45$. In Thailand, vaccine intention was also significantly higher among participants in the intervention group (M = .95, SD = .23) compared to those in the control condition (M = .68, SD = .47), *t*(63) = -2.99, *p* = .002, *d* = -.75. No other significant differences were identified for any other country or outcome variable.

To gain an overview of the data and examine relationships among key variables, we conducted a correlation analysis (Table 6). As expected, vaccine intention was negatively related to both skepticism and PSYDISC, and positively linked to previous dengue experience and exposure to the psychological distance intervention. However, an unexpected pattern emerged in relation to scientific reasoning, which did not correlate with vaccine intention as anticipated.

Table 6

Correlations (Kendall's τ)

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Vaccine Intention[a]	--	--														
2. Skepticism	38.20	16.85	-.37**													
3. PSYDISC	46.06	14.49	-.07*	.21**												
4. SRS	2.76	1.864	-.11 **	-.02	-.16**											
5. AOT- E	62.84	16.93	.00	-.14**	-.23**	.21**										
6. Conspiracy Beliefs	72.86	25.76	-.03	.09**	.14**	-.10**	-.08**									
7. Perceived Tightness	60.86	15.01	.03	-.03*	.14**	-.09**	-.08**	.11**								
8. Political Orientation[b]	53.71	21.64	-.03	.07**	.08**	-.11**	-.16**	.06**	.05**							
9. Religiosity	49.24	32.79	.00	.08**	.17**	-.12**	-.21**	.10**	.10**	.16**						
10. Familiarity with Dengue Vaccines	2.24	2.09	.05	-.10**	.01	-.09**	-.08**	.04*	.09**	.09**	.03					
11. Experience with Dengue	13.27	13.89	.14**	-.03	-.03	.02	.00	.02	.00	.03	.06**	.09**				
12. Age	31.18	10.52	-.08**	-.02	-.13**	.02	.08**	-.01	-.10**	.03	.02	-.14**	.05**			
13. Education	4.30	1.50	.00	-.02	-.16**	.08**	.07**	-.02	-.09**	-.01	-.02	-.15**	.03	.33**		
14. Gender[c]	--	--	.14**	.00	.01	-.01	-.01	-.01	-.02	-.04	.03	-.06*	.01	-.01	.06*	
15. Intervention[d]	--	--	.06*	-.04	-.01	-.01	.02	-.01	.00	.00	.03	.00	.05*	.01	.02	.00

Note. *N* = 1574. *M* = mean. *SD* = standard deviation.

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

[a] Of unvaccinated. No = 0, Yes = 1, I don't know = excluded. *n* = 795.

[b] Missing values (Vietnam) were replaced by the mean.

[c] Experimental group = 1, control group = 0.

[d] Female = 1, others = 0.

Exploratory analyses of demographic factors showed that vaccine intention tended to decline with age and was higher among female participants. In line with our hypotheses, vaccine skepticism showed inverse relationships with AOT-E and familiarity with dengue vaccines, and was positively connected to PSYDISC, conspiracy beliefs, right-leaning political orientation, and religiosity. A negative link between the individual perception of cultural tightness and vaccine skepticism was also observed. Overall, the remaining correlations largely aligned with prior research (for instance, scientific reasoning, open-mindedness, and education were positively interrelated, while PSYDISC showed positive ties to political orientation, religiosity, and conspiracy beliefs).

To further investigate the unique contribution of each predictor to determining our dependent variables, we conducted both a multiple linear regression and a logistic regression (All relevant assumptions were tested and met acceptable thresholds). Table 7 presents the results of a linear regression analysis examining predictors of vaccine skepticism across the entire sample. The model accounted for a considerable portion of the variance in skepticism, $R^2 = .172$, Adjusted $R^2 = .166$. As expected, greater perceived psychological distance to science (PSYDISC), higher conspiracy beliefs, and more right-leaning political orientation were associated with higher levels of skepticism. In contrast, higher AOT-E scores, perception of tightness, and greater familiarity with dengue vaccines predicted lower skepticism. Notably, skepticism was positively predicted by scientific reasoning (SRS), a finding that ran counter to expectations. Other variables, including religiosity, gender, age, education, and the intervention were not significant predictors in the model.

Table 7

Linear Regression - Skepticism (Entire Sample)

Variable	*B*	95% CI for B		*SE B*	β	*p*
		LL	UL			
(Constant)	24.643	17.032	32.253	3.880		<.001

PSYDISC	.334	.274	.394	.031	.287	<.001
SRS	.820	.383	1.258	.223	.091	<.001
AOT-E	-.104	-.156	-.053	.026	-.105	<.001
Conspiracy Beliefs	.082	.052	.113	.016	.126	<.001
Perceived Tightness	-.083	-.136	-.031	.027	-.074	.002
Political Orientation[a]	.052	.015	.089	.019	.067	.006
Religiosity	.006	-.020	.031	.013	.011	.657
Familiarity with Dengue Vaccines	-1.239	-1.621	-.858	.195	-.154	<.001
Experience with Dengue	-.038	-.093	.018	.028	-.031	.185
Age	.026	-.053	.106	.041	.016	.520
Education	.185	-.371	.742	.284	.017	.514
Gender[c]	-.881	-2.417	.655	-.026	-.026	.261
Intervention[b]	-1.323	-2.850	.204	.779	-.039	.090

Note. CI = confidence interval; LL = lower limit; UL = upper limit. R^2 = .172; Adjusted R^2 = .166.
[a] Missing values (Vietnam) were replaced by the mean.
[b] Experimental group = 1, control group = 0.
[c] Female = 1, others = 0.

We also conducted a multinomial logistic regression to better account for categorical differences in vaccine intention (among unvaccinated participants). As shown in Table 8, results allow us to compare those that responded "No/I don't know" vs. the ones that responded "Yes". In line with expectations, lower PSYDISC scores, familiarity with dengue vaccines, and previous experience with dengue significantly increased the odds of intending to get vaccinated. Younger age, higher levels of education, and non-female gender were also associated with increased likelihood of vaccine acceptance. Surprisingly (though in line with previous results), SRS scores were associated with greater vaccine hesitancy. The intervention condition did not emerge as a significant predictor in either comparison.

Table 8

Logistic Regression - Vaccine Intention (Entire Sample - Unvaccinated)

Predictor	*B (SE)*	*SE B*	Odds Ratio	95% CI for Odds Ratio		p^a
				LL	*UL*	
No/I don't know vs. Yes[b]						
Intercept	.998	.595				.093
PSYDISC	-.018	.005	.982	.973	.991	<.001
SRS	-.160	.035	.852	.795	.912	<.001
AOT-E	-.002	.004	.998	.990	1.006	.550
Conspiracy Beliefs	-.004	.002	.996	.991	1.001	.085
Perceived Tightness	.002	.004	1.002	.994	1.010	.691
Political Orientation	.001	.003	1.001	.995	1.006	.861
Religiosity	.001	.002	1.001	.997	1.005	.484
Familiarity with Dengue Vaccines	.230	.053	1.259	1.135	1.397	<.001
Experience with Dengue	.025	.005	1.025	1.016	1.035	<.001
Age	-.021	.006	.979	.967	.992	<.001
Education	.142	.046	1.153	1.055	1.261	.002
Gender (non-female)	.222	.121	1.248	.984	1.583	.067
Intervention (control group)	.026	.120	1.026	.811	1.300	.828

Note. CI = confidence interval; LL = lower limit; UL = upper limit. [a] *p* value for a Wald test statistic. [b] Reference group in the multinomial logistic regression. Missing values for "Political Orientation" were replaced by the mean. R^2 = .086 (Cox & Snell), .115 (Nagelkerke). Model $\chi2(13) = 110.480$, $p < .001$. N = 1224, *n* YES = 665; *n* NO/I'DONT KNOW = 669.

Subsequently, we considered the most appropriate analytic strategy for examining our data. Although we initially ran exploratory multilevel models, we chose not to report these results due to both conceptual and statistical considerations. First, the intraclass correlation coefficients (ICCs) across key dependent variables ranged from .03 to .08, indicating that only a small proportion of variance was attributable to between-country differences. Prior research suggests that ICCs below .10 reflect limited clustering and offer little justification for hierarchical modeling (Hox et al., 2017; McNeish & Stapleton, 2016). Second, our dataset included only eight level-2 units (i.e., countries), which is generally considered insufficient for obtaining stable estimates of standard errors and cross-level interactions

(Kreft & de Leeuw, 1998; Maas & Hox, 2005). Given these constraints, we opted for alternative analytic approaches that better reflect the data structure. For transparency, the exploratory multilevel analyses are available in the supplementary material. As an alternative, we conducted both linear and logistic regressions separately for each national sample. This approach enables a more robust comparison of coefficients across countries while avoiding the methodological limitations associated with insufficient group-level observations. It is worth noting that, given the constraints of our data, we were unable to evaluate cultural tightness at the aggregate level, as it is typically applied. However, we decided to retain individual-level perceptions of tightness, as they still provide a meaningful proxy for broader cultural differences and allow for the exploration of their associations with vaccine attitudes across contexts.

Table 9 presents the results of separate linear regression analyses conducted for each national sample, identifying significant predictors of vaccine skepticism. Across countries, both shared and distinct patterns emerged. PSYDISC was the most consistent predictor, positively associated with skepticism in five out of eight countries (Argentina, Brazil, Colombia, Malaysia, and Mexico), mirroring its robust effect in the full-sample model. Similarly, familiarity with dengue vaccines consistently predicted lower skepticism in five countries (Argentina, Brazil, Malaysia, Mexico, and the Philippines), aligning with findings from the overall analysis. AOT-E appeared as a negative predictor in Brazil, Colombia, Malaysia, and Mexico, again supporting results from the full sample. Additionally, conspiracy beliefs were positively associated with skepticism in Argentina, Brazil, and Malaysia, echoing their role in the full-sample model.

Some predictors appeared more context-specific. For instance, tightness scores were negatively associated with skepticism in four Asian countries (Malaysia, the Philippines, Thailand, and Vietnam) but were significant only in one Latin American country (Mexico). This regional pattern suggests that perceived cultural tightness may act as a protective factor against skepticism in certain Asian contexts. Political orientation and scientific reasoning (SRS) were only significant in Brazil, both positively predicting skepticism. Education, in turn, was only significant in Argentina (also positively), and did not emerge as a significant predictor in the full-sample model. Age was a unique predictor in Malaysia, showing a positive relationship with skepticism, gender (non-female) predicted higher skepticism in Mexico only, and the intervention was significant exclusively in Colombia. Notably, experience with dengue, despite being significant in the full sample, did not reach significance in any of the country-level analyses.

The magnitude and direction of coefficients were generally consistent across countries, with most effects ranging from small to medium. Notable highlights include Argentina and Mexico, where both PSYDISC and familiarity with dengue vaccines showed relatively stronger effects; Brazil, where AOT-E had one of its highest negative coefficients; Vietnam, where tightness emerged with a clearer effect; and again Argentina, where conspiracy beliefs had a particularly strong positive association with skepticism. The adjusted R^2 values varied, ranging from .021 in Thailand to .321 in Brazil, with the Latin American countries generally showing higher model fit (Argentina, Brazil, Colombia, and Mexico had adjusted R^2 values between .152 and .321) compared to Asian countries.

