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UNDERSTANDING VACCINE HESITANCY: THREE ESSAYS ON THE ROLE OF RISK, TRUST, AND COGNITIVE CHARACTERISTICS IN VACCINE ACCEPTANCE

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PREFACE

Discussing vaccine acceptance sometimes feels like walking on eggshells. The topics of vaccine refusal, novax movements, or the opinions of antivaxxers have been at the center of our lives for much of the last two years—and at the center of my personal life in the last four. Therefore, it is perfectly reasonable for us to have very strong feelings about it.

Luckily, this is not a thesis about anti-vaxxers or vaccine refusal, but about vaccine hesitancy. I spend part of the first chapter discussing why there should be a distinction between antivaxxers, people who outright refuse vaccines, and vaccine-hesitant individuals, and why this distinction is important on a substantive level. Vaccine-hesitant individuals are, in some way, all of us. (Almost) all of us were willing to take our COVID-19 vaccine jab as soon as possible. But did we not hear that voice in the back of our head, asking if this vaccine was "really" safe? Or whether we would have been that one-in-a-billion case where something goes wrong? And now that everybody seems to be an expert on vaccines, whom should we trust?

This thesis deals exactly with the feelings and ideas of millions of people who express legitimate concerns over a technological solution to a health threat, a solution that literally injects something into our bodies. It is understandably scary if you ask me.

If the reader believes people's concerns to be legitimate then this is exactly why we should discuss vaccine hesitancy. We might either label people who refuse vaccinations as "crazy" and move on with our lives or try to analyze peoples' beliefs, attitudes, and the underlying mechanisms with the highest ethical standards. In my opinion, therefore, it is very important that such a topic is discussed in an academic perspective that refrains from any unnecessary judgment.

Truth be told, this last statement is not necessarily true. This thesis and most academic work are oriented toward increasing vaccination uptake, and they analyze vaccine hesitancy to "cure" it. I started and finished this thesis believing what scientific research says is true, that vaccines are safe and effective. So, while I recognize peoples'

concerns as legitimate, I do not think there exists any space for a discussion of the objective benefits and limits of immunization. Finally, I must recognize that the global pandemic had clear, causal, effects on this thesis. First, the exponential growth of academic literature on the theme mechanically narrowed the focus of this thesis. Second, because I developed a somewhat selfish presumption of offering some cues to help solve peoples' doubts, contributing a little to the thought of going back to something resembling our "normal" lives. This is the perspective I had while writing this thesis, and in some ways, it is not a-judgmental at all.

Nevertheless, the more I read and worked on this topic, the more I realized that many issues in contemporary society are very nuanced, and understanding mechanisms implies sometimes trying to look at things with someone else's eyes, not our own ideas. Even though we try to find an average value that fits all, people are complex, and careful, and thoughtful, and it's hard to represent them truthfully without demeaning them. On a side note, when I realized how much even small choices about data or their analysis can affect results, I also learned that this complexity exists not only on a theoretical level, but also—perhaps even more so—on a technical one. To me, studying vaccine hesitancy and increasing vaccine acceptance starts perhaps from here, from abandoning the presumption that there's a right and wrong way for people to feel, that one model fits all, that I was studying a topic without prejudice.

So, in the end, independent from what this thesis accomplishes, I guess I have not found strong solutions, but still, I learned important lessons.

INTRODUCTION

Vaccine prophylaxis can undoubtedly be classified among the most important medical discoveries of the last century, and it has been recognized as a major instrument for public health success in the 20th century by worldwide health authorities and the scientific community (Andre et al., 2008, in Yaqub et al., 2014). Pathologies like measles, rubella, or poliomyelitis have seen their potential drastically reduced, and smallpox has been eradicated. The World Health Organization (WHO, 2013) estimates that each year, vaccinations prevent between two and three million deaths.

The idea behind how vaccines work is both simple and brilliant. A vaccine is a biological preparation that contains an agent that mimics a pathogen. When it is administered, it triggers the synthesis of proteins called antibodies. If the body encounters the real infection, our antibodies, together with T-lymphocytes and B-lymphocytes, can develop a strong immune response, protecting the body by "remembering" how to fight the pathogen they first encountered through vaccination. The WHO recommends up to 10 vaccines to be administered before the age of 18 months: BCG (tuberculosis), hepatitis B, polio, DTP (diphtheria, tetanus, and pertussis) Haemophilus influenzae type B, pneumococcal, rotavirus, MMR (measles, mumps, and rubella), and HPV (human papilloma virus). Typically, in high-income countries, additional vaccines are recommended, such as chicken pox and, to older adults, shingles, or seasonal influenza. Most vaccines require multiple doses, while the seasonal influenza vaccine requires a dose every year because of differences in the circulating pathogen. It goes without saying that one additional vaccine has been strongly recommended since last year, the one against the SARS-CoV-2 virus, responsible for the COVID-19 pandemic that erupted in 2020 and that still rages in several areas of the world.

When 80 % to 90 % of the population is vaccinated, an additional benefit develops. This is called herd immunity (Fine et al., 2011), a condition by which, because of the high rate of immunized individuals, the spread and reproduction of pathogens are slowed or stopped. Herd immunity is important both as an indirect measure to prevent the spread of diseases and to protect individuals who cannot be

vaccinated because of medical conditions. Furthermore, besides being effective, vaccines are also cost-effective. For example, the seasonal influenza vaccine provides savings up to $117 for each dose, by reducing sick care and missed days at work (Peasah et al., 2013). Because they provide these benefits, vaccination programs have always been a core activity of the health programs of governments and organizations concerned with improving people's health and wellbeing. A Global Vaccine Action Plan was created in 2011, led by the Bill & Melinda Gates Foundation, the WHO, the United Nations (UN), the United Nations Children's Fund (UNICEF), and 194 partner countries. Its strategic aim was to extend the "benefits of immunization to all people, regardless of where they are born, who they are, or where they live" (WHO, 2013, p. 5). The 10 years since the program began, 2011–2020, has been ambitiously declared "the decade of vaccines". In 2021, however, the decade of vaccines is over, and while much has been done, old challenges are re-emerging, and new ones are showing how complex it can be to reach and maintain consistent immunization rates.

Historians suggest that there has never been a golden age of vaccine acceptance (Hausman, 2019). Whether we trace vaccinations back to variolation, the practice of scraping matter from active pustules into the skin of someone uninfected, or to Edward Jenner's experiments on smallpox, vaccination always had its detractors. In the 1920s, the diphtheria vaccine needed strong persuasive measures to be accepted (Colgrove, 2007), and much can be read about the US government's frustration with parents not vaccinating their children against Polio in the 1960s (Oshinsky, 2006). Aided by strong media coverage, unsubstantiated safety scares have often been the origin of unstable vaccine coverage rates—including in more recent times. An alleged association between the hepatitis B vaccine and multiple sclerosis led to the suspension of the universal vaccination program in France in the 1990s (Dubé et al., 2013), although no evidence of this association has ever been found. The most famous example may be the unfortunately successful article by Andrew Wakefield and colleagues (1998), who claimed there was a positive association between gastrointestinal disorders, autism, and the MMR vaccine. Despite the academic community's inability to replicate the paper's results, the retraction of the article, the recognition of Wakefield's conduct as irresponsible and fraudulent, and his medical license being revoked, the fear of autism continues to be a frequently cited safety concern among parents (Brown et al., 2012).

These few examples—and many more could be mentioned—suggest that reaching a wide and stable vaccine coverage rate is an objective far more complex than expected.

A sub-optimal coverage rate might be more easily explained in countries where vaccines are not readily accessible or affordable, but the occurrence of this issue in high-income countries is puzzling. Research suggests that in contexts that more than others have seen vaccination's beneficial effects, opposition to vaccine prophylaxis has reemerged in the last decade. This has led to a significant increase in the number of individuals who refuse or delay vaccinations for themselves and their offspring despite their availability (Larson et al., 2014). This issue has been labeled "vaccine hesitancy" (The Strategic Advisory Group of Experts on Immunization [SAGE], 2014).

Toward the end of the last decade, the issue became particularly severe, so that it was included in WHO's 13th General Programme of Work for 2019–2023, right next to issues such as Ebola and the climate crisis. Vaccine hesitancy is considered a root cause of long-lasting insufficient coverage rates for common infectious diseases for which vaccines exist. When asked about difficulties implementing vaccination programs, all high-income countries reported such challenges (Larson, 2016). In addition, even though the rate of vaccinated individuals remains sustained, such national measures can hide clusters of under-vaccinated individuals. Indeed, most outbreaks of VPDs have been connected to limited geographical areas where vaccination rates fell below common threshold levels (Falagas and Zarkadoulia, 2008). If possible, this issue became more severe since the eruption of the COVID-19 pandemic. Despite scientists' ability to develop safe and effective vaccines in less than a year, vaccine hesitancy was soon identified as a major threat to the success of the vaccination campaign (Dubé and MacDonald, 2020; Peretti-Watel et al., 2020). Even though a large part of the population says it is willing to accept a COVID-19 vaccine, a consistent number of individuals express refusal or hesitancy (Freeman et al., 2020; Karlsson et al., 2021; Lazarus et al., 2020; Peretti-Watel et al., 2020). At the end of 2021, several high-income countries are experiencing difficulties in reaching sufficient vaccination rates against COVID-19, and these numbers appear not to be improving over time (Daly and Robinson, 2021).

Overall, even though vaccine prophylaxis has strong public support, it appears to be a challenging process, especially in high-income countries and in times where

vaccinations are a fundamental tool to ferry the world out of a pandemic. Given that vaccines are powerful instruments for improving people's health, their under-use in context, where availability and affordability are not constraints, is a controversial topic that should be addressed. In the last 10 years, a consistent stream of research has developed both from different academic perspectives and in support of policy development (Dubé et al., 2021). Vaccine hesitancy is, in fact, a multifaceted phenomenon that has been addressed in different fields of study, from epidemiology to behavioral economics, from social psychology to sociology. For obvious reasons, this empirical and theoretical effort received an off-the-scale impulse in the last year, where many publications from many areas contributed, in most cases, to the body of knowledge on the topic. The COVID-19 pandemic is a very specific example of vaccine hesitancy. However, on many levels, it responds to the same logic that characterizes vaccine hesitancy in a pre-pandemic world.

Naturally, each discipline addressed the issue from its own perspective. However, this created a generous but sometimes scattered body of research. Despite general agreement on concepts to be addressed, no clear consensus emerged on how to measure them or how to open a dialogue between liminal disciplines on the subject. From a public health perspective, a resourceful starting point is represented by several taxonomy models developed to identify predictors of vaccine hesitancy in the middle of the 2010s (MacDonald, 2015; Thomson, 2016). Apart from supply-side issues, these models stressed the centrality of individuals' perceptions in fostering vaccine acceptance. Specifically, different models identified the perceived risk of infectious diseases and perceived trust in vaccines and the vaccination process, the core concepts of individual vaccine acceptance. Interestingly, these elements are part of a much wider sociological debate about changes that technological developments and the transition to modernity generated in the way people perceive risk and trust expert systems. These same elements also stand at the center of half-a-century old models of health behavior, originally developed in the field of economics. Stemming from these models, many recent sociological essays highlighted the central role of these constructs as core determinants of vaccine hesitancy.