Table 9

Linear Regression - Skepticism per Country

Country	Variable	*B*	95% CI for B		*SE B*	β	*p*
			LL	UL			
Argentina	(Constant)	-4.747	-27.957	18.464	11.766		.687
	PSYDISC	.565	.378	.753	.095	.428	<.001
	SRS	1.313	-.206	2.832	.770	.115	.090
	AOT-E	.051	-.118	.219	.085	.042	.555
	Conspiracy Beliefs	.194	.102	.286	.047	.264	<.001
	Perceived Tightness	-.108	-.273	.058	.084	-.081	.201
	Political Orientation[a]	.092	-.020	.203	.057	.104	.107
	Religiosity	-.003	-.083	.077	.040	-.005	.939

	Familiarity with Dengue Vaccines	-2.426	-3.800	-1.053	.696	-.228	<.001
	Experience with Dengue	.031	-.148	.210	.091	.022	.734
	Age	-.024	-.262	.215	.121	-.013	.846
	Education	1.732	.112	3.352	.821	.148	.036
	Gender[c]	-3.774	-8.722	1.174	2.508	-.099	.134
	Intervention[b]	-2.070	-6.813	2.674	2.404	-.054	.390
Brazil	(Constant)	8.913	-10.586	28.413	9.884		.368
	PSYDISC	.206	.043	.368	.082	.177	.013
	SRS	1.327	.006	2.647	.669	.125	.049
	AOT-E	-.224	-.367	-.081	.072	-.230	.002
	Conspiracy Beliefs	.112	.032	.192	.040	.170	.006
	Perceived Tightness	-.018	-.159	.123	.071	-.015	.801
	Political Orientation[a]	.241	.143	.339	.050	.330	<.001
	Religiosity	-.018	-.094	.059	.039	-.032	.649
	Familiarity with Dengue Vaccines	-1.843	-2.932	-.753	.552	-.201	.001
	Experience with Dengue	.025	-.111	.161	.069	.022	.716
	Age	.183	-.054	.419	.120	.099	.129
	Education	.659	-.925	2.242	.803	.056	.413
	Gender[c]	.488	-4.079	5.055	2.315	.013	.833
	Intervention[b]	.746	-3.588	5.079	2.197	.020	.735
Colombia	(Constant)	36.106	15.801	56.412	10.292		<.001
	PSYDISC	.260	.106	.414	.078	.240	.001
	SRS	.950	-.332	2.231	.650	.101	.145
	AOT-E	-.163	-.294	-.032	.066	-.192	.015
	Conspiracy Beliefs	.077	-.014	.168	.046	.119	.098
	Perceived Tightness	-.069	-.212	.074	.072	-.066	.340
	Political Orientation[a]	-.034	-.121	.052	.044	-.054	.435
	Religiosity	-.054	-.121	.012	.034	-.119	.111
	Familiarity with Dengue Vaccines	-.647	-1.650	.356	.509	-.095	.205
	Experience with Dengue	-.038	-.192	.116	.078	-.033	.625

	Age	.063	-.122	.249	.094	.047	.502
	Education	.630	-1.267	2.527	.962	.045	.513
	Gender[c]	-4.062	-8.093	-.032	2.043	-.138	.048
	Intervention[b]	-5.109	-8.986	-1.233	1.965	-.174	.010
Malaysia	(Constant)	36.786	13.736	59.836	11.684		.002
	PSYDISC	.289	.104	.475	.094	.222	.002
	SRS	.814	-.232	1.861	.530	.106	.126
	AOT-E	-.211	-.356	-.066	.074	-.212	.005
	Conspiracy Beliefs	.110	.016	.203	.047	.159	.022
	Perceived Tightness	-.242	-.426	-.058	.093	-.169	.010
	Political Orientation[a]	.009	-.092	.110	.051	.012	.865
	Religiosity	-.004	-.082	.075	.040	-.006	.930
	Familiarity with Dengue Vaccines	-1.267	-2.367	-.168	.557	-.161	.024
	Experience with Dengue	-.103	-.286	.080	.093	-.077	.267
	Age	.353	.096	.611	.130	.186	.007
	Education	.839	-.701	2.378	.780	.075	.284
	Gender[c]	-2.699	-6.772	1.374	2.065	-.085	.193
	Intervention[b]	-.795	-4.913	3.323	2.088	-.025	.704
Mexico	(Constant)	39.427	15.104	63.750	12.338		.002
	PSYDISC	.286	.137	.436	.076	.267	<.001
	SRS	.405	-.847	1.657	.635	.042	.524
	AOT-E	-.147	-.286	-.008	.071	-.147	.039
	Conspiracy Beliefs	.061	-.025	.147	.044	.092	.164
	Perceived Tightness	-.178	-.325	-.032	.074	-.154	.017
	Political Orientation[a]	-.001	-.092	.090	.046	-.001	.990
	Religiosity	.056	-.016	.127	.036	.104	.126
	Familiarity with Dengue Vaccines	-2.137	-3.304	-.970	.592	-.234	<.001
	Experience with Dengue	-.120	-.286	.046	.084	-.089	.155
	Age	-.026	-.262	.209	.120	-.015	.826
	Education	1.050	-1.415	3.515	1.250	.055	.402

	Gender[c]	-5.109	-9.446	-.773	2.200	-.147	.021
	Intervention[b]	-1.775	-5.957	2.406	2.121	-.051	.404
Philippines	(Constant)	43.996	18.560	69.433	12.890		<.001
	PSYDISC	.127	-.083	.338	.107	.097	.234
	SRS	.201	-1.023	1.426	.621	.025	.746
	AOT-E	.014	-.144	.172	.080	.013	.863
	Conspiracy Beliefs	.046	-.053	.145	.050	.068	.356
	Perceived Tightness	-.235	-.422	-.047	.095	-.180	.014
	Political Orientation[a]	.028	-.085	.142	.057	.039	.620
	Religiosity	.038	-.051	.127	.045	.071	.399
	Familiarity with Dengue Vaccines	-1.726	-3.020	-.433	.656	-.192	.009
	Experience with Dengue	-.014	-.173	.145	.081	-.013	.864
	Age	-.063	-.285	.160	.113	-.040	.579
	Education	1.046	-.985	3.077	1.029	.073	.311
	Gender[c]	4.263	-.179	8.705	2.251	.135	.060
	Intervention[b]	.435	-4.089	4.959	2.293	.014	.850
Thailand	(Constant)	44.927	24.712	65.142	10.231		<.001
	PSYDISC	.132	-.064	.327	.099	.114	.186
	SRS	.428	-.847	1.704	.646	.062	.508
	AOT-E	-.071	-.221	.078	.076	-.084	.347
	Conspiracy Beliefs	.029	-.072	.131	.051	.050	.569
	Perceived Tightness	-.197	-.372	-.022	.089	-.190	.028
	Political Orientation[a]	.119	-.005	.243	.063	.163	.059
	Religiosity	-.021	-.100	.058	.040	-.043	.602
	Familiarity with Dengue Vaccines	-.662	-1.693	.368	.522	-.104	.206
	Experience with Dengue	.106	-.182	.394	.146	.059	.467
	Age	.105	-.134	.344	.121	.074	.388
	Education	-.102	-2.240	2.037	1.082	-.008	.925
	Gender[c]	-.711	-5.318	3.897	2.332	-.024	.761
	Intervention[b]	-.432	-4.928	4.063	2.275	-.015	.850

Vietnam	(Constant)	63.458	40.863	86.054	11.451		<.001
	PSYDISC	.104	-.084	.292	.095	.084	.278
	SRS	-.373	-1.559	.812	.601	-.047	.535
	AOT-E	-.103	-.281	.075	.090	-.087	.255
	Conspiracy Beliefs	.052	-.022	.127	.038	.099	.168
	Perceived Tightness	-.379	-.555	-.203	.089	-.288	<.001
	Religiosity	.002	-.055	.058	.029	.004	.957
	Familiarity with Dengue Vaccines	-.461	-1.430	.508	.491	-.068	.349
	Experience with Dengue	-.053	-.180	.074	.064	-.059	.412
	Age	.063	-.219	.345	.143	.034	.661
	Education	-.419	-1.803	.964	.701	-.046	.550
	Gender[c]	2.704	-1.289	6.697	2.024	.092	.183
	Intervention[b]	-3.507	-7.591	.577	2.070	-.119	.092

Note. *CI = confidence interval; LL = lower limit; UL = upper limit. Argentina R^2 = .319; Adjusted R^2 = .271. Brazil R^2 = .365; Adjusted R^2 = .321. Colombia R^2 = .208; Adjusted R^2 = .152. Malaysia R^2 = .281; Adjusted R^2 = .231. Mexico R^2 = .239; Adjusted R^2 = .192. Philippines R^2 = .126; Adjusted R^2 = .063. Thailand R^2 = .098; Adjusted R^2 = .021. Vietnam R^2 = .197; Adjusted R^2 = .144.*

[a] *Experimental group = 1, control group = 0.*

[b] Female = 1, others = 0.

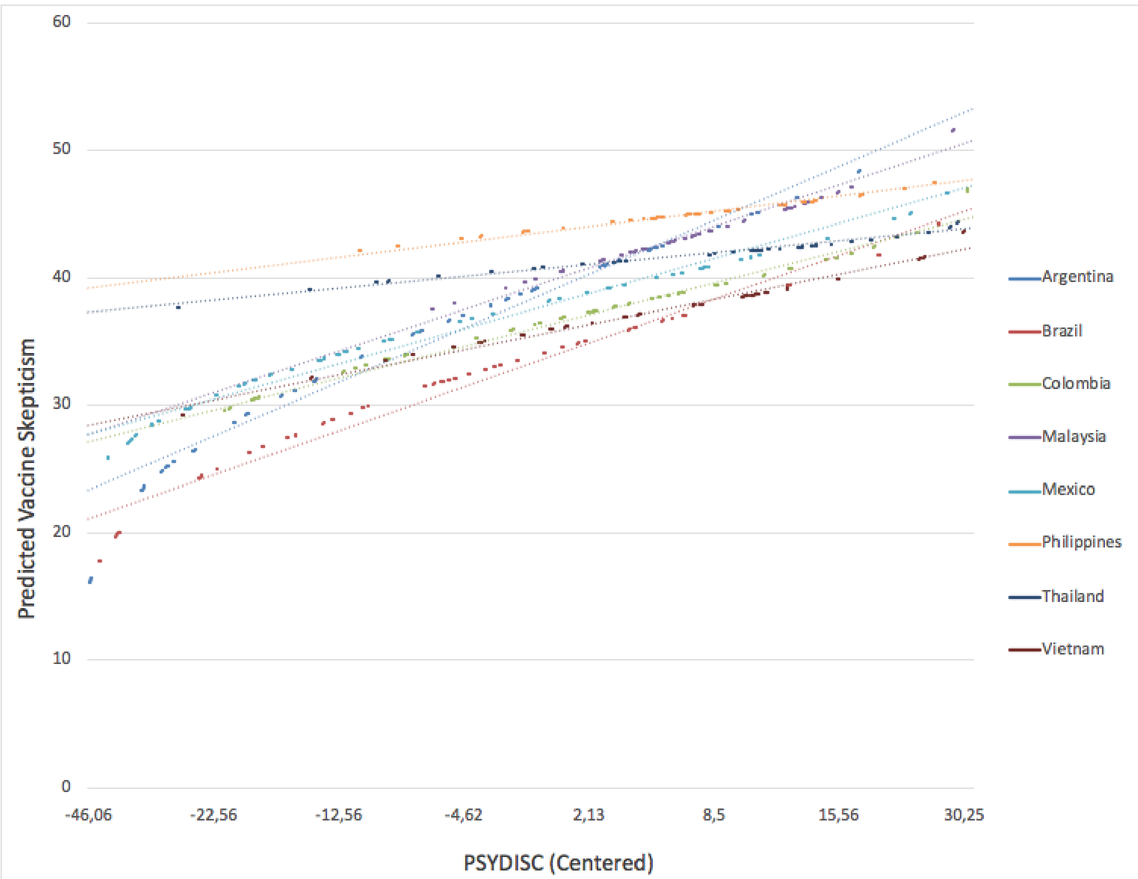
Given the multinational nature of the present study, it is important to consider whether the observed relationships between predictors and outcomes are stable across countries. The goal of such an analysis is not to assume uniformity but to examine the extent to which predictive effects generalize across sociocultural contexts. In line with the MAM proposed in this dissertation, which emphasizes the interaction between individual, cultural, and communication-related variables, testing the consistency of effects allows us to distinguish between universal patterns and context-specific dynamics. When a predictor demonstrates stable associations across countries, it suggests that the effect may be generalizable and robust. Conversely, significant variability between national models supports the notion that cultural or structural differences moderate the relationship in question, reinforcing the need for culturally tailored communication strategies. This type of investigation serves both theoretical and practical purposes, offering empirical insight into the mechanisms through which psychological and contextual variables interact in shaping public responses to science.

To investigate the stability of effects across national contexts, we adopted an approach conceptually similar to multigroup comparisons in structural equation modeling. Specifically, we tested interaction terms between each key predictor and dummy-coded country variables in linear regression models. This allowed us to assess whether the strength or direction of associations varied significantly across countries. To ensure parsimony and focus on the most relevant relationships, we limited these models to predictors that had shown significant effects in more than one country in the country-by-country analyses. In all models, Argentina was selected as the reference category. This means that each interaction term tested whether the slope of the predictor variable differed significantly in the respective country compared to Argentina. We complemented the analysis with slope plots, providing an intuitive visualization of how the effects differed by national context. Together, these procedures support a more nuanced understanding of which psychological and contextual variables demonstrate consistent predictive utility across cultures and which appear to be shaped by national or cultural factors.

The analysis of PSYDISC revealed notable cross-country variation in its predictive relationship with vaccine skepticism. The interaction regression model showed significant interaction terms for three countries: the Philippines ($\beta = -0.100$, $p = .002$), Thailand ($\beta = -0.105$, $p = .001$), and Vietnam ($\beta = -.067$, $p = .029$), indicating that the strength of the association between psychological distance and skepticism was significantly attenuated in these contexts compared to the reference group (Argentina). Notably, these same countries were also those in which PSYDISC had not emerged as a significant predictor in the country-by-country regressions, further supporting the interpretation that the effect of psychological distance on skepticism is weaker in these contexts. Visual inspection of the slope plot in Figure 3 confirms these patterns: while Argentina, Brazil, Colombia, Malaysia, and Mexico displayed stronger positive associations—indicating that higher perceived psychological distance consistently predicted greater skepticism—other countries showed flatter slopes or reduced effects. These findings suggest that while the overall relationship between psychological distance and vaccine skepticism is robust, its intensity varies depending on the national context, underscoring the importance of considering cultural and structural moderators when applying psychological constructs across diverse populations.

Figure 3

Effect of Psychological Distance on Vaccine Skepticism across Countries

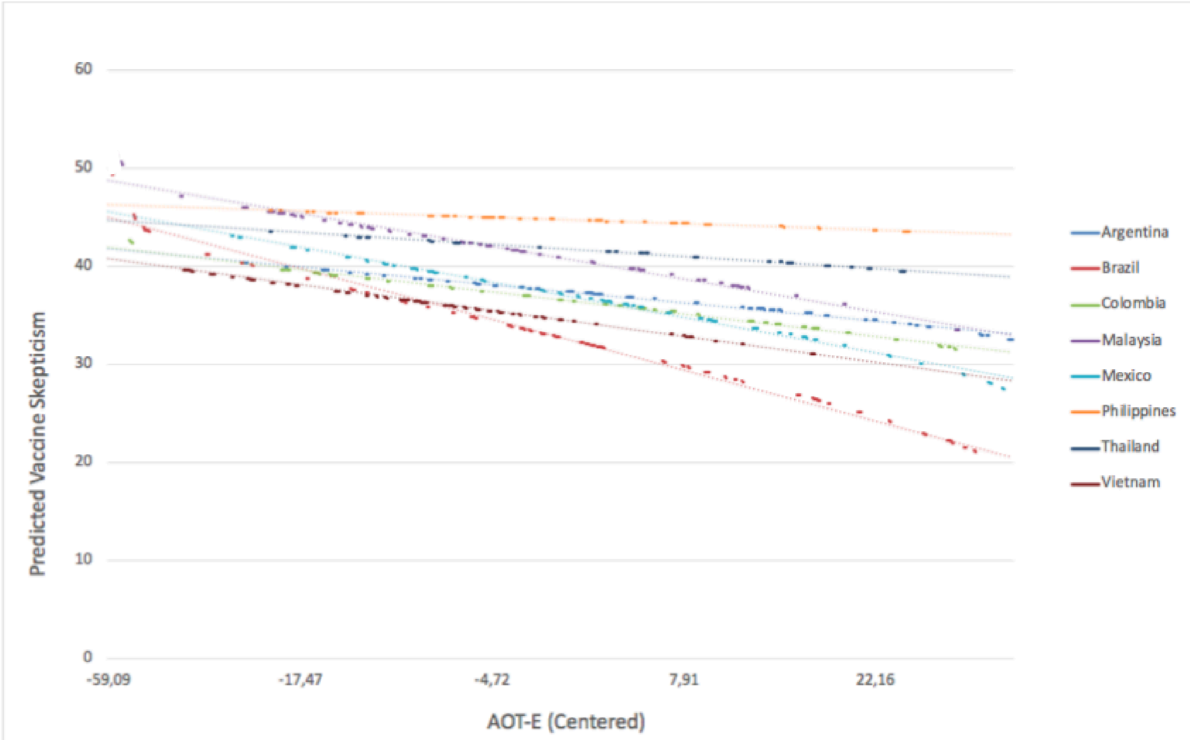


The analysis of AOT-E also revealed meaningful variation in its association with vaccine skepticism across countries. In the interaction regression model, Brazil was the only country for which the interaction term reached statistical significance (β = –0.090, p = .016), indicating that the negative relationship between actively open-minded thinking and skepticism was significantly stronger in Brazil compared to the reference group (Argentina). Although the interaction terms for Mexico (β = –0.052, p =

.163) and Malaysia (β = –0.037, *p* = .289) did not reach statistical significance, AOT-E was a significant predictor in both countries in the country-by-country regressions. In the slope plot (Figure 4), both display steep negative trajectories, suggesting that the protective role of open-minded thinking may indeed be robust in these contexts but failed to reach significance in the interaction model due to shared variance with other predictors or model complexity. Vietnam presents an especially interesting case: despite exhibiting one of the steepest negative slopes, AOT-E was not a significant predictor in either the country-level or interaction regression models. This apparent discrepancy may reflect issues related to measurement validity, such as differences in how open-mindedness is conceptualized or expressed in the Vietnamese cultural context, rather than statistical power. In contrast, countries such as the Philippines and Thailand display relatively flat slopes, consistent with non-significant effects across both analytic strategies. Collectively, these findings suggest that the relationship between open-minded thinking and vaccine skepticism is context-sensitive, with varying levels of predictive strength across countries. They highlight the importance of examining effect stability and considering how cultural or structural factors may moderate the influence of psychological dispositions on science-related attitudes.

Figure 4

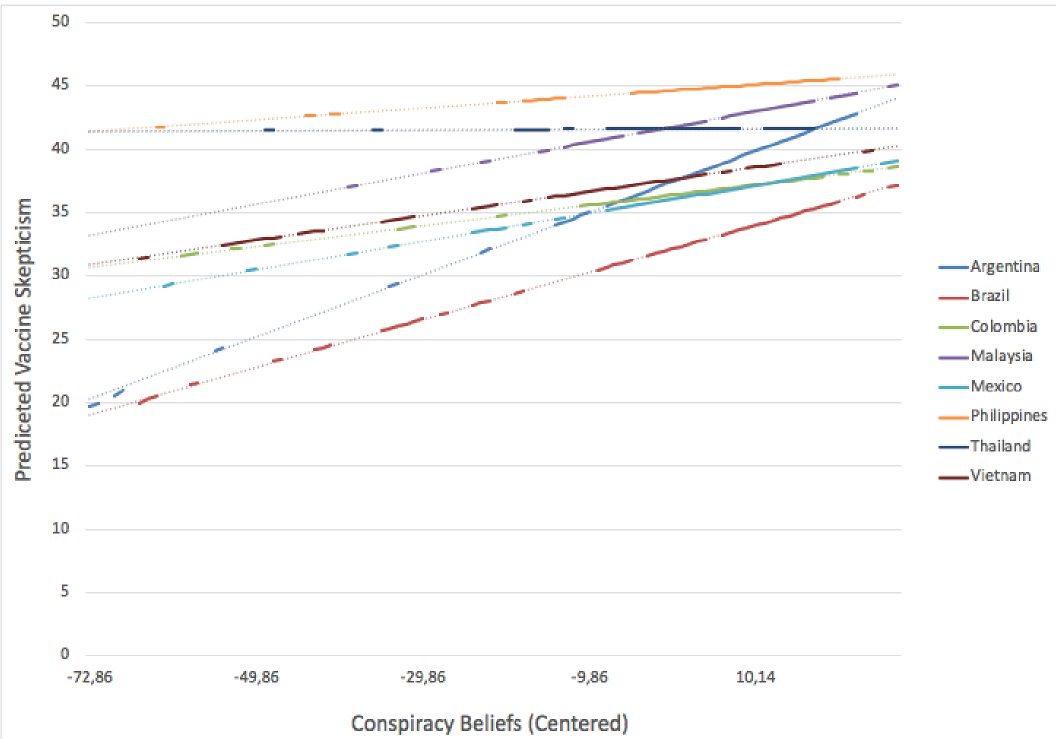
Effect of AOT-E on Vaccine Skepticism across Countries



The analysis of conspiracy beliefs as a predictor of vaccine skepticism revealed substantial variability across countries. In the country-by-country regressions, conspiracy beliefs were significantly associated with higher skepticism in Argentina (β = .264, *p* < .001), Brazil (β = .170, *p* = .006), and Malaysia (β = .159, *p* = .022), suggesting a robust and positive association in these contexts. The interaction regression identified significant negative interaction terms for Colombia (β = –.079, *p* = .016), Mexico (β = –.077, *p* = .029), The Philippines (β = –.095, *p* = .003), Thailand (β = –.114, *p* < .001), and Vietnam (β = –.092, *p* = .015), indicating that the effect of conspiracy beliefs on skepticism was significantly weaker in these countries compared to Argentina, the reference group. Visual inspection of Figure 5 supports these findings: Argentina and Brazil display the steepest positive slopes, consistent with stronger effects, while Mexico, Thailand, and Vietnam show flatter slopes, indicating attenuated relationships. Malaysia presents an intermediate case—with a slope that is steeper than in the lower-bound countries but not significantly different from Argentina in the interaction model. Collectively, these results suggest that the influence of conspiracy beliefs on skepticism is not uniform; in some countries, particularly in Latin America, conspiratorial thinking appears to be a stronger driver of vaccine skepticism than in Southeast Asian contexts. These differences highlight the importance of accounting for cultural and informational environments when designing interventions aimed at curbing the spread of conspiracy beliefs and their impact on science-related attitudes.