In this thesis, I start from these contributions, with the goal of focusing on, and further developing, how the perceptions of risk and trust can be recognized as relevant

elements to analyze vaccine hesitancy. Although this thesis comprises four independent chapters, a theoretical one and three empirical ones, each of them is tied to the others by the centrality of these concepts. At the same time, I also try to move beyond available contributions, framing the notions of risk and trust perception through the lenses of recent developments in cognitive sciences. I show how an interpretative framework based on the ways our cognition works can support the analysis of individuals' systems of beliefs and further enlighten the issue of vaccine hesitancy.

In the first chapter, I introduce the theme of vaccine hesitancy, starting from the very definition of the term, and I build a theoretical framework that includes more recent advancements in the academic literature. This chapter relies heavily on Beck's (1992) and Giddens' (1990, 1999) views of modern "reflexive" societies. The relevance of these authors' theoretical contributions will systematically return in each empirical chapter, reconnecting vaccine hesitancy to a broader sociological discourse. Moving toward the individual level, classic models of health behavior by Rogers (1975), Becker (1974), and Ajzen (1985) are discussed. Finally, through the contributions of Brekhus (2015), Cerulo (2010), DiMaggio (1997), and Zerubavel (1997), I introduce more recent development in cognitive sociology, aimed at discussing the relevance of cognitive processes in individual decision-making. I discuss whether it is possible to include such perspectives in the analysis of vaccine hesitancy, and I show how a theory of action informed by a cognitive perspective can help integrate existing empirical efforts.

In the second chapter, the first empirical one, I refer to such cognitive sociology approaches to test whether they could apply to the study of vaccine acceptance. I use data from an original survey of a sample of Italian citizens, and I investigate whether it is possible to identify subgroups in the population characterized by different worldviews based on different patterns of the relationship between perceived risk and trust measures. I analyze within-cluster characteristics, testing whether cognitive segmentation is connected to different average perceived risk and confidence levels. Furthermore, I investigate if cognitive segmentation also entails a mean of social stratification correlated with individuals' socio-demographic characteristics and if core predictors of vaccine hesitancy are articulated differently in each group. This chapter directly draws from recent cognitive approaches to show how, beyond

sociodemographic characteristics, peoples' segmentation might be drawn along invisible but surveyable cognitive characteristics, a source of variance that should be considered in vaccine acceptance research.

In the third chapter, I further explore how certain specific cognitive processes might be connected to a differential in vaccine acceptance. I introduce the notions of intuitive and analytic cognition, suggesting that different individuals lean toward one of these two cognitive "styles" with varying degrees of strength and that this might influence day-to-day behavior, perceptions, and decisions. I then investigate whether cognitive styles have a direct association with vaccine hesitancy and an indirect one through various measures of perceived risk of infectious diseases. I further investigate the relative magnitude of these associations, and I underline the relevance of specific measures of risk perception, such as emotional and affective concerns versus probabilistic judgments. In this chapter, I underline the possibility of empirically identifying individuals based on specific cognitive characteristics that could indeed be correlated with vaccine acceptance. Furthermore, I highlight individuals' qualitatively complex perceptions of risk, and I suggest how enhancing the attention to cognitive processes and affective concerns might be a key to addressing vaccine hesitancy.

Finally, in the fourth chapter, I investigate vaccine hesitancy during the COVID-19 pandemic, exploiting rich longitudinal comparative data to test whether perceived risk and trust are relevant predictors of vaccine acceptance, even in this very peculiar circumstance. I analyze the association between risk perceptions, trust, and willingness to be vaccinated against COVID-19 at three different levels. First, I test the existence of a cross-sectional association between individual levels. Second, cross-sectionally at the country level, I investigate whether there might be longstanding contextual characteristics that affect vaccine acceptance over the course of the pandemic. Finally, I analyze this issue longitudinally, exploring if a within-country variation in perceived risk and trust is correlated with a variation in vaccine acceptance. In this chapter, I underline the importance of disentangling the main relationships of this thesis at different levels of analysis, and I stress that vaccine acceptance is a multifaced topic that could involve issues far beyond its own boundaries.

Overall, this thesis tries to address, with respect and attention, a controversial topic that in the last year has been, whether we liked it or not, at the center of our

everyday lives. I try to do so by, on one hand, focusing on a specific sub-dimension of all the elements of vaccine acceptance, and on the other hand by expanding the interpretative framework referring to the most recent contributions, hoping to provide a complete and hopefully interesting analysis of this issue.

CHAPTER I

A FRAMEWORK FOR VACCINE HESITANCY

1. Defining Vaccine Hesitancy

Vaccine hesitancy is a term that once appeared mostly in academic contributions. However, with the COVID-19 pandemic, the concept has become more familiar to anyone who listened to the news about setbacks in vaccination programs. Despite its wide use, the definition of vaccine hesitancy has been quite ambiguous, delineating a set of wide and heterogeneous elements involved with vaccine acceptance. To embrace different individuals, groups, situations, and many explanatory factors, definitions were quite ample, resembling more a catchall category than a concept. For example, vaccine hesitancy has been described as a set of beliefs (Opel et al., 2011), attitudes (Yaqub et al., 2014), or behaviors (Gust et al., 2005), or even a combination of them.

In 2012, the WHO began investigating vaccine skepticism more deeply as a determinant of declining coverage rates in high-income countries. It constituted a work group with the scope of harmonizing definitions and conceptual models of vaccine acceptance. SAGE (2014) first elaborated what has become widely used as the definition of vaccine hesitancy, the "delay or refusal of vaccines despite availability of vaccine services" (p. 7). Unfortunately, knowing this definition does not tell us in more pragmatic terms "what" vaccine hesitancy is, and how it differs from other ways of engaging with vaccine acceptance. To define the core concept of this work in more substantive terms, it might be easier to start from what vaccine hesitancy is not.

Vaccine hesitancy is not "vaccine refusal" or "vaccine opposition." Although often used interchangeably, the latter terms indicate two dichotomous states, acceptance and refusal, anti-vaccine versus pro-vaccine individuals. More recent academic essays have underlined the importance of moving away from these

definitions (Kumar et al., 2016), embracing the more nuanced and multifaced term of "vaccine hesitancy." The last 10 years of research on the issue have clearly shown how the idea of individuals hesitating to receive a vaccine can be far more complicated than a dualistic view of acceptance and refusal. In addition, from a public policy perspective, the use of more neutral wording followed the idea that to increase vaccine acceptance, it might be important to move away from words that could divide or polarize public opinion (Dubé et al., 2021).

Second, vaccine hesitancy is not an anti-vaccine movement or a form of citizen activism. Vaccine hesitancy does not represent, in fact, the activity of committed individuals who see themselves as part of an anti-vaccine movement. This latter term usually designates a wide variety of groups who actively invest time and resources in publicly voicing their concerns about vaccines and vaccinations, possibly looking forward to a policy change regarding immunization programs or mandates. Within the same semantic area, it is also possible to include different types of anti-vaccine groups that advocate for different vaccine policies, such as political parties. These groups do not have vaccines as a major focus. Rather, they embrace this issue as a part of a broader effort related to political ideologies or interests, including vaccines in their portfolio as a marginal component of a broader cause (Dubé et al., 2021). On the more radical side, it is also possible to trace groups that advocate for alleged victims of vaccines, or individuals who support beliefs in pseudo-sciences, supernatural phenomena, and conspiracy theories (Aarnio and Lindeman, 2005; Browne et al., 2014; Genovese, 2005; Gervais and Norenzayan, 2012; Pennycook et al., 2012).

Contrary to these groups, many vaccine-hesitant individuals do not define themselves as "novax" or "antivax". They do not take part in any kind of action against vaccines or vaccinations, and they do not actively propose any policy change (Dubé et al., 2021). Refusing vaccines does not automatically make an individual an antivaccination activist. It might certainly be the case that some vaccine-hesitant individuals do participate in movements against vaccine prophylaxis, but the concept of vaccine hesitancy overlaps anti-vaccine movements only marginally.

What is vaccine hesitancy, then?

Vaccine hesitancy represents legitimate concerns about an issue involving people's health (Dubé et al., 2021). It has been used in recent literature to indicate those

situations where people have doubts or apprehensions regarding vaccinations. Vaccine hesitancy does not necessarily refer to actual uptake: in many regions, vaccine uptake might be high, for example, because of mandatory policies, yet hiding a considerable share of vaccine-hesitant individuals (Dubé et al., 2021). The concept should therefore be used in those situations where individuals have doubts and insecurities about the opportunity to be vaccinated.

For these reasons, the idea of vaccine hesitancy represents a shift from the dualistic views of vaccine refusal or opposition and anti-vaccine activism. Instead, it indicates a perspective including attitudes and beliefs along a continuum ranging from active demand for vaccines to complete refusal, and vaccine-hesitant individuals might express several heterogeneous positions between these two extremes. On some levels, it might also be misleading to consider only a bi-dimensional continuum. Vaccine hesitancy might represent a decision-making process among genuinely uncommitted individuals, with no definite opinions or little knowledge and interest in vaccines, who randomly forget or delay some vaccines on one hand and informed, very interested, and committed individuals on the other (Peretti-Watel et al., 2015). Saying that vaccine-hesitant individuals are neither for nor against vaccination does not imply that they endorse intermediate attitudes regarding vaccination in general. For example, individual resistance might strongly depend on the type of vaccine, since people may accept one vaccine, decline a second one, and be suspicious about a third. For these reasons, the concept of vaccine hesitancy embraces a heterogeneous ensemble of ideas, attitudes, beliefs, and behaviors in a range of possible positions, where individuals are united by sharing "varying degrees and motives of indecision" (Peretti-Watel et al., 2015, p. 3).

To understand the reasons and processes leading to vaccine hesitancy, and what micro and macro characteristics are associated with it, several theoretical and empirical contributions have been made in recent years, aimed at identifying a recurring set of elements that could affect vaccine acceptance. As the wide definition of the term might suggest, researches empirically showed that vaccine hesitancy is a complex issue standing at the intersection of individual decisions and societal needs, within the historical, political, and socio-cultural context in which vaccination occurs (Brunson, 2013; Dubé and MacDonald, 2020; Dubé et al., 2013; Dubé et al., 2021). Fortunately,

recent contributions from different fields have made it possible to identify a recurring set of elements that have been linked to limits of vaccination coverage and correlated with vaccine hesitancy. Indeed, empirical investigations showed that

> similar determinants of vaccination acceptance or refusal emerged including contextual determinants (broad influences such as communication and media, religious values, social norms, health policies, etc.); organizational determinants (or factors related to the accessibility and quality of vaccination services), and individual determinants (such as ... knowledge, attitudes and beliefs or sociodemographic characteristics) (Dubé et al., 2015, pp. 99-100).

In this chapter, I first describe two of the most widely used theoretical models that developed a schematic taxonomy of elements of vaccine acceptance. I then focus on the elements at the core of this thesis, concerned with individuals' characteristics and the way risk and trust are perceived. I show how well-established theoretical models of health behavior can frame this issue, and I highlight their limits. Finally, I illustrate how recent developments in cognitive sciences can make substantial contributions to the analysis of systems of beliefs and whether they could apply to vaccine hesitancy.

2. The 5 A's and 3 C's: A Taxonomy of Vaccine Hesitancy Determinants

Vaccines reach their potential only when individuals behave according to vaccination recommendations. However, as previously argued, vaccination is the result of a complex set of beliefs, behaviors, and attitudes in a wide interlocking system of people, funding, policies, contexts, and providers (Brewer et al., 2017). It might be sufficient to imagine that deciding to be vaccinated can be a very different experience for a parent in a developing country, who perhaps must walk hours to the closest city, and for a European citizen who can schedule an appointment online and receive a shot in a drive-through. It is therefore important to underline that vaccine acceptance is part of a system that includes a variety of individual and contextual elements.

To identify and partially systematize these determinants, two models have been particularly useful. They are the 5 A's (Thomson et al., 2016) and the 3 C's (Mac Donald et al., 2015) models of vaccine acceptance. The two models have similar dimensions, and they try to describe the more commonly agreed-upon determinants of vaccine uptake, the lack thereof could potentially lead to vaccine hesitancy. Although the focus of this thesis is limited to a specific subset of these elements, considering the wider picture might help reveal the complexity of the issue to be analyzed and more pragmatically illustrate the heterogeneity mentioned above.

The 5 A's model (Thomson et al., 2016) has been elaborated under a public health perspective to offer a practical taxonomy of vaccine uptake determinants. The authors aimed to diagnose the possible causes of vaccine hesitancy. The model enlightens five important dimensions: Access, Affordability, Awareness, Acceptance, and Activation.

1) **Access** represents the ability to reach or be reached by vaccines and vaccination programs. It underlines the importance of the geographical context, such as the place of birth, the location of vaccination centers, the frequency of contacts with healthcare systems, and the general convenience of access to vaccination facilities. Indeed, empirical studies have shown that closer geographical proximity to healthcare facilities translates into a higher likelihood of infants being vaccinated, especially in developing contexts (Antai, 2009; Halliday et al., 2003; Olusanya, 2010). Higher vaccination rates are consistently found in places where vaccines are routinely offered such as in workplaces, schools, and universities (Ambrose and Sifakis, 2009; Crocker et al., 2012; Halliday et al., 2003), where elderly individuals have more frequent contact with healthcare facilities, and where geographical inconveniences to reach these facilities are reduced. (Cox et al., 2012).
2) **Affordability** represents the relationship between vaccination costs, both financial and non-financial, and acceptance. Empirical studies have found positive correlations between economic incentives and vaccine uptake, such as between state-funded influenza vaccine vouchers and acceptance rates (Blank et al., 2012). Non-financial costs also should be mentioned, such as the time needed to become vaccinated. Lack of available time is the most cited non-

financial deterrent to vaccine uptake, especially for parents with young children. (Blank et al., 2012).

3) **Awareness** represents individuals' knowledge about vaccines and the vaccination schedule. Research has shown that individuals with more knowledge about the characteristics and benefits of immunization are more willing to be vaccinated. Furthermore, as Thomson et al. (2016) reported, one of the most important reasons for not receiving the influenza vaccine in the UK was, simply put, not having enough information about its benefits.
4) **Acceptance** is, for the scope of this thesis, the most relevant component of the 5A's model. It represents a wide range of individual beliefs involving a) the characteristics of the vaccines, b) the perceptions of the risk of disease, c) individual characteristics, and d) the social context.
    a) Vaccines' characteristics involve perceptions of safety and efficacy and concerns about possible side effects. The authors underline the positive relationship between perceptions of a vaccine's safety and acceptance. For example, believing a vaccine is "safe and effective" might generate a five-fold increase in willingness to be vaccinated (Galarce et al., 2011).
    b) The perception of VPDs as more dangerous is associated with a higher willingness to be vaccinated. Perceived risks can be variously articulated, but they generally involve dimensions such as the severity of the disease, the likelihood of contagion, and the perceived vulnerability to the disease (Brewer et al., 2017).
    c) Individual characteristics involve a large series of beliefs about health practices, trust in institutions, professional policies, the role of emotions, and cognitive biases. Individual interests in alternative medicine, emotional judgments, and cognitive biases have been found to be correlated with vaccine refusal (Attwell et al., 2018; Weinstein et al., 2007). Similarly, higher trust in government authorities, health professionals, and vaccine policies are correlated with higher vaccine acceptance (Brewer et al., 2017; Larson et al., 2015).

d) Finally, acceptance is context-dependent, influenced by characteristics such as generalized levels of social responsibility and the influence of peers.

5) **Activation** refers to external actions that might nudge individuals toward vaccine uptake. For example, various reminder systems such as leaflets at parents' meetings, announcements to healthcare workers in nursing homes, or posters in schools have been found to increase vaccine acceptance (Halliday et al., 2003; Jackson et al., 2011).

The 5A's model is useful for highlighting the variety of determinants of acceptance. It includes a wide variety of elements, and it is flexible enough to be applied to different situations involving vaccine acceptance. It underlines the simultaneous importance of individual and contextual elements, and it shows that being vaccinated is the result of a complex series of conditions and evaluations that must be fulfilled.

A second key model in vaccine hesitancy research is the "3 C's model of vaccine acceptance" (MacDonald et al., 2015). This model reframes and re-organizes in three simple and focused points all the elements illustrated in Thomson's (2016) model. It has become the most used and cited model of the determinants of vaccine acceptance.

This model highlights three dimensions: Convenience, Complacency, and Confidence.

1) **Convenience** represents several contextual factors involving the physical availability and affordability of vaccines. Geographical accessibility, price, the ability to pay, and the ability to understand the functioning of vaccines and vaccination services are baseline determinants of vaccine acceptance. In addition, the real or perceived quality of the vaccination services and the convenience of time, place, and cultural context of administration are found to be of utmost importance in determining vaccine acceptance and overall coverage, especially in less advantaged contexts.
2) **Complacency** refers to the perception of the potential harmfulness of vaccine-preventable diseases (VPDs). Complacency exists when the perceived risk of

VPDs is low and vaccinations are not deemed necessary. It is interesting to note that vaccinations themselves might be a major cause of complacency. The effectiveness of vaccination programs has made several VPDs uncommon, reducing individuals' awareness of the risks of those diseases (Larson et al., 2015).

3) **Confidence** represents the trust individuals have in the safety and effectiveness of a vaccine, in the scientific community, and in the system that developed them, from manufacturing companies to policy-makers deciding vaccination schedules. Confidence is one of the most important and at the same time debated concepts in vaccine hesitancy research. Later, I discuss how this definition changed over time to include different elements. Nevertheless, despite different interpretations of the specific items that constitute the concept of confidence, it generally represents the idea that "vaccines work, are safe, and are a part of a trustworthy medical system" (Brewer, 2017, p. 160).

The 3 C's model of vaccine hesitancy highlights, therefore, three fundamental components of vaccine acceptance: the importance of accessibility and affordability of vaccines, the perceived risk of VPDs and the level of trust individuals place in vaccines and the vaccination process. At the individual level, the latter two elements reframe in a more precise and systematic way what the 5 A's labeled as acceptance: the wide set of beliefs and attitudes identified as predictors of vaccine acceptance.

The 3 C's model has been deductively elaborated in the field of public health—Noni MacDonald is a renowned Canadian pediatrician—from the meta-analysis of empirical results on determinants of vaccine hesitancy with a clear policy-oriented goal in mind: identifying causes of vaccine hesitancy. This model is, in the first instance, a pragmatic tool to address a public health issue. Nonetheless, it is interesting to note that the key elements of this model, perceived risk of VPDs and trust in a valid coping response, are core elements of a wider, 30-year-long sociological discourse about the perception of technological advances in modern societies, and how this change influences and is influenced by individuals' perceptions of risk and trust. This theoretical contribution comes mainly from the work of Ulrich Beck (1992) and Anthony Giddens (1990, 1999) and their interpretation of the passage from linear

modernity to reflexive modernization. Their view of western contemporary societies, transitioning from wealth production and distribution, to risk production and distribution, constitutes an important theoretical framework that highlights the issues surrounding technological solutions such as vaccine prophylaxis. Perhaps naively, the 3 C's model has been able to identify relevant components of a modern challenge of utmost sociological relevance.

In the following paragraphs, I focus on how individual-level vaccine acceptance is part of a broader discourse on the relevance of perceived risk and trust in contemporary societies, and how it can be placed in a wider sociological framework. Later, I discuss how models of health behaviors have been used to identify relevant predictors of health-related choices, and how they can be used to analyze vaccine hesitancy. Finally, after describing the limits of these models, I discuss how recent developments in cognitive sciences could be useful for analyzing individuals' beliefs related to the issue under investigation.

3. A Modern Issue

Vaccine hesitancy can be seen as a specific case of an increasingly common flow, where the river of contemporary society appears to be moving. It is the result—perhaps a transitory one—of a long-term process, where individuals started "coming to terms with the limits and contradictions of the modern era" (Giddens, 1999, p. 6), and it shares its etiology with several other issues. Vaccine hesitancy "and other hot-button issues such as pandemics, GMO foods, [and] stem-cell research raised the fears and consciences of Western industrial nations as nuclear radiation, chemical wastes, asbestos, and lead poisoning drove fear in the 1970s–1980s, and famine and war before that" (Price and Peterson, 2016, p. 59). Critical reflection on hot-button topics appears to be a peculiarity of modernity.

Beck (1992) maintained that modernity is characterized by two main phenomena: the marginalization of basic needs and the production of risks. Pre-modern societies had to face the challenge of covering the elemental demands of individuals while controlling inequalities generated by different distributions of wealth. In societies of material shortage—as Beck called them—the fight between the threat of invisible

risks versus visible material misery led to an obvious outcome: overlooking the perverse effects of production in the name of satisfying basic needs. In time, the constantly increasing capabilities of material production and exponential technological development allowed us to exit times of scarcity. Wealth-creation allowed—on average—for the satisfaction of basic needs such as the availability of goods, health services, safe hygienic conditions, and the stable protections of laws and the welfare state (Beck, 1992). In this frame, problems and conflicts over resources distribution overlapped with problems arising from production: the creation, definition, and distribution of risks determined by technological development.

The shift from wealth distribution to risk distribution characterized, according to the author, western contemporary societies, mainly because higher living conditions went hand in hand with the transformation of risks by technological development. "Manufactured uncertainties" produced in the modern era—direct but unintended consequences of scientific and technological development—have an unprecedented disruptive potential and a new ability to travel across time and space. One vivid, well-known example of modern risk is the Chernobyl disaster that, in 1986, showed the disruptive power of technological development. Its effects have been experienced thousands of miles away, across nations and continents, traveling across space with no boundaries. And the Pripyat area continues to be a reminder of how this kind of risk can also travel through time, being a burden for generations. Other risks can be less catastrophic in the short term, but even more tragic and insidious in the long run, such as the undeniable—and scientifically sustained—climate crisis.

Manufactured uncertainties in the modern world seem to have an additional peculiarity: they do not necessarily answer to classic dynamics of social stratification. Wealth is unequally distributed in modern societies, and so are risks. Different geographic areas have different exposure to risk, and in the same area, the same risk—perhaps a polluting substance—might have disparate effects on different individuals, depending on their gender, eating habits, type of work, level of information, level of education, and other characteristics. At the same time, risks also answer to a different logic, ignoring classical social stratification. In many cases, everyone is exposed to the same level of risk, with no possibility of choice or protection. We might drink from different glasses, but the water in them comes from the same water supply. Radiation

hits both the rich and the poor, the educated and the uneducated. According to this view, "risks don't do any class distinction" (Giddens, 1990, p. 125).

The thesis of Beck (1992) and to a minor extent Giddens (1990) can be seen as revolving around this statement: technological change created a level of wealth sufficient to ferry western developed countries out of hardship, but it also generated unpredicted and more severe consequences. If, in the name of the war against a tangible scarcity, individuals previously accepted a certain number of collateral effects, when this driver ceases to be of primary importance, the very legitimating premises of modernization fail (Beck, 1992). Where the risk of obesity replaces hunger, the ongoing process of modernization loses its justifying roots.