Figure 5

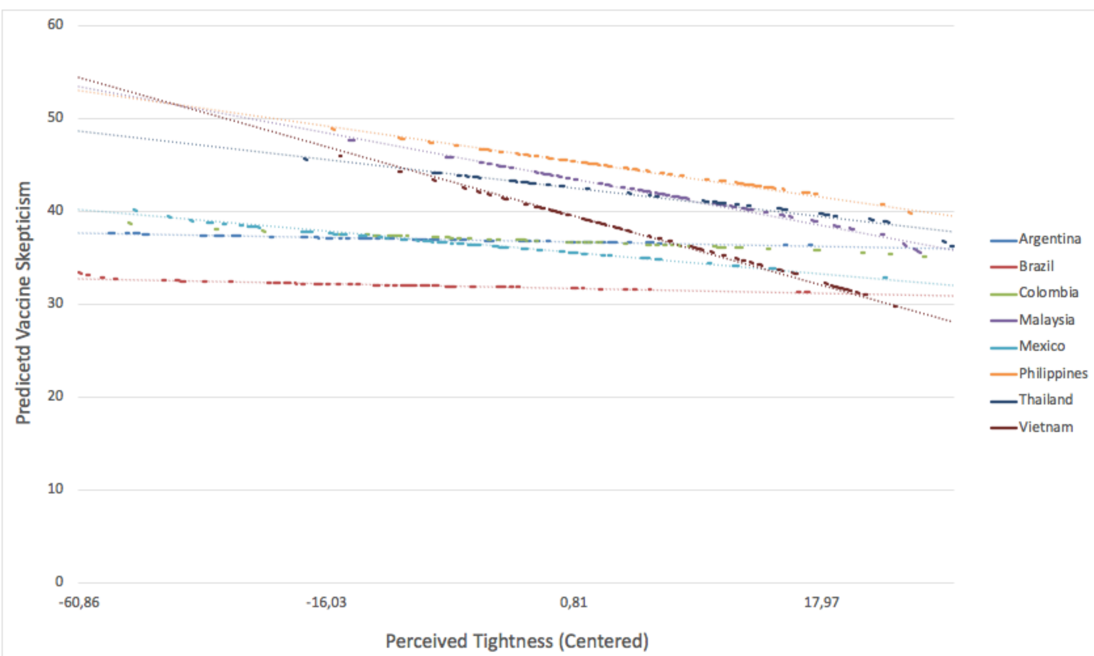
Effect of Conspiracy Beliefs on Vaccine Skepticism across Countries



The analysis of perceived cultural tightness revealed limited but noteworthy cross-national variation in its relationship with vaccine skepticism. In the country-by-country regressions, tightness emerged as a significant negative predictor in Malaysia (β = –0.169, p = .010), Mexico (β = –0.154, p = .017), the Philippines (β = –0.180, p = .014), Thailand (β = –0.190, p = .028), and Vietnam (β = –0.288, p < .001). In the interaction regression, the interaction term for Vietnam reached significance (β = –0.109, p = .003), and the interaction for Malaysia was marginally significant (β = –0.063, p = .054), suggesting that in both countries, the negative association between tightness and skepticism was stronger than in the reference group (Argentina). For Mexico, the Philippines, and Thailand, no significant interaction emerged, indicating that although the direction of the effect was similar, it did not differ statistically from that observed in Argentina. The slope plot supports these conclusions: Vietnam displays the steepest negative slope, visually confirming its distinctive predictive pattern (see Figure 6). Malaysia's line is also relatively steep, reinforcing its marginal interaction effect. Mexico, the Philippines, and Thailand show downward slopes consistent with the country-level results but without sufficient divergence from Argentina to reach statistical significance in the interaction model. Taken together, the findings suggest that while the overall effect of tightness on skepticism is generally modest and stable, it may be amplified in specific cultural contexts such as Vietnam and, to a lesser extent, Malaysia—highlighting the importance of integrating cultural dimensions into science communication research.

Figure 6

Effect of Perceived Tightness on Vaccine Skepticism across Countries



Finally, the analysis of familiarity with dengue vaccines revealed a consistently negative association with vaccine skepticism across several national contexts, indicating that greater familiarity tends to reduce skepticism. In the country-by-country regressions, greater familiarity was significantly associated with lower skepticism in Argentina (β = –0.228, p < .001), Brazil (β = –0.201, p = .001), Malaysia (β = –0.161, p = .024), Mexico (β = –0.234, p < .001), and the Philippines (β = –0.192, p = .009), supporting its robust protective role. However, in the interaction regression model, none of the interaction terms reached statistical significance, suggesting that the strength of this association did not differ significantly from that observed in the reference group (Argentina). The slope plot visually supports these conclusions: all countries exhibit similarly negative trends, with the steepest declines observed in Brazil, Mexico, Malaysia, and the Philippines, precisely the countries where familiarity was most predictive of reduced skepticism in the country-level models. Overall, these results suggest that the relationship between familiarity and vaccine skepticism is largely stable across countries, reinforcing the potential of familiarity-based interventions in reducing hesitancy in diverse cultural contexts.

Figure 7

Effect of Familiarity with Dengue Vaccines on Vaccine Skepticism across Countries

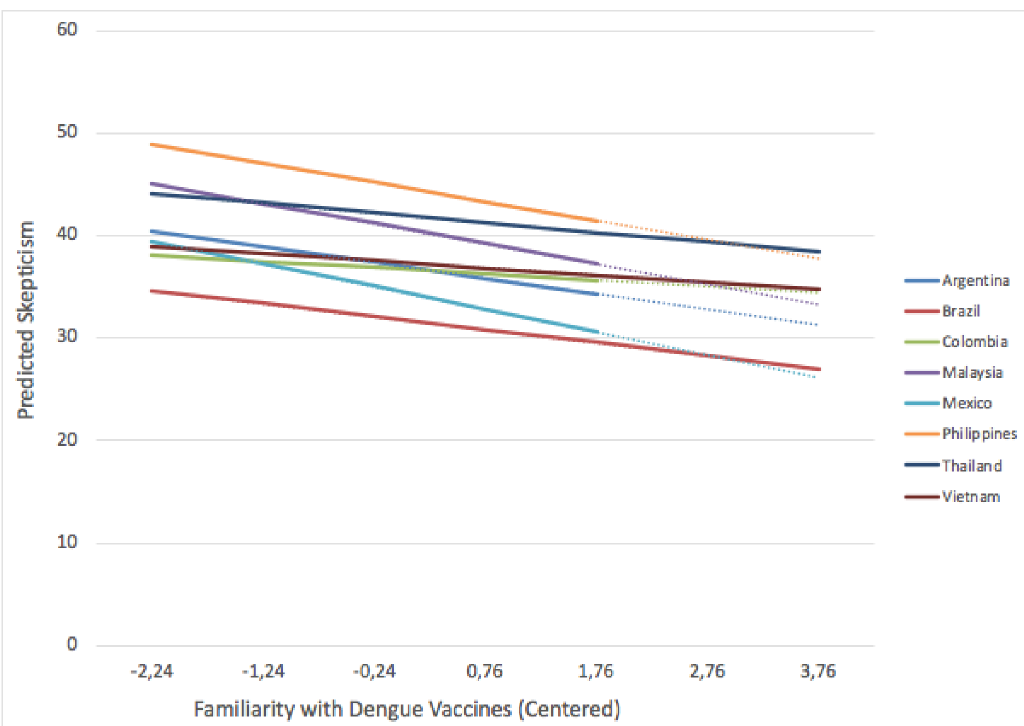


Table 10 presents the results of multinomial logistic regression analyses conducted separately for each national sample. Due to limited sample size in several countries, we opted to include only the variables that had been significant in the full-sample model and were of primary interest for this study, namely, PSYDISC, SRS, familiarity with dengue vaccines, and experience with dengue. Sociodemographic variables were excluded from the country-specific models to preserve degrees of freedom. Despite this adjustment, some subsamples still failed to meet the common rule of thumb of at least 10 observations per variable, and a few models did not reach statistical significance. As such, these results should be interpreted with caution.

Across countries, the most consistently significant predictor was SRS, which was positively related to vaccine hesitancy in Argentina, Colombia, Mexico, and Vietnam. Familiarity with dengue vaccines emerged as a protective factor in Argentina, Malaysia, and Thailand. Previous experience with dengue was also positively associated with vaccine intention in Malaysia, Thailand, and Vietnam. These findings broadly mirror the full-sample results, although with considerable variability across contexts. However, the role of PSYDISC is questioned, as it did not emerge as a significant predictor in any of the countries.

Table 10

Logistic Regression - Vaccine Intention per Country

Country	Predictor	*B (SE)*	*SE B*	Odds Ratio	95% CI for Odds Ratio		*p*[a]
					LL	*UL*	
No/I don't know vs. Yes[b]							
Argentina[c]	Intercept	1.341	.759				.077
	PSYDISC	-.022	.012	.978	.954	1.002	.073
	SRS	-.288	.104	.750	.612	.920	.006
	Familiarity with Dengue	.319	.157	1.376	1.012	1.871	.042

	Vaccines						
	Experience with Dengue	.000	.012	1.000	.977	1.024	.972
Brazil[d]	Intercept	1.027	.712				.149
	PSYDISC	-.019	.012	.982	.959	1.005	.124
	SRS	-.021	.110	.979	.789	1.214	.845
	Familiarity with Dengue Vaccines	.308	.169	1.360	.976	1.895	.069
	Experience with Dengue	.025	.013	1.025	.998	1.052	.068
Colombia[e]	Intercept	.874	.742				.239
	PSYDISC	-.004	.013	.996	.971	1.020	.722
	SRS	-.290	.111	.749	.602	.931	.009
	Familiarity with Dengue Vaccines	.052	.143	1.053	.797	1.393	.715
	Experience with Dengue	.017	.014	1.017	.989	1.045	.237
Malaysia[f]	Intercept	.475	.859				.580
	PSYDISC	-.023	.015	.977	.948	1.006	.117
	SRS	-.114	.082	.892	.760	1.047	.163
	Familiarity with Dengue Vaccines	.596	.174	1.814	1.291	2.550	<.001
	Experience with Dengue	.036	.016	1.036	1.004	1.070	.030
Mexico[g]	Intercept	.605	.552				.273
	PSYDISC	.004	.009	1.004	.986	1.023	.671
	SRS	-.275	.089	.759	.638	.903	.002
	Familiarity with Dengue Vaccines	.111	.134	1.117	.859	1.453	.410
	Experience with Dengue	.019	.012	1.019	.995	1.043	.118

Philippines[H]	Intercept	-.327	.852				.701
	PSYDISC	-.005	.014	.995	.969	1.022	.732
	SRS	.019	.089	1.019	.856	1.214	.832
	Familiarity with Dengue Vaccines	.174	.152	1.190	.883	1.603	.254
	Experience with Dengue	.012	.012	1.012	.988	1.036	.324
Thailand[i]	Intercept	-2.307	1.328				.082
	PSYDISC	-.003	.020	.997	.959	1.037	.891
	SRS	-.039	.128	.962	.748	1.236	.760
	Familiarity with Dengue Vaccines	.447	.206	1.564	1.044	2.344	.030
	Experience with Dengue	.075	.030	1.078	1.015	1.144	.014
Vietnam[j]	Intercept	1.434	1.415				.311
	PSYDISC	-.011	.022	.989	.948	1.033	.629
	SRS	-.325	.150	.723	.539	.969	.030
	Familiarity with Dengue Vaccines	.160	.210	1.173	.777	1.771	.447
	Experience with Dengue	.075	.032	1.077	1.013	1.146	.018

Note. CI = confidence interval; LL = lower limit; UL = upper limit. [a] *p* value for a Wald test statistic. [b] Reference group in the multinomial logistic regression.