In such a framework, it could be quite hard to make a case for vaccine hesitancy, because Beck's (1992) theoretical approach, written almost 30 years ago, refers to risks that can hardly be juxtaposed to vaccination. The climate crisis and asbestos have been empirically proven to be hazardous. On the contrary, vaccination has repeatedly been shown to be perfectly safe. Not a single peer-reviewed academic publication has been able to link vaccination to any kind of (major) collateral effect.

This last statement could nonetheless not be convincing for Beck himself. In several passages, he maintained what seems to be a very radical view of scientific work, up to defining scientists' practices as "fraudulent" (p. 81). He is particularly keen on underlining how the burden of causal proof has the consequence of ignoring the potentially hazardous effects of technological development. Innocent until proven guilty, according to Beck, is a practice that systematically underestimates dangerous risks. Even more harshly, Beck implied that scientists might look for causal relations and insist on the methodological and theoretical quality of their work to protect their careers and material possessions, since the hand that produces risks is the same one that feeds them. In a very strong and debatable paragraph, Beck described parents looking at their children coughing from an unrecognized sickness. Infants' faces have "voices, eyes and tears" (p. 80), bumping into a wall of correlations. For the sake of honesty, it must be recognized that in this overly pietist account might lie the nature of an issue like vaccine hesitancy. For parents whose children are affected by a mysterious sickness, probability is not a true concern, but the personal meaning of the whole experience is. If Beck was somehow anti-science in this part, he gave us a hint of where

the roots of vaccine hesitancy are. Even though some incidents are scientifically irrelevant, they may have a true, personal, and experiential meaning. And even if the risk posed by vaccinations has not increased over time—in fact, it has declined—the perception of risk may have changed radically.

Following this argument, the issue is not risk itself, but the more complex individual perception of risk. In this way, not in terms of objective risk, but in terms of perceived risk, vaccine hesitancy is a very clear case of unintended consequences of technological development in modern societies. Risks can be objective, as earthquakes, but also subjectively perceived (Price and Peterson, 2016), or socially constructed (Rosa et al., 2015). The modernity described by Beck (1992) subsumed a period where rapid technological development has been accompanied by the blooming of related anxieties—independently from their real nature. In this form, Beck's view of the transition from linear modernization to reflexive modernization can be supported, where he explicitly stated that "to the extent that these conditions occur, one historical type of thinking and acting is relativized or overridden by another" (Beck et al., 1994, p. 19).

The theory of reflexive modernization suggests that individuals who are more educated and living in high-income countries should be more critical toward vaccination uptake. These individuals should be more able to approach medical science reflexively and conclude that science, other than not being able to protect individuals completely, is the cause of increased risk. Even before Beck's work, Inglehart (1977) showed that in countries with access to technology and material comfort, individuals might have moved past the benefits that science has brought to their lives. These individuals may show less confidence in what science might add in the future and be wary of the negative unintended consequences of scientific and technological development. Consequently, reflexive modernization in developed high-income countries "translates into more debate on science and technology, more information-seeking about scientific solutions, and ultimately into a lesser inclination to support vaccinations, as they may be deemed unsafe and not entirely without risks" (Makarovs et al., 2017, p. 2).

Along this same line, Giddens (1999) does not see modern societies as more hazardous, but "increasingly occupied with the future (and also with safety), which

generates the notion of risk" (p. 3). According to Giddens, people in contemporary western developed societies are encouraged to exert ever more control over their lives and assess risks and benefits to make their future secure. With so much under control, individuals start to focus on minimizing existing risks (Price and Peterson, 2016). Tradition is no longer used as a guideline principle; no part of nature has not been affected by human activity, and risks are not seen as inevitable anymore. This is especially true concerning health, which has become a super value: "the rhetoric of self-empowerment conveyed by health promotion praises ... individuals who exercise control over their own behavior" (Gilkey et al., 2013, in Price and Peterson, 2016, p. 5). "Vaccination-related issues have not escaped from these structural features of contemporary societies, especially the crisis of legitimacy faced by science, expertise and medical authorities" (Peretti-Watel et al., 2015, p. 5).

Many aspects of our lives depend on systems that are beyond our understanding, making individuals unable to evaluate an increasing number of risks independently. As modern societies are characterized by growing specialization, trust becomes increasingly important, and this does not happen without difficulties. People are required to trust individuals and systems that they do not fully understand, in a sort of leap of faith (Giddens, 1999). In a very specialized environment, where individuals must delegate the knowledge on many fields of everyday life, fear of unintended consequences results in a lack of trust not only in a product but also in the science and technology that stands behind it. In a way, science is the first victim of its own success. The provisional nature of scientific knowledge, and its openness to confutation and revision, makes science its own biggest critic. In this scenario of gray areas of scientific research, the fundamental self-criticism, the open declarations of ignorance, and the lack of permanent results might weaken the trust of lay people in expert systems. It is in this milieu that simmers a different kind of knowledge. "Ignorance always provides grounds for skepticism" (Giddens, 1990, p. 91). Orthodox science is increasingly forced to compete with other forms of knowledge, and "the claim to universal legitimacy of science becomes much more disputed than before" (Beck et al., 1994, p. 186). "Sciences, quasi-sciences and pseudo-sciences become competing sources that produce a flood of over-specialized, hypercomplex and contradictory findings" (Peretti-Watel et al., 2015, p. 5). Where science is necessary but not sufficient anymore,

we can find the most varied beliefs, having their own intrinsic truth, independent from scientific knowledge. These new "alchemists" are immune to the critique of science, and they found their truth in a field that strongly interacts with science, using science to reject its premises (Beck, 1992, p. 237).

If only Beck could see where we stand today, he would probably change his mind on the role of academic research.

The theory of reflexive modernization constitutes a plausible framework for discourse on vaccine hesitancy. In facing the issue of the creation and distribution of wealth, from both the production and consumer sides, the manufactured uncertainties of scientific development have been overlooked to achieve what seemed a more fundamental goal. Once this driver ceased to exist, individuals became less prone to accept scientific development's collateral effects sustaining wealth production. Modernity becomes "reflexive," meaning that the modernization process—especially in terms of technological advancement—is a subject of scrutiny and reflection, together with the individuals, institutions, and scientific principles that take part in this process. Individuals start to focus on minimizing existing risks, but in an extremely specialized society, where ignorance of the vast majority of human knowledge is the unavoidable norm, this process might have perverse effects. Ignorance can turn into skepticism of the very premises of scientific research and leave room for unscientific beliefs that are immune to the strict rules of scientific knowledge. Vaccine hesitancy seems almost a textbook case of this process, where scientific agreement on the lack of collateral effects nonetheless left room for the development of strong skepticism about vaccines and a drop in confidence in the product, the producers, and distributors of vaccines (Larson et al., 2016).

In this paragraph, I have shown that the way people perceive risk and whether they trust experts' knowledge is theoretically relevant to an informed analysis of vaccine acceptance, empirically recognized by recent models of vaccine hesitancy, and part of a sociological discussion about the consequences of technological transformations. In the following section, with the help of relevant models of health behavior, I aim to systematize surveyable dimensions of perceived risk and trust that can be empirically used to analyze vaccine hesitancy. I illustrate the most relevant

models, highlighting their potential and limits, and how recent developments in the study of cognition might add important elements to the analysis of the issue at stake.

4. Theories of Individual Health Behavior

Substantial research has empirically explored how preferences and attitudes can influence peoples' decision to get vaccinated. In the general framework portrayed above, one main area of research is on how people look at infectious diseases—the risks or hazards—and the second area of investigation is on how people evaluate coping responses, which includes various dimensions of trust. This distinction and the causal ordering of how thoughts and feelings motivate people to get vaccinated is similar in different theories frequently used to analyze vaccine uptake. These models suggest that people make decisions based on the potential consequences, analyzing the potential outcomes of each possible decision and deciding for the best possible future scenario. The common characteristic of these models—and at the same time a significant limitation—is that they consider individuals as rational actors, pursuing the best outcome for themselves and maximizing expected utility.

In his 1974 work, Becker developed a theory, the "health belief model and sick role behavior", more easily called the "health-belief model". It was directed at understanding the "activity undertaken by those who consider themselves ill, for the purpose of getting well" (Kasl and Cobb, 1966, p. 531). The explicit intention was to develop a model that could explain a patient's behavior without relying on previous "medical" models. One year later, Rogers (1975) postulated a theory to investigate "the effects of fear appeals upon attitude change" called "protection motivation theory". The author intended to classify a limited series of variables in fear appeals and "the cognitive process postulated to mediate the acceptance of a communicator recommendation" (p. 95). These two theories have similar assumptions, aiming at understanding a health-related behavior in a hazardous situation through a limited set of variables. Becker's and Rogers's models are classic contributions, starting points for channeling behavioral and social sciences into explaining health-related decisions and intentions directly affected by individuals' perceptions.

The key elements of both models are, in the context of vaccination intentions, the perceptions of the risks of an infectious agent and the availability of a safe and effective coping response.

According to health behavior models, risk perceptions can be decomposed into two main explanatory variables:

- Perceived susceptibility (Becker, 1974) is the conditional probability that an event, such as an infectious disease, may occur, provided there is no adaptation behavior (Rogers, 1975) measuring the individual's perceived exposure probability;
- Perceived noxiousness represents the perceived magnitude of an adverse event, such as a VPD. Becker (1974) argued that "even when an individual recognizes personal susceptibility, action will not occur unless he or she also believes that becoming ill would bring serious organic and/or social repercussions" (Becker, 1974, p. 411).

Brewer et al. (2017) suggested renaming the first risk dimension the "perceived likelihood" of a person becoming infected, and the second one the "perceived severity" of the infection. Extensive empirical essays have shown both these risk perceptions to be positively associated with higher vaccine acceptance (Brewer et al., 2016; Oster, 2018; Weinstein, 2007).

It must be noted that more recent systematization has shown that people have a broader, more complex understanding of risk, involving emotional and affective factors (Slovich et al., 2005; Weinstein et al., 2007). People might in fact base their judgments on an activity or technology—such as vaccines—not only on what they think about it but also on the way they feel about it. This includes dimensions such as anxiety, worry, and fear. In addition, since individuals might be poor judges of probabilities (Tversky and Kahneman, 1974), in potentially risky scenarios, people might fail to calculate objective risks (Anderson et al., 2015) and be driven by an affective orientation toward the option that feels the safest to them. For this reason, in addition to the two dimensions indicated by classic models of health behavior, two additional dimensions should be considered. The first is the perceived susceptibility to disease that emphasizes a "constitutional" property of individuals, their perceived

general vulnerability to VPDs. The second is the perceived "feeling at risk", highlighting the emotional component of risk perception (Weinstein et al., 2007).

The second key component of health-behavior models is the perceived efficacy of a protective response, an element recurring in both Rogers's (1975) and Becker's (1974) theories. Applied to vaccination, in recent years several authors have interpreted the perception of a viable coping response with the term confidence (Larson et al., 2016). Confidence is an umbrella term that includes beliefs that "vaccines work, are safe, and a part of a trustworthy medical system" (Brewer, 2017, p. 160). It has been empirically recognized to be one of the main determinants of vaccine acceptance (Dubé et al., 2021). Confidence is a faceted construct that overlaps with the perception of trust in vaccines, trust in delivering institutions, and a broader conviction about the healthcare system and science. There is little consensus about components of confidence, even though it seems to be a major construct for understanding vaccine uptake behavior. Since it is quite a wide term, open to multiple interpretations, and given the importance of the construct, many efforts have been made recently to find a shared definition, mainly to measure the concept. The U.S. National Vaccine Advisory Committee (2014) defined confidence as "(1) the trust that parents or health care providers have in immunizations ... (2) in the providers(s) who administer(s) vaccines, and (3) in the processes that lead to vaccine licensure and the recommended vaccination schedule" (p. 119). Larson et al. (2015) defined confidence as "trust in the vaccine (the product), trust in the vaccinator or other health professional (the provider), and trust in those who make the decisions about vaccine provision (the policymaker)" (p. 2). Several indexes and scales have been proposed for measuring confidence, such as the "Carolina HPV Immunization Belief and Attitude Scale" (McRee et al., 2010) and the "Vaccination Confidence Scale" (Gilkey et al., 2014). In this context, I consider confidence to be a property of individuals on three different aspects that follow the systematization by Larson et al. (2015): trust in the product, the providers, and the process.

As for risk perception, confidence in vaccines is generally associated with an increase in vaccine uptake (Schmid et al., 2017). It has shown noteworthy contextual variability, with the European region displaying significantly lower confidence than other areas of the world (Larson et al., 2016). Confidence plays a fundamental role in

supporting individuals' decision to be vaccinated (Yaqub et al., 2013), while distrust in pharmaceutical companies, physicians, government, and researchers has been repeatedly connected with vaccine hesitancy (Majid and Ahmad, 2020). Hesitant individuals might doubt that pharmaceutical companies push a profit-oriented pro-vaccine agenda (Dubé et al., 2016), that physicians might obtain financial incentives to support vaccination (Attwell et al., 2017; Blaisdell et al., 2016; Vandenberg and Kulig, 2015), that governments could push policy interventions to favor vaccine uptake because of their ties with pharmaceutical companies (Helps et al., 2018), or that researchers could have withheld research results unfavorable to a pro-vaccine agenda (Attwell et al., 2017).

Roger's (1975) and Becker's (1974) models help define a theoretical approach involving a limited number of dimensions to empirically analyze vaccine hesitancy. However, as I mentioned in the introductory chapter, being vaccine-hesitant is a phase of concern before the actual vaccination behavior, whereas these models were originally developed in the field of economics with the aim of finding a series of elements to explain the behavior of individuals. On the other hand, perhaps because they recognized the need for a link between perceptions and action, models of health behavior included an additional variable between perceived risk and trust and a behavioral outcome. The authors (Becker, 1974; Rogers, 1975) emphasized the need for a "cognitive mediation", temporally located after appraising the risks and trust. It is a process where relevant dimensions are perceived, classified, and interacted with to generate an intention toward an action. Becker (1974) calls this process "motivation", referring to a "differential emotional arousal in individuals caused by some class of stimuli" (p. 413). Rogers (1975) expanded this view. Subjective appraisal of risk and trust arise what the author called "protection motivation," "an intervening variable that has the typical characteristics of a motive: it arouses, sustains, and directs activity" (p. 98). In the author's view, reaching a certain level of protection motivation triggers a behavioral response.

Within the framework of fully rational actors, the "theory of reasoned action" (Ajzen, 1985) expanded this micro-level explanation. It traced a causal path between beliefs, intentions, and actions to understand the psychological components of volitional behavior. Barring unforeseen events and considering a limited interval of

time, a person's intention is a function of two elements: the attitude toward a behavior—hence the beliefs about its expected utility—and a subjective norm, the perception of "social pressure to perform or not perform the behavior in question" (p. 12). In this way, a behavior (B) is predicted by an intention (I) that is directly proportional to the weighted sum of an attitude toward the behavior and a subjective norm. Ajzen's model, therefore, developed a "chain" connecting an individual's beliefs about a certain behavior—although in the strict context of fully rational individuals—and the behavior in question. According to the theory of reasoned action, a behavior is assumed to be determined by intentions, which can be explained as functions of beliefs about the expected utility of a certain behavior and the perception of social pressure to perform it. "In the final analysis, then, a person's behavior can be explained by reference to his or her beliefs" (p. 14).

Consistent empirical research has used individuals' self-reported risk and trust perceptions as explanatory factors in vaccine uptake intentions. Unfortunately, a clear theoretical passage from perceptions to action is rarely seen. Ajzen's model has the merit of raising the issue of how to connect intended behavioral outcomes with an individual's ideas and beliefs and specifying a theoretical model to interpret them.

The main limit of these theories is that they assumed a completely rational actor who thoughtfully searches for information, evaluates it, impartially elaborates it, and then makes a decision. However, it is more likely the case that individuals take decisions only with limited information, limited time, and limited cognitive capacity and ability, and that they display only bounded rationality (Simon, 1955). In a field such as health-related decisions, where evaluations must be taken about probabilities, the picture might be even more complicated. As Tversky and Kahneman (1974) pointed out in their Nobel-prize winning study, it is possible to say that "people rely on a limited number of heuristic principles which reduce the complex task of assessing probabilities and predicting values. ... In general, these heuristics are quite useful, but sometimes they lead to severe and systematic errors" (p. 1124). It could, moreover, be argued—as I later illustrate—that cognition is not necessarily intentional (Vaisey, 2008, 2009). It might be the case that, in the quest for a limited set of variables, the complexity of peoples' perceptions and cognitive processes may have been overlooked. This last point calls into play one additional piece of the puzzle about the investigation of

vaccine hesitancy: the analysis of the complex ways people elaborate their understanding of predictors of vaccine acceptance.

5. A Cognitive Perspective: Analyzing Systems of Beliefs

Based on models of health behavior, a remarkable amount of research has investigated how perceptions of risk and trust influence the likelihood of vaccine acceptance. The success of these models, nonetheless, seems also to involve a certain stagnation in the way vaccine hesitancy has been addressed, especially from a sociological standpoint.

The starting point is a focus on cognitive mediation, of paramount importance and perhaps one clue to understanding vaccine hesitancy. The authors (Ajzen, 1985; Becker, 1974; Rogers, 1975) seem to interpret cognitive mediation as a simple, quasi-Pavlovian stimulus–response function. This passage, in light of recent developments in cognitive sciences, might be a key to explaining the mechanisms through which groups of individuals—although distant in time and space—can develop similar ideas and preferences about a specific social object, sharing the same rejection for vaccination. Developing a theory-driven comprehension of vaccine hesitancy might therefore require understanding how mechanisms of cognition are used to interpret culturally specific social objects.

The key to this intricate problem might come from recent developments in cognitive sciences, and a large body of work as a coordinated study of culture and cognition (Deanna, 2014). Cognitive research and social research—particularly in the field of cultural sociology—have not come into contact until very recently. The seminal paper of DiMaggio (1997) and the work of Zerubavel (1997) started a research stream that has been preoccupied with "embracing cognitive science as a means of better understanding culture" (Strandell, 2017, p. 2), with the goal of exploring socio-neural aspects of cognition through empirical studies (Cerulo, 2010).

The intuition behind the importance of cognitive processes has been available since the 1950s when such processes were first investigated. Psychologists hypothesized the existence of mental structures used to perceive, process, and retrieve information, and they searched for ways to make inferences about them (DiMaggio,

1997). Technological development, especially the use of functional magnetic resonance imaging, allowed cognitive neuroscientists to visualize the structures the brain uses to acquire, organize, and store information (Cerulo, 2010). From that point, "cognitivists have developed ingenious empirical techniques that permit strong inferences about mental structures" (DiMaggio, 1997, p. 266). This has allowed them to analyze the complexity of the brain, and it has provided glimpses of the partitioning of mental structures. In recent years, this body of knowledge has been elaborated by social psychologists and cultural sociologists, "helping to investigate the ways in which sociocultural factors guide the process of human thought" (Cerulo, 2005, in Danna, 2014, p. 1002). For the time being, disciplines such as anthropology, economics, linguistics, cognitive psychology, and sociology of culture and cognition, underline mental architecture as constitutional elements of higher-order cognition in humans. In this framework, the idea has been to develop a broadly applicable perspective that provides key insights into how groups of people construct their beliefs on a certain social object by considering underlying mental structures. This has raised questions about how environments and experiences shape cognitive mechanisms, and how these, in turn, produce groups of people who share similar ways of understanding the world, possibly becoming the basis for new forms of population segmentation.

Investigating vaccine hesitancy can certainly be driven by the focus on predictors individuated by classic models of health behavior. However, analyzing the complex system of beliefs developing from the interplay of these predictors can benefit from including aspects of cognition that are neither cognitive "universals"—the domain of cognitive scientists—nor the product of individual nuances—the domain of psychoanalysis (Danna, 2014). The middle road lies in showing "how existing or developing sociological theories are in line with accepted neurobiological findings" (Danna, 2014, p. 1005), overcoming the limitations of classic models of health behavior.

5.1 Two Systems of Cognition

The main limit of classic models, as noted earlier, is that they depict social agents as rational individuals. Cognitive sciences have shifted this issue, suggesting that the dichotomy to be investigated does not only concern full or limited rationality,

but more deeply, conscious and unconscious cognition. Prior studies have shown that cognition is characterized by two systems, System 1 and System 2 (Stanovich and West, 1998), that generate two basic types of cognitive processing. Different names are given to these processes: fast/slow (Kahneman, 2011), practical/discursive (Vaisey, 2009), and intuitive/deliberate (Evans and Stanovich, 2013). The most important characteristic "is the principle that there are two different types of cognitive processing, one being autonomous ... and the other requiring controlled attention" (Leschziner, 2019, p. 4). Automatic or autonomous cognition is "effortless, immediate, unverbalized and subconscious thought" (Brekhus, 2015, p. 29) through which we efficiently process information without much review. Automatic cognition allows us to use a sort of "automatic pilot", quickly responding to stimuli without conscious effort. Analytic or deliberate cognition "involves slow, deliberate, conscious, verbalized thought processes" (Brekhus, 2015, p. 29). Deliberate cognition implicates a different neural experience. So, when they are engaged in deliberate thought, individuals may reject or override the results of their previous automatic cognition process and put an active effort into cognitive activities (Cerulo, 2010). It could be said that deliberate cognition is our deep-level, conscious cognition method, but several studies on the dual processes of cognition show that automatic cognition is often the system in charge (Vaisey, 2008, 2009).

Cognitive psychologists have explored individual conditions under which automatic cognition might dominate analytic cognition and vice-versa. Empirical results showed that automatic cognition can occur outside of consciousness, while analytic thought demands consciousness. Automatic cognition is more likely to occur when we are under stress; analytic cognition can, on the other hand, be triggered by the disruption of well-established routines (Cerulo, 2010). Swidler (1986) argued that, during settled times, we rely more on routine and therefore on automatic cognition. During unsettled times, on the other hand, we encounter disruptions that "require us to deliberate extensively about our values, and think more about remaining consistent with our ideology, or changing it to account for the challenges to our worldview" (Brekhus, 2015, p. 30). It is curious that several authors such as Lizardo and Strand (2010) have suggested that transitions from automatic to deliberate cognition happen more often in times when societal–cultural scaffolding is not stable. In this context, it

reminds us the passage from linear modernization to reflexive modernization (Beck, 1992).

On a similar line, Petty and Cacioppo (1986) elaborated a dual-process theory investigating the cognitive processes through witch a persuasive message can generate an attitude change. In the Elaboration Likelihood Model (ELM) (Petty and Cacioppo, 1986), a persuasive message can be processed either through a *central route* or through a *peripheral route*. In the *central route* processing, a considerable cognitive effort is involved with the evaluation of the message, and the results of such a process can have long-lasting, enduring effects. When individuals are unwilling or unable to do relevant cognitive efforts, or they are more likely to depend on previous acquired cues to interpret a message (Angst and Agarwal, 2009), the interpretation of a persuasive message follows a *peripheral route*, where conscious cognitive assessments leave the palace to general impressions, emotional statements and heuristic biases.