[c] Argentina R^2 = .091 (Cox & Snell), .121 (Nagelkerke). Model $\chi 2(4)$ = 16.275, *p* = .003. *N* = 171, *n* YES = 89; *n* NO/I DON'T KNOW = 82

[d] Brazil R^2 = .064 (Cox & Snell), .092 (Nagelkerke). Model $\chi 2(4)$ = 10.831, *p* = .029. *N* = 165, *n* YES = 45; *n* NO/I DON'T KNOW = 120

[e] Colombia R^2 = .056 (Cox & Snell), .075 (Nagelkerke). Model $\chi 2(4)$ = 8.946, *p* = .062. *N* = 155, *n* YES = 81; *n* NO/I DON'T KNOW = 74

[f] Malaysia R^2 = .148 (Cox & Snell), .198 (Nagelkerke). Model $\chi 2(4)$ = 26.461, p = < 001. *N* = 165, *n* YES = 81; n NO/I DON'T KNOW = 84

[g] Mexico R^2 = .073 (Cox & Snell), .098 (Nagelkerke). Model $\chi 2(4)$ = 14.893, *p* = .005. *N* = 196, *n* YES = 110; *n* NO/I DON'T KNOW = 86

[H] Philippines R^2 = .018 (Cox & Snell), .024 (Nagelkerke). Model $\chi 2(4)$ = 2.976, *p* = .562. *N* = 161, *n* YES = 80; *n* NO/I DON'T KNOW = 84

[i] Thailand R^2 = .094 (Cox & Snell), .144 (Nagelkerke). Model $\chi2(4)$ = 10.903, *p* = .028. *N* = 111, *n* YES = 24; *n* NO/I DON'T KNOW = 87

[j] Vietnam R^2 = .133 (Cox & Snell), .191 (Nagelkerke). Model $\chi2(4)$ = 13.814, *p* = .008. *N* = 97, *n* YES = 70; *n* NO/I DON'T KNOW = 27

Discussion

The present study set out to investigate psychological and contextual determinants of dengue vaccine skepticism and intention across eight countries. It pursued two complementary objectives: first, to assess the effectiveness of a psychological distance intervention designed to reduce skepticism and increase vaccine acceptance; and second, to examine how individual and macro-level variables shape vaccine-related attitudes and intentions. By doing so, it aimed to test the applicability of the proposed multilevel model of science communication.

Several key findings emerged from this investigation. The intervention, adapted from previous work on science communication (Vlasceanu et al., 2024), sought to increase perceived relevance and urgency by reducing the psychological distance between individuals and the issue of dengue. While significant differences were observed in the mean levels of vaccine skepticism and intention between the control and intervention groups, the effect of the intervention was not significant when other variables were included in the full-sample linear and logistic regression models. This suggests that the intervention’s influence may be overshadowed by stronger individual-level predictors when analyzed in combination. However, country-specific analyses revealed a meaningful effect in Colombia, where the intervention significantly reduced vaccine skepticism, pointing to possible contextual moderators of its effectiveness.

These findings raise important questions about the applicability of existing literature on psychological distance to the specific context of dengue vaccine communication. While prior studies have shown that reducing psychological distance can be effective in the context of climate change

(Vlasceanu et al., 2024; Jones et al., 2016; Loy & Spence, 2020), our results suggest that this strategy may have limited utility in settings where the issue is already perceived as personally and socially relevant.

There are several possible explanations for this discrepancy. One relates to the nature of the focal issue and the psychological processes it engages. Climate change is a diffuse, abstract, and temporally distant threat that requires individuals to integrate complex systems thinking and probabilistic reasoning. As such, interventions that reduce psychological distance aim to concretize and personalize the issue, thereby fostering engagement with behaviors such as reducing carbon footprints, supporting environmental policies, or sharing climate-related content online. In contrast, dengue presents a concrete, immediate public health risk in endemic areas, with a clearly defined preventive behavior: vaccination. This clarity of action and proximity of threat may reduce the need for psychological reframing, and suggest that other mechanisms, such as trust in institutions, perceived vaccine efficacy, or logistical barriers, may be more influential in shaping attitudes and behaviors in this context.

A second, yet related explanation concerns contextual factors specific to the countries included in this study. Given the particularly high prevalence of dengue cases in many of the sampled locations, participants may have already viewed the disease as psychologically close, leaving limited room for the intervention to further reduce distance or shift perceptions. The modest and context-specific effects observed (limited primarily to Colombia and Thailand) highlight the importance of considering macro-level influences, such as epidemiological trends and cultural norms, when designing science-based interventions. Rather than assuming universal applicability, these findings point to the value of tailoring communication strategies to the salience, familiarity, and perceived relevance of the issue within each sociocultural context.

Beyond the intervention, a central goal of this study was to examine how individual-level psychological and demographic factors influence dengue vaccine skepticism and intention. Overall, the results were largely consistent with existing literature, while also highlighting a few notable divergences.

PSYDISC emerged as the most consistent and robust predictor of vaccine skepticism. Individuals who perceived science as more distant (either socially, temporally, spatially, or in terms of practical relevance) were significantly more likely to express skeptical attitudes across most national samples. This finding aligns with recent work positioning psychological distance as a domain-general factor that undermines engagement with scientific information and trust in scientific institutions (Većkalov et al., 2024).

Familiarity with dengue vaccines was another strong and consistent predictor, negatively associated with skepticism across most countries and in the full sample and positively associated with intention in the full sample. This supports prior research showing that greater exposure to and knowledge about vaccines fosters more favorable attitudes (Thomson et al., 2016). Experience with dengue, though somewhat less consistent, was positively associated with vaccine intention in both the full-sample and in certain country-level models, reinforcing the role of personal relevance and disease salience in shaping vaccination attitudes. Together, these findings suggest that science communication efforts should emphasize clear, accessible information about dengue vaccines and strategically align with periods of high disease prevalence, when personal and social relevance are heightened and receptivity to vaccination messages may be stronger.

Actively open-minded thinking (AOT-E) also predicted lower skepticism in the full sample and in multiple countries. This finding supports the view that the willingness to revise one's beliefs in light of new evidence serves as a protective factor against science denialism and vaccine resistance (Bonafé-Pontes et al., 2025; Pennycook et al., 2020). However, the absence of a significant association between AOT-E and vaccine intention raises the question of whether its influence is primarily limited to shaping attitudes rather than translating into behavioral intentions.

Conversely, conspiracy beliefs were positively associated with skepticism, replicating a well-established relationship documented across vaccine contexts (Darbandi et al., 2024; Hornsey et al., 2018b; Jennings et al., 2023). This effect was observed in both the full model and several national samples, particularly in Latin America, where distrust in institutions and exposure to misinformation may amplify conspiratorial thinking (Roberti et al., 2024). Similarly to the AOT-E, however, no associations were found between conspiracy beliefs and vaccine intention, which may raise questions about the scope of its influence. Political orientation to the right also emerged as a significant variable that positively influenced skepticism in the full sample and in Brazil. These findings are consistent with prior research showing that ideological worldviews, especially those emphasizing individualism and distrust of state-led initiatives, can undermine vaccine confidence (Kahan et al., 2011).

A few findings, however, diverged from expectations. Most notably, scientific reasoning (SRS), though theoretically expected to reduce skepticism and promote vaccine intention, was positively associated with both higher skepticism and lower intention in the full sample. In addition, SRS was negatively related to vaccine intention in several national models, further reinforcing this unexpected pattern. While counterintuitive, these results may reflect methodological limitations, particularly the lack of measurement invariance across countries, raising concerns about whether the scale captures the same underlying construct in different sociocultural contexts.

This possibility is supported by recent findings that the SRS does not always perform consistently across cultural settings. Caliciuri and Lanz (2024) found that the scale did not function as expected in an Italian sample, with five items failing to load sufficiently onto the latent factor and a resulting short version achieving only moderate reliability ($\omega = .61$). Similarly, Bašnáková et al. (2021) reported that Slovak participants performed markedly worse on a decontextualized version of the scale, suggesting that item interpretation may rely on topic-specific knowledge or familiarity. These limitations have led to the development of alternative formats, such as Golumbic et al.'s (2022) Everyday Science Reasoning Scale, which recontextualizes the original items around familiar, real-world scenarios. Taken together, these findings underscore the need for further adaptation and validation of scientific reasoning measures that can capture relevant cognitive processes across diverse populations and cultural frames.

In addition to measurement concerns, theoretical explanations should also be considered. One compelling account is that individuals with stronger reasoning abilities may be more skilled at defending their preexisting beliefs, a phenomenon known as motivated reasoning (Kunda, 1990). Rather than promoting unbiased engagement with evidence, scientific reasoning may, in some contexts, enable selective evaluation that reinforces ideological or identity-consistent views (Kahan, 2013; Kraft et al., 2015). It is interesting to acknowledge that similar, unexpected patterns have emerged in other studies: Sarathchandra et al. (2018) found that higher SRS scores were associated with greater acceptance of vaccines among liberals but greater resistance among conservatives, highlighting the role of ideological priors in shaping how reasoning skills are applied. Zhang et al. (2024) found little evidence of a relationship between scientific reasoning and vaccine hesitancy in Shanghai, China, pointing to the possible influence of cultural or contextual factors. Dalyot and Baram-Tsabari (2023) similarly reported that scientific reasoning did not necessarily predict the decisions or justifications made by parents weighing the risks of Wi-Fi radiation, while Azodi and Dietz (2019) observed that higher SRS scores were linked to greater perceptions of risk and stronger support for regulation in the context of biotechnology—contrary to the expectation that scientific reasoning would align with pro-science attitudes. Together, these findings suggest that scientific reasoning may not uniformly foster trust in science or expert consensus, particularly when competing values, cultural frames, or ideological commitments are at play (Kahan et al., 2012).

Beyond the cognitive and dispositional variables discussed above, we also examined the role of sociodemographic characteristics in shaping vaccine attitudes and intentions. These variables showed weak and inconsistent effects. In the full sample, none of the demographic predictors were significantly associated with vaccine skepticism. However, in country-level analyses, education was positively associated with skepticism in Argentina and age in Malaysia. Conversely, non-female gender was negatively linked to skepticism in Colombia and Mexico. For vaccine intention, two demographic variables reached significance in the full sample: age was negatively associated with intention, while education had a positive effect. Due to sample size limitations, we were unable to examine whether these effects are replicated in each national sample. Future research is needed to clarify the conditions under which these factors may meaningfully shape vaccine attitudes, and how they might interact with cultural and contextual influences.

Given the mixed evidence in the literature regarding the role of cultural tightness in shaping vaccine attitudes, we approached this variable exploratorily. Prior research suggests that tightness does not inherently promote or discourage vaccination but rather amplifies prevailing social norms, whether supportive or resistant to vaccination efforts (Jones et al., 2022, Shi et al., 2024). Notably, much of this work has focused on the COVID-19 pandemic, during which vaccine hesitancy was highly politicized and polarized in many settings (Dolman et al, 2023; Ebeling et al., 2023). It is possible that, over time, prevailing norms, particularly in tight cultures, have shifted toward greater acceptance of vaccination, especially as public health campaigns became more widespread and institutional trust recovered. Our results contribute to this evolving debate by showing that perceived cultural tightness negatively predicted vaccine skepticism in the full sample, suggesting that in the current context, tighter cultures may have come to support pro-vaccine norms. However, the lack of a significant association between tightness and vaccine intention raises questions about its actual behavioral consequences. It is possible that while tightness influences attitudes, other variables, such as familiarity, personal experience, or trust in institutions, may play a more central role in shaping whether individuals ultimately choose to get vaccinated.

Country-level regressions further revealed that this effect was more pronounced in Asian countries, including Vietnam, Thailand, Malaysia, and the Philippines, while tightness was largely unrelated to skepticism in Latin America. These findings are consistent with Shi et al. (2024), who found that cultural tightness was positively associated with vaccination intention in several Asian countries and enhanced the influence of perceived and collective norms. Thus, while our findings cannot confirm a consistent directionality of the effect across all contexts, they support the idea that tightness may strengthen adherence to dominant public health norms, particularly in regions where vaccine acceptance is relatively high.

Macro-level analyses also highlighted clear regional patterns. As discussed above, in Asian countries, perceived cultural tightness appeared to play a more meaningful role in shaping vaccine skepticism, while in Latin American countries, individual-level ideological and epistemic variables, such as political orientation and conspiracy beliefs, were more predictive. These patterns point to the importance of culturally tailored intervention strategies: in tighter societies, aligning public messaging with dominant social expectations may be particularly effective, while in looser or more ideologically polarized societies, directly addressing sources of mistrust and misinformation may be more critical. Overall, the findings highlight the value of accounting for macro-level cultural context when designing and implementing public health interventions.