The most important consequence—both substantive and methodological—of the existence of a non-deliberative processing system is that it must be considered an important corrective to theories of rational action that dominate models of health behavior. The empirical evidence on individuals perceiving, processing, storing, and retrieving information in an unconscious way should be considered when analyzing systems of preferences, ideas, and attitudes toward a social object like vaccination.

When discussing empirical results, it is also important to recognize that the replicability of a number of studies involving dual-process mechanisms has been questioned. In the sub-field of priming studies, where the administering of a stimulus is supposed to generate an unconscious behavioral change, dozens of earlier studies have failed to pass a reproducibility test (Chivers, 2019). Reasons behind this 'reproducibility crisis' range from low statistical power of original experiments, the formulation of hypothesis after knowledge of the results and, finally, a certain tendency of academic per-reviewed journals of not accepting papers showing null-results.

Despite such issues, the recent push for transparency and the request for open and reproductible science left unaltered the importance of investigating subconscious processes and the relevance of automatic cognition in individuals' decision-making processes.

If a representation designed on rational actors is not sustainable, cognitive science, together with sociology and social psychology, has elaborated complex models to consider how cognition can inform a theory of action on social objects. These models can be found at the intersection of culture and cognition, strictly tied to the concepts of "mental schemas". To explain how mental schemas may be involved in behavioral intentions toward vaccine acceptance, it is necessary to identify three levels of analysis. First, the micro-level is represented by an individual cognitive mechanism at the neural level, informed by the empirical results of cognitive sciences. Second, the meso level is constituted by cognitive schemas. Third, the macro-level is represented by thought communities, where cognitive schemas are shared among individuals generating aggregates of preferences on social objects.

5.2 Neural Patterns, Cognitive Schemas, and Thought Communities

At the micro-level, cognitive schemas represent the physical structure of experiences, "patterns of activation across the configurations of neurons that fire together in a vast network of potential combinations" (Conrey and Smith, 2007 in Strandell, 2017, p. 4). In other words, cognitive schemas are nothing more than a pattern of electrical impulses between a certain number of neurons, activated each time the human brain connects with human experiences, such as imagining, calculating, and tasting. Cognitive schemas are not immanent: there is not a predefined schema for an object; they are not physical structures, but patterns. For each social object or activity, each schema is executed out of millions of possible configurations—represented by edges between neurons—with a tendency toward a similar pattern. In this way, it doesn't exist a defined and definitive pattern of activations representing an apple, a dog, or the concept of love.

As people experience things, certain neural connections are created or reinforced. Thus, whenever a similar pattern is activated, the strength of the connections increases, becoming more salient (Mandler, 1984). Objects are evaluated by their fit with previously learned schemas, in a continuous process of retrieving, learning, and classifying. This allows human beings to recognize situations, individuals, objects, places even if their characteristics change, inferring how to classify and interact with social objects. A "car" with three wheels will always be

recognized as a “car”, even if it doesn’t respect all the characteristics that we normally assign to a car. Although cognitive patterns might be seen as nothing more than electrical impulses, with an average of 86 billion neurons (Strandell, 2017), the size of the networks that the mind can build can represent complex abstract logics and social objects. Cognitive schemas—that we now know to be modeled after recurring neural networks—are indeed structures that allow us to “represent characteristics of people, places, objects or events and allow us to infer what these entities do, where they fit, and what to expect of them” (Cerulo, 2010, p. 117).

It is clear that the interaction between individuals and their cultural and social environment is of fundamental importance to the way neural connections are created. Cognitive schemas indeed “allow for efficient ... interaction with people who share similar cultural experiences” (Strandell, 2017, p. 6). They allow for some stability of cultural reproduction while having transportable properties across similar contexts. Even though we might change country or continent, we would almost always be able to understand what entering a restaurant implies. It is the consequence of being able to transpose a cognitive schema related to restaurant features to a different context.

On the second level, the idea that cognitive schemas are generated by every human activity implies that this can happen through either conscious or unconscious processing. “System 1” activities can contribute to connecting synapses and also, on a substantive level, to the formation of preferences and attitudes. Individuals learn all kinds of things unconsciously. Exposure to similar stimuli generates similar cognitive patterns (Bargh et al., 1996; Wyer, 1997). Abstract but culturally recurring schemas, such as roles, identities, or preferences, allow for interaction with individuals who share a similar cultural experience (Berger and Luckmann, 1966). Among other things, this is why people acquire wide cultural knowledge, including norms and ideas that they do not endorse. This is one way stereotypes are created, by reifying a generic schema and then applying it to individuals who have some salient features. By abstracting schematic patterns out of single occurrences, and subsequently forming implicit attitudes, individuals might associate, for example, a certain skin color or gender with certain traits out of prejudices derived from structural cultural conditions (Shepherd, 2011).

Since forming cognitive schemas depends strongly on the social and cultural context, it is very likely that individuals who share similar characteristics, contexts, or experiences might share similar cognitive schemas on specific social objects. At the same time, having a certain interpretative framework of a social object can influence how other individuals form their cognitive schemas. This could mean that individuals are characterized not only by similar preferences but also by shared interpretative and epistemic frameworks of the same social object. Mental schemas become specific cognitive structures on a certain social object or activity. Therefore, they are part of an individual *and* distributed among groups of individuals. Thoughts are co-produced in the cultures, sub-cultures, networks, and organizations to which we belong (Brekhus, 2015). Seen in this way, it can be said that thinking is a distinctly social phenomenon.

Fleck (1936) first proposed the idea of "thought communities," collections of individuals "who come to see the world from a particular institutional or subcultural paradigm" (p. 20). Because of their social and cultural positioning, individuals develop specific thinking styles shared with other actors who stand at the intersection similar standpoints. The author highlights the existence of an indissoluble link between individuals' thinking styles and their belonging to communities of like-minded people, where a continuous, endogenous process of meaning-making is shared between individuals and the thought community they belong to. In his view, thought communities relevance goes beyond specific subjects, becoming a foundation for individuals' epistemologies. As an example, the author (Fleck, 1936[1986]) suggests that the communication between a physicist and a cabalist on a certain celestial phenomena is essentially impossible not only because of different ideas, but more so because of entirely different epistemologies on the nature of things. Fleck further underlines how this process is not only synchronic, between groups of individuals in a certain time-space but also diachronic. Individuals' embeddedness in a certain historical context is a primary source of though community formation. As an example, the author suggests that the pursuit of the philosopher's stone does not seem nowadays illogical because of unfruitful empirical trials, but because it is at odds with the generalized contemporary thinking style (p. 97). It seems perfectly reasonable, on the contrary, to pursuit creating the oxymoron of an unbreakable glass, explicitly because this idea is part of our current worldview concerning the capabilities of our societies'

technological abilities. The sharp discrimination between fantasy and observation, between symbolism and naturalism is a peculiarity of 'modern' thinking styles, a byproduct of the historical period individual's happen to inhabit. To Fleck, cognition is a distinctively collective phenomena that strictly intertwines individuals and multiple communities. In this view, shared cognitive schemas can be seen as the collective thinking of "an interacting community" (Brekhus, 2015, p. 31) with similar thought styles.

From similar premises, Mannheim (1939) further explored the idea that humans think as members of collectives, and that their mental structures are shaped by social structures. Mannheim argued that it is not "isolated individuals who do the thinking, but men [and women] in certain groups, who have developed a particular style of thought" (Mannheim, 1939, p. 3).

The efforts of the Chicago School of Sociology empirically highlighted this shared meaning-making process. Here, scholars focused on the study of individuals embedded in specific communities,—such as ethnic enclaves, neighborhoods, impoverished communities, workplaces—highlighting that individuals acted as 'social wholes' (Thomas, 1914 in Clarke and Leigh Star, 2008), "making meaning together and acting on the basis of those meanings" (Clarke and Leigh Star, 2008 p. 14).

Along the same lines, Simmel (1955) suggested the idea that individuals are a pluralistic mix of multiple affiliations that shape who they are and what they think. Robert K. Merton's (1957) notion of "pluralistic ignorance" suggests that people act based on a shared representation of collective opinions. The notion of shared representations is also central in contemporary theories of culture (Berger and Luckmann, 1966; Clarke and Leigh Star, 2008). Those authors argue that culture does not exist as an abstract entity entirely external to individuals but that it is simultaneously individuated and socially distributed.

More recently, the social worlds framework (Strauss, 1978; Clarke and Leigh Star, 2008) has become a major perspective in science and technology studies (STS) to examine the meaning-making processes of an heterogeneous groups of actors involved with techno-sciences. Using the term 'social worlds' (Clarke and Leigh Star, 2008), this research stream highlights the importance of identifying the meaning-making processes of groups of individuals who share a common standpoint that "generate[s]

shared perspectives that then form the basis for collective action" (Clarke and Leigh Star, 2008 p. 115). Beyond that, the authors argue that multiple social worlds interact between each-other resulting in an *arena* (Clarke and Leigh Star, 2008) connected by 'mutual concern and commitment to action' (Clark and Leigh Star, 2008:113).

The point of these century-long theoretical contributions is that, while some features of our thinking are purely personal, others are not. Empirical studies in cognitive sociology remind us that "what goes on inside our heads is also affected by the particular thought communities to which we happen to belong" (Zerubavel, 1997, p. 9). Thus, much of our thinking on specific social objects transcends our subjectivity and is often grounded in our common social experiences. In addition, Lizardo (2010) suggested that people cluster with like-minded people by unconsciously registered antipathies or sympathies, engaging in the activity of "fence building" (Mullaney, 2006), and surrounding themselves with like-minded social networks. This leads to changes in the composition of an individual's network and the reproduction of the characteristics of a thought community. It reinforces the individual's cognitive schemas on specific social objects and actions. This suggests that there might be groups of individuals that, because of their specific social standpoint, at the intersection of several contexts and experiences, might share similar attitudes, beliefs, and ideas on a specific social object as a result of sharing similar cognitive schemas. If individuals develop certain interpretative frameworks of reality as a response to understanding the world through similar "lenses" given by the configurations of their mental structures, can people distant through space and sometimes time, share similar ideas, including about vaccine acceptance?

Connecting to the beginning of this chapter, the formation of thought communities appears to be strongly correlated with the features of modern societies. The "reflexive" modernization process and characteristics of modern societies might have had an impact on the way people develop ideas and beliefs, through the formation of distinctively "modern" cognitive schemas and in the way these schemas are shared (Zerubavel, 1997). Modern societies are characterized by cognitive pluralism. They are "a by-product of the growing structural as well as functional differentiation within modern society" (Zerubavel, 1997, p. 18). As we become functionally more different from one another, we also come to inhabit more specialized thought communities. In

an increasingly specialized world, we should not be surprised to find greater cognitive diversity (Zerubavel, 1997). At the same time, partly because of structural characteristics such as greater physical and social mobility (Turkle and Papert, 1990), and partly because of technological advancements, modernity has allowed individuals to be exposed to a higher number of shared experiences and information, embedding people in multiple thought communities (Zerubavel, 1997, in Brekhus, 2007). These are also more easily shared with individuals who are physically distant yet situated at the intersection of the same social, cultural, and individual standpoints.

On the topic of vaccine hesitancy, restructuring classic models of health behavior through a cognitive-informed perspective allowed us to overcome their main limitations while maintaining their empirically based validity.

First, recognizing the existence of a "dual system of cognition" and the relevance of unconscious mind processes forces us to overcome models that assume fully rational actors. This includes the assessments of key predictors of health-related decisions through a variety of emotional and non-cognitive perceptions.

Second, the mechanism of forming cognitive schemas is a strong candidate to enlighten the "black-box" process of cognitive mediation between perceptions and intentions. Despite being relatively simple, cognitive schemas can constitute the micro-foundation mechanisms for complex abstract cultural logics (Strandell, 2017, p. 14). This may be a way to understand how perceptions can generate complex systems of beliefs on a certain social object.

Finally, the mechanisms of shared belief systems, thought communities (Fleck, 1936[1986]) constitute a powerful perspective, based on neuro-biological findings, to hypothesize, in the framework of reflexive modernization processes, the unconscious generation of networks of individuals who have similar ideas on the controversial topic of vaccine acceptance.

6. Conclusion

This chapter provides a theoretical framework for the issue of vaccine hesitancy, the relevant approaches used to analyze it, and the most recent developments in the analysis of systems of beliefs. Although vaccination programs rely on strong

public support, it is not a process without challenges. Several high-income countries, where vaccines have proved to be a successful public health tool (Yaqub et al., 2014), are facing a widening partisan debate in which a significant number of individuals are not willing to be vaccinated. In many cases, this has led to decreased coverage for several VPDs. These same issues have been acknowledged for the acceptance of COVID-19 vaccinations (Dubé et al., 2021).

I began by discussing the importance of clearly defining the concept of vaccine hesitancy, representing those situations where people express legitimate concerns on an issue involving their own or their close ones' health (Dubé, et al., 2021). I noted how this should be differentiated from the concepts of outright refusal or from forms of citizen activism.

Throughout this chapter, I focused on individual-level issues of vaccine acceptance. It is indeed important to remember the importance of contextual factors. These include the availability and affordability of vaccines and the geographical convenience of uptake. Nevertheless, this thesis focuses on the elements correlated with individual-level vaccine acceptance, and the complex interplay of perceptions, beliefs, cognitive characteristics, and vaccine hesitancy.

In the first part, I maintained that vaccine hesitancy can be seen as a phenomenon nested in a broader contemporary sociological debate about the perception of risk and science in contemporary "risk societies" (Beck, 1992). Rapid technological advancements have reduced the perception of dangers as inevitable and encouraged individuals to minimize risks to make their future secure (Giddens, 1999). However, this has been accompanied by the blooming of related anxieties. Perceived hazards were increasingly seen as direct but unintended consequences of scientific progress (Beck et al., 1992). Furthermore, in a very specialized environment, fear of unintended consequences may have resulted in a lack of trust not only in a product, but also in the technology, science, and institutions that stand behind it. Vaccinations have clearly not escaped this process (Peretti-Watel et al., 2015).

In this framework, several theories have been developed to identify a limited set of predictors of individual vaccine uptake and health-protective behaviors more generally. Derived directly from utility models in economics, theories such as the "Health Belief Model" (Becker, 1974) and the "Protection Motivation Theory"

(Rogers, 1975) provided a starting framework to address individual vaccination intentions empirically. Despite differences, similar elements and causal paths are imagined.

A third element individuated by such theories is the process of "cognitive mediation" between perceptions and the intention to act. I argued that this component, theoretically relevant but substantially treated as a black box, might be a crucial element. I further emphasized that a major limitation of classic models is that they consider individuals as mainly rational actors, pursuing the best outcome for themselves and maximizing expected utility. For this reason, in the second part of the chapter, I tried to convey how recent discoveries of the brain's processing mechanisms might help to clarify how individuals perceive and treat information to create beliefs, ideas, and intentions toward the prospect of receiving a vaccination.

First, I underlined how recent research has agreed that human cognition is made up of two types of processes, required by different tasks, and characterized by their conscious character (analytic cognition) or their unconscious and heuristic character (automatic cognition). On a second note, I discussed the importance of developments in cognitive sociology for informing the analysis of vaccine hesitancy. I suggested that the foundation for the analysis of systems of beliefs might lie in the way our brains process stimuli and that complex representations can be produced by forming "cognitive schemas". They are shaped through each human experience, reiterated, and reinforced by the repetition of similar stimuli, allowing us to navigate the reality we encounter. Interestingly, the literature suggests that individuals occupying similar places, at the intersection of several social standpoints, might develop similar cognitive schemas and gather into "thought communities" (Fleck, 1936[1986]).

The notion of cognitive schemas is a relevant perspective on the process of "cognitive mediation," whereas the concept of thought communities is important for explaining why distant individuals can, aided by technological developments of contemporary societies, develop similar ideas on the same social object.

Within the framework of "reflexive modernization", predictors of vaccine acceptance individuated by classic models of health behavior stand still at the foundation of the analysis of vaccine hesitancy. Recent research has highlighted the complex ways people perceive risk and trust, including emotional and non-cognitive

appraisals. Finally, investigating how individuals develop ideas and intentions toward vaccination and how these are shared between groups could entail locating cognitive variation and exploiting it as an explanatory factor in vaccine acceptance.

The following chapters are three separate essays that analyze vaccine hesitancy, each from a different perspective. Although the chapters are independent of each other, they are all tied to the ideas developed in this theoretical chapter.

CHAPTER II

SHARED UNDERSTANDING OF VACCINE ACCEPTANCE: HOW PERCEIVED RISK AND TRUST FRAME INDIVIDUALS' VACCINE ACCEPTANCE[1]

Abstract

Extensive research has framed vaccine hesitancy as a property of a heterogeneous group of individuals, ranging from total acceptance to complete refusal. Nevertheless, not much research has explored this heterogeneity, mainly focusing on central tendencies of single belief-related items. Using data from an original survey on a sample of Italian citizens, this chapter examines this heterogeneity, exploiting individuals' cognitive variation to map clusters of individuals who share similar cognitive schemas on vaccine uptake. The results showed the existence three groups, characterized by a different articulation of predictors of vaccine hesitancy, revealing different understandings of vaccine uptake. We then analyzed within-cluster characteristics and showed that cognitive segmentation was connected to different levels of perceived risk, confidence, and support for vaccination. We further showed that cognitive clustering also entailed a mean of social stratification that was correlated with individuals' educational levels, and that the predictors of vaccine hesitancy were articulated differently in each group. This study, adopting a recent perspective in the analysis of systems of beliefs, moved one step further in disentangling the complexity of vaccine acceptance. Results suggested the usefulness of including individuals' cognitive characteristics in vaccine hesitancy research and in the development of interventions addressed at increasing vaccine acceptance.

[1] This chapter was co-authored with Prof. Giuseppe A. Veltri..
Mauro Martinelli: Conceptualization, Methodology, Formal analysis, Writing – original draft, review & editing, Visualization.
Giuseppe A. Veltri: Conceptualization, Methodology, Supervision, Resources, Funding acquisition.

1. Introduction

Vaccine prophylaxis is a major public health success of the 20th century, preventing around 2 to 3 million deaths every year (WHO, 2013). Although it can count on strong public support, it is not a process without challenges. Vaccine hesitancy, the delay or refusal of vaccine prophylaxis (WHO, 2014), has re-emerged as an issue, especially in places that more than others have seen vaccination's beneficial effects (Larson et al., 2014). Skepticism toward vaccines is not a recent phenomenon, but a contemporary resurgence of the issue seems to be particularly severe, enough to be included in the 2019 13th WHO General Programmes of Work, right next to Ebola and the climate crisis. This phenomenon is even more critical in the light of the COVID-19 pandemic, since vaccine acceptance will be fundamental to limit the spread of the SARS-CoV-2 virus. Unfortunately, recent research suggests that distrust in vaccine safety and efficacy is likely to become a major issue (Peretti-Watel et al., 2020).

Vaccine acceptance is often imagined as a homogeneous debate between two oppositional factions, pro versus against, acceptance versus refusal. However, research has shown that vaccine hesitancy may be based on very different reasons, attitudes, and ideas. The recognition of this complexity also calls for greater efforts to disentangle it. Social psychology and cognitive sociology suggest that groups of individuals can be characterized by implicit epistemic frameworks of the same social object. In other words, "not all people organize their thinking about the world in similar ways" (Goldberg, 2011, p. 1398), so it is possible that groups of individuals frame their understanding of vaccination in consistently different fashions. Prior empirical research might have overlooked this complexity and the different lenses people used to interpret this issue. To address this gap, following recent works from Goldberg (2011), Baldassarri and Goldberg (2014), Boutyline (2017), and DiMaggio et al. (2018), we investigated whether groups of individuals are characterized by different epistemologies regarding vaccine acceptance, and we further explored if this segmentation also entailed a mean of social stratification and a differential propensity to accept vaccinations.

We considered this issue in the case of Italy, a high-income country with significant levels of vaccine skepticism, using data from an original survey implemented between September and November 2019.

This chapter contributes to our understanding of vaccine hesitancy by investigating whether individuals' heterogeneity can be linked not only to single preferences but also to wider epistemologies. This would advocate for the relevance of analyzing people's ideas as relational systems and exploring how this segmentation might be a means of social distinction. At the same time, understanding vaccine hesitancy is a fundamental step to developing better strategies to increase vaccine acceptance. Paying more attention to how people develop certain worldviews, and how these are structured, can support the development of more systematic ways to help people understand the benefits of immunization.

2. Theoretical Background

2.1 Socio-Demographic Determinants of Vaccine Hesitancy

Vaccine acceptance is a complex issue at the intersection of individual decisions and societal needs. Reasons behind vaccine hesitancy are still being explored, but researchers have identified an extensive set of elements empirically proven to affect vaccine uptake, including: "contextual, organizational and individual ones, such as ... knowledge, attitudes and beliefs, or socio-demographic characteristics" (Dubé et al., 2015, pp. 99–100). The investigation of the association between individual socio-demographic characteristics and vaccine acceptance is a central focus of vaccine hesitancy research (Bocquier et al., 2017). In recent studies, scholars focused on several predictors, with special attention to individuals' socio-economic status and educational level. Unfortunately, "when indicators of ... socioeconomic status (SES) are considered—as the level of education, household income, employment situation—results are inconsistent" (Anello et al., 2017, p. 4674). Several studies showed a positive correlation between SES and immunization status (Kim et al., 2007), whereas others showed a negative one (Pavlopoulou et al., 2013). Several studies found a negative association between educational level and vaccine hesitancy (Omer et al., 2009; Makarovs and Achterberg, 2017), while others found the opposite (Dubé et al., 2013; Giambi et al., 2018) or that vaccine hesitancy is higher at extremes of the spectrum of both education and income (Carpiano and Bettinger, 2016). Larger-scale studies suggest that this relationship might be strongly context-dependent, at both

national and local levels (Bocquier et al., 2017). In this complex empirical scenario, studies of the Italian context are extremely limited and inconclusive (see, for example, Anello et al., 2017; Giambi et al., 2018).

At the same time, a growing trend suggests that, whereas in the past vaccines were mostly refused by lower educated people (Dubé et al., 2015), today's hesitant individuals are also well-educated people claiming the right to make an "informed" decision about vaccination (Kirkland, 2012). Experience-based health information has gained a level of legitimacy and credibility similar to evidence-based scientific information. Dubé et al. (2015) highlighted a growing trend to seek information on user-generated websites rather than traditional evidence-based information sources. Online narratives are interesting, memorable, and in-demand (Kata, 2010), whereas "messages from official sources tend to be factual, cryptic, and forgettable" (Brewer et al., 2017, p. 157).