To complement the main findings, we examined the cross-national stability of key predictors of vaccine skepticism through a series of interaction regressions and slope visualizations. This analysis revealed that while some psychological and contextual variables, such as AOT-E and familiarity with dengue vaccines, showed consistent predictive utility across countries, others, including PSYDISC, conspiracy beliefs, and cultural tightness, varied meaningfully by national context. In some cases, effects were significantly stronger or weaker in specific countries compared to Argentina, the reference group. These results underscore the context-sensitive nature of science-related attitudes and support the central premise of the Multilevel Analytic Model: that individual-level cognition, communication framing, and cultural norms interact to shape public responses to science. By identifying both generalizable patterns and culturally contingent effects, this analysis contributes to a more nuanced understanding of how psychological dispositions and societal context jointly influence vaccine skepticism.

Additional country-level analyses of participants' self-reported reasons for vaccine hesitancy further reinforce this point. While concerns about possible side effects emerged as the most frequently cited reason across the full sample, notable differences were observed between countries. For example, financial cost was a major barrier in Argentina and Thailand, but was far less salient in Brazil and Colombia. Similarly, perceptions of not being at high risk varied substantially, with particularly high rates in Colombia and Vietnam, where fear of needles was also commonly reported. These findings underscore the heterogeneity of practical and perceptual barriers to vaccination and highlight the need for context-sensitive approaches that address the specific concerns most salient within each population.

Several limitations should be acknowledged when interpreting our results. The use of online data collection may have limited the representativeness of the sample in each country, potentially excluding populations with lower digital literacy or limited internet access, such as older adults or individuals living in rural areas.

Another important limitation concerns the psychometric comparability of the instruments used across countries. Measurement invariance analyses were conducted to assess whether the scales captured the same constructs equivalently across national contexts. As detailed in the Appendix B (Tables C1-C5), none of the instruments met the standard criteria for metric or scalar invariance. While several configural models showed acceptable absolute fit, changes in fit indices across increasingly constrained models exceeded recommended thresholds (ΔCFI > .01 and/or ΔRMSEA > .015), indicating a lack of equivalence in factor loadings and intercepts across countries (Davidov et al., 2014; de Van de Schoot et al., 2012; Leitgöb et al., 2023). These findings caution against direct cross-national comparisons of latent means and suggest the need for careful interpretation when generalizing results across cultural settings.

Despite these results, we decided to proceed with our analyses, bearing in mind the following considerations. All scales demonstrated acceptable internal consistency and, when tested in the full sample, their factor structures replicated the dimensionality reported in their original validation studies. In addition, the majority of associations observed were theoretically consistent and in line with prior findings, with the exception of the SRS, which yielded unexpected patterns.

Noninvariance may stem from multiple sources, as outlined in the literature on cross-cultural methodology. These include construct bias (differences in how constructs are understood across groups), method bias (e.g., response styles or administration procedures), and item bias (e.g., problematic translations or culture-specific interpretations) (Davidov et al., 2014; Fischer & Karl, 2019; van de Vijver, 1998). In our case, even though administration procedures were standardized, it is conceivable that both construct and item bias were at play, particularly given that the instruments had not yet undergone full adaptation or validation in all national samples.

Also, it is worth noting that the interpretation of noninvariance remains contested in the literature. While some scholars argue that the absence of equivalence invalidates group-level comparisons of latent means (Church et al., 2011; Steenkamp & Baumgartner, 1998; Van de Schoot et al., 2012), others maintain that some degree of noninvariance is expected in cross-cultural research and may reflect real differences in how constructs manifest across societies (Davidov et al., 2014; McCrae, 2015; Thielmann et al., 2019; Vandenberg & Lance, 2000). From this perspective, noninvariance does not inherently undermine the value of cross-cultural analysis but rather underscores the need for caution and further investigation. We view our analyses as an exploratory step toward understanding culturally situated patterns in science-related attitudes and hope future research will build upon these findings through more extensive cultural validation and refinement of existing measures.

Yet another limitation concerns the logistic regression models, which were constrained by a reduced sample size, as analyses were limited to participants who had not yet been vaccinated. This may have diminished statistical power and impacted the stability of the estimated effects. Finally, although the study included participants from multiple countries, the relatively small number of national samples limited our ability to conduct multilevel modeling to formally account for country-level variance, which could have provided a more comprehensive understanding of contextual influences.

Despite these limitations, the present study offers several important contributions to the literature on vaccine hesitancy and science communication. As one of the first large-scale, cross-cultural investigations focused specifically on dengue vaccine skepticism and intention, it broadens the scope of vaccine research beyond the well-studied context of COVID-19 and affirms the validity of our proposed multilevel model of science communication. More specifically, it demonstrates and qualifies how individual-level variables (e.g., scientific reasoning, open-mindedness, previous experiences), message-level interventions (i.e., psychological distance framing), and macro-level cultural factors jointly influence science-related outcomes, thus offering empirical support for the integrative structure of the MAM. The study also introduces PSYDISC as a novel and robust predictor of vaccine attitudes, highlighting its potential value in future public health research. Moreover, by testing a low-cost, evidence-based intervention in diverse, real-world contexts, the study provides valuable insight into the practical feasibility (and limits) of strategies aimed at increasing vaccine acceptance.

These findings carry practical implications for public health communication. They underscore the need for tailored messaging strategies, particularly in tight cultures, where aligning with prevailing social norms may be key to intervention success. Additionally, the consistent role of familiarity and experience with dengue suggests that educational campaigns should leverage moments of heightened disease salience and emphasize personal and societal relevance, ideally through trusted, locally resonant sources. While the intervention effects were modest, the data suggest that even brief, relevance-based strategies can be a useful component in broader efforts to promote vaccine acceptance, especially when embedded within culturally informed communication frameworks.

Building on the present findings, future research should aim to refine and expand the psychological distance intervention by incorporating multiple sessions, visual or interactive materials, and other design elements that could enhance engagement and message retention. Longitudinal studies are particularly needed to assess how vaccine attitudes and intentions evolve over time and to evaluate the durability of intervention effects. Crucially, such studies should include behavioral measures, such as actual vaccine uptake, to examine whether stated intentions lead to real-world action. Further research should also investigate potential mediating mechanisms, including emotional engagement, perceived risk, and trust in science, to better understand how and why these interventions exert their effects. Finally, efforts should be made to reach larger samples and underrepresented populations.

In the context of growing concerns over dengue outbreaks and persistent vaccine hesitancy, this study underscores the urgency of developing effective strategies to improve vaccine acceptance. By examining a wide range of psychological, social, and cultural factors across diverse national settings, the present study showed that individual cognition, contextual norms, and targeted messaging all play meaningful roles in shaping vaccine attitudes. While no single solution will address the complexities of vaccine skepticism, the present findings support the value of psychologically informed, culturally-grounded interventions, particularly those that highlight personal and societal relevance in disease prevention.

General Discussion

Understanding how people respond to science is a challenge of growing urgency in today's world. From public health crises to climate change and technological innovation, global challenges increasingly hinge on the ability of science to inform individual and institutional decision-making. Yet, empirical evidence consistently shows that scientific information alone is often insufficient to change minds or guide behavior (Kahan, 2015; Lewandowsky et al., 2017). The complex web of psychological, social, and contextual factors that shape how science is communicated and received calls for more integrative and nuanced approaches.

This dissertation responds to that call by proposing and applying a Multilevel Analytic Model (MAM) of how individuals engage with and respond to scientific content, grounded in the theoretical and methodological tradition of social psychology. The MAM acknowledges that outcomes are seldom shaped by a single factor; rather, they result from the dynamic interaction of variables at multiple levels of analysis: micro (individual cognitive and motivational traits), meso (interpersonal and group dynamics), macro (sociocultural and institutional context), and message-level characteristics (such as content, framing, and delivery format). By integrating these dimensions, the model provides a comprehensive framework for examining the complex processes involved in science-related communication. Drawing on six manuscripts developed over the course of the doctoral research, this dissertation offers a cumulative and context-sensitive contribution to understanding how scientific messages are processed and received in Brazil and beyond.

The purpose of this general discussion is to synthesize the main contributions of these studies through the lens of the proposed multilevel model. It highlights how each manuscript contributes to different levels of analysis, explores their theoretical and practical implications, acknowledges their limitations, and outlines directions for future research. In doing so, it reaffirms the importance of grounding science communication research in robust theoretical frameworks while maintaining responsiveness to real-world challenges.

Integration of Findings through the MAM Framework

Micro-Level (Individual Factors)

At the micro-level, the MAM emphasizes the role of individual traits, dispositions, and motivations in shaping how scientific information is processed. Several manuscripts in this dissertation directly address these individual-level influences, underscoring their centrality to understanding science reception.

Findings from Manuscripts 1, 3, and 6 consistently emphasize the role of intraindividual factors in shaping responses to scientific content. Manuscript 1 demonstrates that participants' ability to discern true from false COVID-19 messages shared in politically-oriented WhatsApp groups was significantly influenced by political orientation, trust in media sources, and levels of open-minded thinking. Manuscript 3 shows that favorable attitudes toward genetically modified (GM) foods were associated with higher levels of both general and domain-specific scientific literacy, as well as open-minded thinking and right-wing political orientation. In contrast, GM skepticism was linked to conspiracy thinking and motivations related to health and natural eating. Manuscript 6, which examined dengue vaccine acceptance across eight countries, further illustrates the impact of micro-level variables. Vaccine skepticism was positively associated with perceived psychological distance to science, conspiracy beliefs, and right-wing political orientation, and negatively associated with open-mindedness and prior knowledge about dengue vaccines.

To further investigate these individual-level dispositions, Manuscripts 4 and 5 focused on adapting and validating two important instruments for the Brazilian context: the Actively Open-minded Thinking about Evidence (AOT-E) scale (Pennycook et al., 2020) and the Scientific Reasoning Scale (SRS; Drummond & Fischhoff, 2017b), respectively. Both instruments showed robust psychometric properties and replicated expected correlations with related constructs, such as conspiracy beliefs, science literacy, and attitudes toward science. The AOT-E scale captures individuals' willingness to revise their beliefs in light of new evidence, a trait that has been linked to reduced susceptibility to misinformation and improved reasoning (Bronstein et al., 2021; Pennycook et al., 2020). The SRS measures the ability to evaluate the quality of scientific information, encompassing skills like causal inference and methodological reasoning. Its adaptation confirmed expected associations with scientific literacy, attitudes toward science, and rejection of pseudoscientific beliefs, aligning with findings from international validations (Čavojová et al., 2019; Bergan, 2021; Drummond & Fischhoff, 2017b; Marin et al., 2024). Together, these tools provide a culturally appropriate and methodologically sound foundation for studying how people understand and respond to scientific information.

Taken together, the findings across these manuscripts demonstrate the critical role of micro-level variables in science communication. They underscore the importance of accounting for cognitive and motivational differences when evaluating how people interpret, accept, or reject scientific information. Moreover, they provide a strong empirical foundation for future interventions aimed at fostering reflective thinking, scientific reasoning, and trust in credible sources.

Meso-Level (Group Factors)

The meso-level of the MAM highlights the influence of interpersonal relationships and group dynamics on how scientific messages are processed. Among the studies presented in this dissertation, Manuscript 1 is the only one that directly attempted to empirically test meso-level hypotheses. It examined whether group identification with politically-oriented WhatsApp chats influenced participants’ discernment of message accuracy. Although no significant moderating effect was observed - likely due to low levels of perceived identification with the experimental groups - the study was grounded in strong theoretical assumptions drawn from social identity theory, group-based reasoning, and social motivational constructs (Lewandowsky & Oberauer, 2016; Stets & Burke, 2000; Tajfel & Turner, 1979), such as the need to belong (Baumeister & Leary, 1995).

This limited empirical coverage points to the challenges of operationalizing meso-level mechanisms, particularly in online and survey-based designs. Factors such as real-time interaction, group belonging, and peer deliberation may require alternative methodologies to be effectively captured. Nonetheless, the theoretical relevance of this level remains crucial.

The MAM is designed as a flexible framework: it does not require all levels to be empirically tested in every study, but rather encourages a cumulative understanding of the different forces shaping responses to science communication. Future research should thus aim to fill this gap by directly engaging with group-level processes, including peer influence, social trust, and identity-based polarization. Investigating these dynamics in real-world settings (such as classrooms, community groups, or digital platforms) can help expand the empirical reach of meso-level inquiry and strengthen the integrative potential of the multilevel model.

Macro-Level (Cultural and Contextual Factors)

The macro-level dimension of the MAM encompasses the broader sociocultural and institutional factors that influence how science is communicated and received. Among the studies in this dissertation, Manuscript 6 offers an empirical engagement with this level. Conducted across eight countries, the study examined how national contexts, and cultural tightness (Gelfand et al., 2011), in particular, affects public responses to dengue vaccine. The findings showed that higher cultural tightness was associated with lower vaccine acceptance, even after accounting for individual psychological variables. This result underscores the importance of considering cultural context when interpreting science-related attitudes and behaviors.

In addition to cultural tightness, Manuscript 6 also highlighted important country-level differences in vaccine acceptance patterns. Brazil, for example, showed the highest overall intention to vaccinate against dengue. This may reflect the country's longstanding tradition with national immunization programs, as well as the acute public salience of dengue given its high incidence rates. In contrast, the Philippines showed the second lowest intention to vaccinate, a result likely shaped by the well-known controversy surrounding the Dengvaxia vaccine. The public backlash and institutional mistrust that followed the vaccine's suspension may have left a lasting impact on public perception. These cases illustrate how national histories, public health infrastructure, and prior experiences with science-based interventions shape public attitudes at the macro level and highlight the need for communication strategies that are responsive to specific cultural and political contexts.

The study also showed that the relevance of individual-level predictors varied across countries, underscoring the interplay between micro- and macro-level dynamics. Some influences, such as prior experience with dengue or familiarity with dengue vaccines, were consistently significant across contexts. Others, like political orientation and conspiracy beliefs, were only predictive in specific national settings. Likewise, the effect of perceived cultural tightness emerged in some countries but not in others. These variations illustrate how the meaning and weight of individual-level variables are shaped by broader sociopolitical and cultural environments, reinforcing the value of a multilevel framework for science communication research.

By integrating macro-level insights into a multilevel framework, the MAM contributes to a more comprehensive and context-sensitive understanding of science communication. While such factors are often overlooked in favor of more easily measurable individual differences, Manuscript 6 shows that macro-level context can significantly shape how scientific messages are received. Future studies should continue to explore these dynamics, particularly in underrepresented regions and populations, to better inform culturally tailored science communication strategies.

Message-Related Variables (Content, framing, format)

The message-level dimension of the MAM concerns how characteristics of the message itself—such as content, framing, and medium—affect public responses to scientific information. Several manuscripts in this dissertation addressed this dimension, offering insights into how the structure and delivery of information can contribute to shaping belief and attitude formation.

Manuscript 1 contributed to this level by testing science-related messages in the context of WhatsApp, a ubiquitous and influential messaging platform in Brazil and many other countries. By embedding true and false COVID-19 content within fictitious WhatsApp group chats, the study provided ecologically valid insights into how message reception is influenced by both content and context.

In Manuscript 3, the role of framing was examined in the context of genetically modified (GM) foods. Participants were randomly assigned to receive one of three types of informational content focusing on either the people involved in GM production, the processes used, or the final product itself. Findings indicated that, regardless of framing focus, providing information about GM foods increased favorable beliefs, suggesting that factual content may be effective in improving attitudes toward specific controversial scientific topics.

Finally, Manuscript 6 tested a message-level intervention aimed at reducing psychological distance to science. Participants in the intervention condition received vaccine messages created to emphasize the immediate relevance of dengue. The intervention produced mixed results, with significant effects in very limited cultural contexts. These findings highlight the potential but also the limitations of universal message designs and underscore the importance of cultural tailoring in science communication strategies.

Together, these studies illustrate how variations in platform, content framing, and psychological proximity can influence public engagement with science. They also emphasize the need to test communication strategies across different formats and populations to understand what works, where, and for whom.

Theoretical and Methodological Contributions

The primary theoretical contribution of this dissertation is the development and application of the Multilevel Analytic Model (MAM), which provides a structured yet flexible framework for understanding the effects of science communication. One of its key strengths lies in its ability to capture not only the distinct contributions of each level of analysis, but also the dynamic interactions between them—for instance, how cultural or institutional settings can shape the influence of individual traits or the effectiveness of specific message strategies. Unlike linear or one-dimensional models, the MAM integrates psychological, social, cultural, and communicative variables into a coherent multilevel approach. Its design accommodates both comprehensive and focused applications: researchers may address all four levels in a single study or emphasize specific dimensions based on context, research questions, or practical limitations. This flexibility enhances the model's utility across diverse research designs and cultural settings, as demonstrated by the six studies that comprise this dissertation.

Methodologically, this dissertation combines experimental, psychometric, and cross-cultural approaches to study real-world topics using contextually relevant platforms and culturally adapted instruments. This triangulation strengthens the reliability and ecological validity of the findings while demonstrating the value of grounding empirical work in a robust theoretical model.

Among its key contributions are the adaptation and validation of two psychometric tools for the Brazilian context: the Actively Open-minded Thinking about Evidence (AOT-E) scale and the Scientific Reasoning Scale (SRS). These instruments enable more precise and culturally sensitive measurement of cognitive dispositions that are central to science communication processes. Additionally, the dissertation addresses highly relevant and timely topics such as COVID-19 misinformation, genetically modified foods, and dengue vaccine acceptance, issues that not only carry substantial public health and policy implications but also reflect the broader societal tensions surrounding scientific authority and trust. By investigating these challenges through the lens of the MAM, the dissertation reinforces the importance of context-aware, interdisciplinary approaches to advancing the science of science communication. Together, the theoretical innovation and methodological execution presented in this dissertation contribute to advancing a more nuanced, inclusive, and practical science of science communication.

Limitations and Directions for Future Research

Despite its contributions, this dissertation is not without limitations. One important constraint lies in the limited scope of dependent variables across the studies. Most outcomes rely on self-reported beliefs, attitudes, and intentions, which, although informative, do not fully capture public engagement with science. Understanding whether and how people actually behave based on scientific information (e.g., by taking action, seeking further knowledge, or influencing others) remains an open question. Future research should build on the MAM by incorporating behavioral indicators, such as information sharing, policy support, or participation in science-related initiatives.

Another limitation concerns the empirical coverage of the meso-level dimension. Although Manuscript 1 attempted to operationalize group identification and need for belonging, it did not yield significant effects - partly due to challenges in simulating group dynamics within online experimental designs. Future research should include more group-related measures and adopt more immersive or interactive methods to examine peer influence, group polarization, and social identity mechanisms.

In addition, the studies included in this dissertation rely primarily on online surveys and self-administered experimental tasks. While these methods offer important advantages in terms of reach, scalability, and control, they can limit both the representativeness of the sample and the ability to examine science communication in real-world contexts. Channels such as face-to-face conversations, institutional outreach, or media campaigns were not directly examined. Future research should explore how scientific information is processed and negotiated in these alternative communicative settings, which may involve different cognitive, emotional, and social mechanisms than those captured in digital or survey-based research.

Finally, expanding the cultural diversity of samples remains a critical challenge. Although this thesis includes a cross-country study and focuses on Brazil as an underrepresented context, future work should aim to include greater representativeness of the global South, and specially marginalized, rural, or offline populations whose perspectives on science are often absent from the literature. Addressing these gaps will not only improve the generalizability of findings but also ensure that science communication strategies are inclusive and equitable.

Concluding Remarks

This dissertation set out to advance a more integrated understanding of how scientific information is received, evaluated, and acted upon by the public. By proposing the Multilevel Analytic Model (MAM) and testing it across a series of empirical studies, the project bridges theoretical innovation with practical application in science communication. The MAM offers a flexible and dynamic lens through which researchers and practitioners can assess the combined influence of individual cognition, social context, cultural environment, and message design.

The studies included in this thesis contribute to diversifying the field of science communication, both in terms of geography and methodology. They examine socially and scientifically pressing topics—including COVID-19 misinformation, genetically modified foods, and dengue vaccine acceptance—through rigorous psychometric, experimental, and cross-cultural approaches. The validation of measurement tools like the AOT-E and SRS further strengthens the foundation for cumulative, comparative research in underrepresented contexts.

Ultimately, this work emphasizes that effective science communication is not a matter of simply conveying facts, but of understanding the complex social and psychological ecosystems in which those facts are received. By combining theoretical depth with empirical breadth, the dissertation makes a meaningful contribution to the development of a more responsive, evidence-based science of science communication—one that is well-positioned to meet the challenges of an increasingly complex and interconnected world.

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Appendix A: Experimental Stimuli Manuscript 3

Pessoa

Chamamos de transgênico o organismo que passou por modificações genéticas, ou seja, mudanças em seu DNA que resultaram no desenvolvimento de novas características.

As evidências científicas acumuladas nas últimas décadas apontam que os alimentos geneticamente modificados são seguros para o consumo humano e animal. Centenas de estudos que analisaram os transgênicos disponíveis comercialmente concluíram que seu consumo não apresenta riscos à saúde.

Quando refletimos sobre alimentos geneticamente modificados, é interessante pensar nas pessoas que trabalham nesta área como, por exemplo, o especialista Fábio Faleiro. Pesquisador da Embrapa Cerrados e professor de agronomia na Universidade de Brasília, ele é mestre e doutor em genética e melhoramento pela Universidade Federal de Viçosa e pós-doutor em genética e biotecnologia pela Universidade da Flórida. Em mais de 20 anos de carreira, Fábio aplicou técnicas de modificação genética em diversas frutas e grãos. Ganhador de vários prêmios, ele é co-autor do livro "Biotecnologia, transgênicos e biossegurança", que ressalta a segurança do consumo de transgênicos.

Processo

Chamamos de transgênico o organismo que passou por modificações genéticas, ou seja, mudanças em seu DNA que resultaram no desenvolvimento de novas características.

As evidências científicas acumuladas nas últimas décadas apontam que os alimentos geneticamente modificados são seguros para o consumo humano e animal. Centenas de estudos que analisaram os transgênicos disponíveis comercialmente concluíram que seu consumo não apresenta riscos à saúde.

Quando refletimos sobre alimentos geneticamente modificados, é interessante pensar nos processos utilizados nesta área como, por exemplo, o DNA Recombinante. Essa técnica consiste em selecionar o “pedaço” do DNA responsável pela característica desejada e adicioná-lo ao material genético de outra fonte. A seleção de qualidades consideradas mais atraentes vem ocorrendo há milênios, tanto no cruzamento de animais quanto no cultivo de plantas. O surgimento das técnicas de DNA Recombinante permitiu que essas alterações sejam feitas de maneira precisa, previsível e controlada. Saber exatamente onde o DNA está mudando reduz o risco de mutações indesejadas.

Produto

Chamamos de transgênico o organismo que passou por modificações genéticas, ou seja, mudanças em seu DNA que resultaram no desenvolvimento de novas características.

As evidências científicas acumuladas nas últimas décadas apontam que os alimentos geneticamente modificados são seguros para o consumo humano e animal. Centenas de estudos que analisaram os transgênicos disponíveis comercialmente concluíram que seu consumo não apresenta riscos à saúde.

Quando refletimos sobre alimentos geneticamente modificados, é interessante pensar nos produtos desenvolvidos nesta área como, por exemplo, o milho resistente a pragas. Atualmente, grande parte do milho plantado no Brasil é geneticamente modificado. Entre os principais motivos está sua capacidade de combate aos insetos que se alimentam das plantações, como a lagarta-do-cartucho, a lagarta-da-espiga e a broca-do-colmo. A resistência a pragas é uma das características mais frequentemente inseridas em plantas geneticamente modificadas. Essa tecnologia reduz a necessidade de usar inseticidas sintéticos convencionais, que podem afetar o meio ambiente e a saúde humana.

Appendix B: Complementary Materials for Manuscript 6

Multigroup CFA Goodness-of-fit Indices

Table C1

Vaccine Skepticism Scale

Invariance	χ2 (df)	RMSEA [90% CI]	CFI	TLI/NNFI	MFI
Configural	721.75 (216)***	.10 [.10, .12]	.88	.84	.85
Metric	920.87 (272)***	.11 [.10, .12]	.85	.84	.81
Scalar	1173.65 (328)***	.11 [.10, .12]	.80	.83	.76

Table C2

PSYDISC Scale

Invariance	χ2 (df)	RMSEA [90% CI]	CFI	TLI/NNFI	MFI
Configural	*The model is not admissible: lavaan WARNING: covariance matrix of latent variables is not positive definite in group 8; use lavInspect(fit, "cov.lv") to investigate.*				
Metric	1825.13 (868)***	.07 [.07, .08]	.90	.89	.74
Scalar	2171.06 (952)***	.08 [.08, .08]	.87	.87	.68

Table C3

Scientific Reasoning Scale

Invariance	χ2 (df)	RMSEA [90% CI]	CFI	TLI/NNFI	MFI
Configural	375.72 (352)	.02 [.00, .03]	.98	.98	.99
Metric	684.64 (422)***	.06 [.05, .06]	.79	.78	.92
Scalar	954.65 (492)***	.07 [.06, .08]	.63	.67	.86

Table C4

AOT-E

Invariance	χ2 (df)	RMSEA [90% CI]	CFI	TLI/NNFI	MFI

Configural	448.18 (160)***	.10 [.08, .10]	.89	.84	.91
Metric	747.01 (209)***	.11 [.11, .12]	.79	.77	.84
Scalar	952.71 (258)***	.12 [.11, .12]	.73	.76	.80

Table C5

Tightness x Looseness Scale

Invariance	χ2 (df)	RMSEA [90% CI]	CFI	TLI/NNFI	MFI
Configural	71.92 (72)	.00 [.00, .04]	1.00	1.00	1.00
Metric	149.35 (107)**	.04 [.03, .06]	.96	.96	.99
Scalar	422.14 (142)***	.1 [.09, .11]	.76	.80	.91

Experimental Stimuli

Introductory Text

There are currently **two commercially available vaccines against dengue fever**. Both are attenuated and prevent infection caused by the four serotypes of the virus: DENV-1, DENV-2, DENV-3 and DENV-4. **Dengvaxia®**, developed by Sanofi, is recommended for children from 6 years of age, adolescents and adults up to 45 years old. It is only recommended for people previously infected with one of the dengue viruses (seropositive). **QDenga®**, from the pharmaceutical company Takeda, is recommended for children from 4 years of age, adolescents and adults up to 60 years of age.* It is the first vaccine recommended for both people who have already had dengue and those who have never contracted the disease. As research advances, it is likely that **other dengue vaccines** will become available to the public in the near future.

*Recommendations may vary according to local regulations.

Source: Sociedade Brasileira de Imunizações (March/2024)

Illustration: Jornal da USP

Experimental Condition

Almost half of the world's population, **about 4 billion people**, live in areas with a risk of dengue. The global incidence of the disease has markedly increased over the past two decades, posing a **substantial public health challenge**. From 2000 to 2019, the World Health Organization (WHO) documented a ten-fold surge in reported cases worldwide **increasing from 500,000 to 5.2 million**. Dengue is transmitted by the bite of an infected mosquito and **affects infants, young children, and adults**. The infection may be asymptomatic, or it may present with symptoms ranging from a moderate fever to a disabling high fever, with severe headache, pain behind the eyes, muscle and joint pain, and rashes. The disease can evolve into severe dengue, characterized by shock, shortness of breath, severe bleeding and / or complications in the organs. There is no specific medicine to treat dengue. In 2023, **more than 5000 dengue-related deaths** were reported across the globe.

Sources: OMS, PAHO, and CDC

Illustration: Tua Saúde

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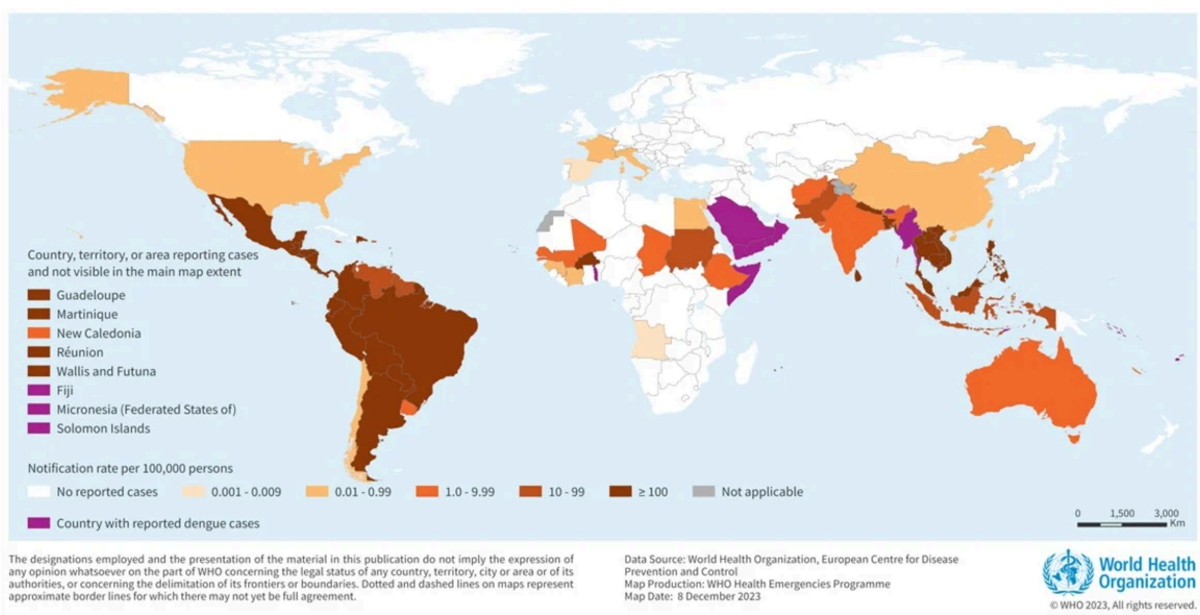
In *[country]*, nearly ***[number]*** **dengue cases** were recorded in the first *[number]* months of 2024.



[a red circle was placed around the country being discussed]

Source / Illustration: World Health Organization

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What aspects of personal life and society can be affected by dengue? Select all the alternatives you think are appropriate.

- ▢ Individual health
- ▢ Relationships
- ▢ Productivity
- ▢ Well-being
- ▢ Public health
- ▢ Economy
- ▢ Tourism

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ALL the aspects listed are potentially affected by dengue!

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We want to know your point of view on how dengue can affect you and your community. Write a brief paragraph below telling us your opinion.

Control Condition

The **Paris 2024 Olympic and Paralympic Games** were the biggest event ever organized in France. They took place between the months of July and September, when Paris became the center of the world – not just the world of sport, but much more. The Games were a **popular, multicultural festival** shared by many people around the planet and represented a new adventure for France, unlike anything the country had experienced before. As Paris is a unique city, the Games in the French capital represented a **complete spectacle** designed for athletes, spectators, and the television audience. Paris' iconic landmarks were transformed into sporting arenas that offered spectators an **unparalleled experience**, providing an excellent backdrop for sporting prowess. Paris 2024 wanted to show that the **fundamental values of sport** should be an important part of people's lives and prove that we can achieve excellence while championing sustainability.

Sources: Adapted from Olympics.com

Illustration: CNN Brasil

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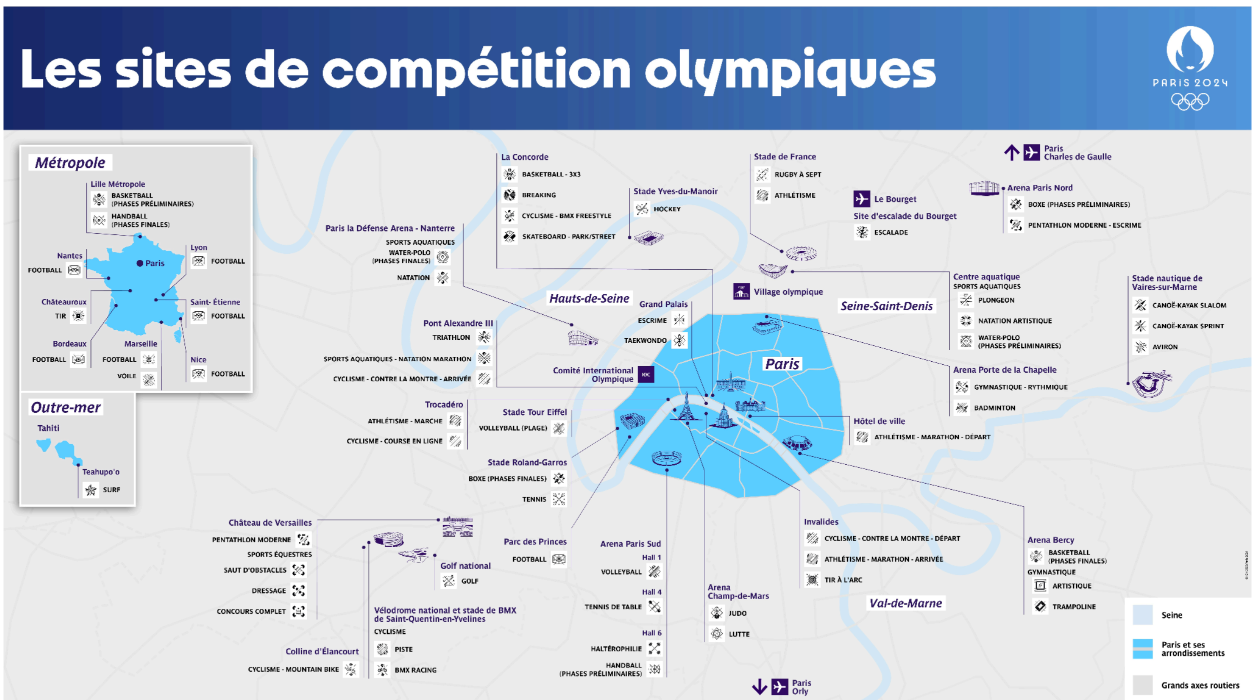
The Paris 2024 Olympic Games mobilized around **10,500 athletes** from **32 sports** across **35 competition venues**.



Source: Olympics.com

Illustration: Press Paris 2024

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Thinking about the host cities of the Olympics over the years, which aspects listed below could be affected by the Games? Select all the alternatives you deem appropriate.

- ▢ Business
- ▢ Tourism
- ▢ Environment
- ▢ Well-being of residents
- ▢ Health system
- ▢ Functioning of public services
- ▢ Safety
- ▢ Traffic

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ALL the aspects listed are potentially affected by the Olympic Games!

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We want to know your point of view on how the Olympic Games may affect the cities in which they take place. Write a brief paragraph below telling us your opinion.