This paradigmatic change calls into play how individuals select, retrieve, and use information to develop beliefs and attitudes on vaccine-related issues. Recent literature suggests that beyond socio-demographic characteristics, the cornerstone issue to be investigated might be the very process by which people develop their worldviews by deeming different information sources as trustworthy. Given that "the way we decide which evidence is convincing is ... not guaranteed by any specific method or form of evidence" (Hausman, 2019, p. 100), the problem might move from what people believe to how people construct meaning and share a similar epistemology with other individuals.

2.2 Conceptualizing and Measuring Cognitive Schemas

The key to this intricate problem might come from recent developments in cognitive science and from the coordinated study of culture and cognition. Studies of the brain have determined that external and internal inputs generate activation patterns across neurons, revealing the brain's representational and processing mechanisms. The reification of activation patterns leads to the formation of cognitive schemas, "abstract cognitive structures[s] that individuals acquire through experience or acculturation" (Boutyline, 2017, p. 357). Cognitive schemas embody our taken-for-granted assumptions about the world under conditions of incomplete information (DiMaggio,

1997). They allow humans to "represent characteristics of people, places, objects or events and ... infer what these entities do, where they fit, and what to expect of them" (Cerulo, 2010, p. 117). In other words, cognitive schemas represent contextually and culturally defined "lenses" through which individuals interpret the reality surrounding them (Cerulo et al., 2021). These schemas are in turn used to organize, process, and retrieve experiences (Strandell, 2017). Cognitive schemas are strongly context-dependent, and for this reason, they might be both a part of an individual and distributed among groups of individuals. Individuals sharing the same cultural milieu are more likely to share similar cognitive schemas, belonging to what Fleck (1936[1986]) called "thought communities": groups of individuals who share the same worldview on a specific social object. Berger and Luckmann (1966) argued that culture does not exist as an abstract entity entirely external to individuals. Rather, it is both individuated and socially distributed. Merton's (1957) notion of "pluralistic ignorance" suggests that people act on the basis of a shared representation of collective opinions. If belonging to a particular thought community implies that its members mediate their experiences using similar cognitive building blocks, then "they presumably also employ similar reasoning in understanding and responding to the realities they encounter" (Goldberg, 2011, p. 1400). Finally, cognitive schemas are relational systems, a "configuration of ideas and attitudes in which the elements are bound together by some form of constraint or functional interdependence" (Converse, 1964, p. 207, in Baldassarri and Goldberg, 2014, p. 54). Theories referring to relational networks suggest that the meaning of symbols in a cultural system rests not in the signs themselves, but in the relationships between them.

Applying these concepts to vaccine uptake, the heterogeneity of vaccine-hesitant individuals might be seen as comprising multiple groups of individuals whose mental representation of the issue is structured similarly, based on the pattern of relationships in each cognitive schema. If it is possible to account for this heterogeneity by showing that it is systematic and that it can be minimized within groups and maximized between clusters of individuals, this would point toward the existence of multiple belief systems on the issue of vaccine hesitancy.

2.3 Core Determinants of Vaccine Acceptance

Cognitive schemas are characterized by how different elements of a certain social domain are bounded together. Therefore, to understand if groups of individuals show systematically different shared understandings of vaccine acceptance, core predictors of vaccine acceptance could be used. Research has shown that the way individuals perceive the risk of VPDs and trust vaccinations are principal components in determining vaccine uptake or refusal (Brewer et al., 2017; Giambi et al., 2018; Yaqub et al., 2014). These elements stand at the center of several health-specific behavioral theories which are often used to frame vaccine hesitancy.

Nearly all theories focus on two dimensions of risk perception: the perceived severity of disease and the perceived likelihood of contagion. The severity of a disease represents the magnitude of an adverse event such as VPDs (Becker, 1974). The likelihood of contagion is instead the "probability of being harmed by a hazard under certain behavior conditions" (Brewer et al., 2007, p. 137). Psychometric tradition and cultural sociology recently pointed out that people have a more complex conception of risk that calls into play an individual's cognitive systems (Slovich et al., 2005). Kahan (2014) suggested that on the issue of vaccine hesitancy, emotional assessments toward vaccines may trump the calculus of objective risks and benefits. That is, people base their judgments on an activity or technology—such as vaccines—not only on what they think about it but also on the way they feel about it. In this interpretation, risk is an affective state, distinct from cognitive judgment. For this reason, two additional dimensions should be considered. The first is the perceived susceptibility to disease, emphasizing an individual's perceived vulnerability to VPDs. The second is the perceived feeling at risk, highlighting the emotional component of risk perception (Weinstein et al., 2007).

The second fundamental component of vaccine acceptance is trust in a valid coping mechanism. In vaccine hesitancy research, this is often interpreted in terms of confidence (Larson et al., 2016). Confidence is a faceted construct, usually positively associated with an increase in vaccine uptake, although there have been mixed results in the literature, mainly because of conflicting definitions of the concept. There is, in fact, little consensus about the components of confidence, and several scales have been proposed to measure it (Gilkey et al., 2014; Opel et al., 2011). Following the systematization by Larson et al. (2015), we define confidence as "trust in the vaccine

(the product), trust in the vaccinator or other health professional (the provider), and trust in those who make the decisions about vaccine provision (the policymaker)" (p. 2).

In this chapter, we aim at moving the focus of attention from what people believe to how beliefs are organized, using predictors of vaccine acceptance to uncover whether individuals differ qualitatively in the way they construct their representation of vaccine uptake. Second, we investigate whether group segmentation also entails a means of social distinction or stratification by analyzing if socio-demographic characteristics are differently associated with the probability of belonging to each group. Finally, we analyze each group separately, to understand if different shared understandings of the issue are correlated with differences in the individuals' propensity to be vaccine-hesitant.

Therefore, three research questions drive this chapter:

Q1) Relying on measures of perceived risk and confidence, do groups of individuals show different shared cognitive schemas on vaccine acceptance?

Q2) Does the group partitioning of Q1 also represent a source of social distinction or stratification?

Q3) Is there a different association between core predictors of vaccine hesitancy and the willingness to vaccinate in each group?

3. Data, Variables, and Methods

3.1 Data

[1]Given the limited availability of data on the Italian context and the specific aim of this chapter, between September and November 2019, an original online survey was administered to 1008 Italian citizens between 20 and 64 years old who participated in an online panel of a major Italian survey company. We used a non-probabilistic quota sampling method, stratifying participants by gender, age, geographical location, and educational level. The number of individuals in gender, age, class, and

[1] Data and code to replicate the analysis is available on OSF.io at: https://bit.ly/3kjkIdQ

geographical location quotas was proportional to the 2018 Italian population surveyed by the Italian National Institute of Statistics (ISTAT). Educational levels (low = less than 9 years of education, medium = between 9 and 13 years of education, and high = over 13 years of education) were equally distributed among respondents. To account for this sampling characteristic, probability weights were applied in the analysis. Quota sampling, although far from an ideal probabilistic sampling method, was chosen with careful consideration for the availability of research funds and research goals, primarily to map individuals' cognitive structures. For this reason, estimates in the following analysis must be considered carefully, always taking this liability into account.

3.2 Variables

In this section we describe the main variables used in the analysis. A complete description of survey questions, variables, and coding can be found in Table 1 in the appendix section. Our main predictor variables measured the perceived risk of VPDs and confidence in vaccination. We measured four distinct risk perception concepts: severity of VPDs, the likelihood of contagion, susceptibility to VPDs, and feeling at risk. Questions about perceived risk were preceded by asking respondents to imagine they would have to take care of a child, today, in Italy. In addition, the perceived likelihood of contagion and feeling at risk were preceded by asking respondents to imagine two hypothetical scenarios: whether the child received or did not receive all the Italian mandatory and recommended vaccinations. We called these conditioned questions with and without vaccination. Additional questions investigated the perceived probability and severity of side effects, the anticipated regret for the possible side effects of vaccination, or the development of VPDs following the decision not to vaccinate. Finally, confidence was measured by a question articulated in a battery of 6 statements, isolated from a comprehensive matrix of determinants of vaccine hesitancy developed by the Strategic Advisory Group on Experts working group (SAGE) on vaccine hesitancy (Larson et al., 2015). The question investigated trust in the safety and effectiveness of vaccines (the product), trust in physicians, the scientific community, and the production chain (the providers), and trust in official authorities (the policymakers). The 19 variables used in the analysis can be partitioned into three

issue domains: risk perception without vaccination, risk perception with vaccination, and confidence. Following Weinstein et al. (2007), we used a 7-point Likert scale as the answering option, recoding the limited number of "Don't know" answers with the intermediate value (4).

As a measure of vaccine hesitancy, we asked respondents to rate, on a scale from 0 to 10, whether they would hesitate to administer to the hypothetical child all the Italian mandatory and recommended vaccinations. Given the skewed distribution (*M:* 3.05; *SD*: 3.5; *Mdn*: 1), the variable was dichotomized, where 0 indicated no hesitancy and 1 and above indicated hesitancy.

Socio-demographic variables surveyed the respondents' educational level, gender, age, and whether respondents had children (childless, one child, more than one child), whether respondents had a religious affiliation (dichotomic, yes/no), their geographic area of residence (north-east, north-west, center, and south and islands) and rural or urban area of residence (metropolitan area, city/urban center, rural area). We listwise deleted 20 cases that had missing values in this last socio-demographic variable, reducing the analytical sample to 988 cases.

3.3 Methods

Accounting for heterogeneity in individuals' cognitive schemas "requires that we simultaneously examine the relationships between variables and individuals" (Goldberg, 2011, p. 1404). This requires a method that compares individuals by detecting groups that vary with respect to patterns of relationship between attitudinal variables, without making assumptions on underlying individual characteristics—such as socio-demographic variables. To address this problem, we used Goldberg's (2011) relational class analysis (RCA). RCA is a graph partitioning method based on the assumption that individuals are related to one another to the extent to which they construct meaning in a similar way. RCA measures the degree to which each pair of respondents employed the same cognitive schema, and uses this measure to create groups (Boutyline, 2017). As a measure of schematic similarity, Goldberg (2011) proposed a metric he called relationality, which "measures whether the components of two vectors of the same set of variables follow a similar pattern" (Goldberg, 2011, p. 1404). Intuitively, two individuals are as schematically more alike as their pattern of

response is closer, and it can be ultimately be shown that relationality measures "the degree of linear dependency between two individuals' vectors of responses" (Boutyline, 2017, p. 354). RCA computes relationality for each pair of items, for each pair of observations in the dataset, resulting in a complete, undirected, weighted graph. The vertices of the graph represents individual respondents, and edge weights the average relationality between all couple of respondents in the dataset. Finally, individuals are divided into groups of schematically similar respondents using a partition maximization algorithm. Belonging to the same group does not imply having identical opinions, though. Two individuals can have very different opinions but agree that the issue is structured in a similar way. For example, a democratic and a republican will probably have very different ideas, but they might agree on the debate arena to be structured in a similar way. There is a continuum with two extremes, the democratic and republican parties, inside a democratic framework. For this reason, groups individuated by RCA may contain individuals with different attitudes, but that recognize a similar relation of closeness or opposition between the items making up a specific issue domain. Each group is therefore characterized by a distinctive pattern of relationship between opinions, "suggesting that its members organize their beliefs ... using the same rationale" (Baldassarri and Goldberg, 2014, p. 58). (A more detailed explanation of RCA is available in the appendix section. For a complete description of the characteristics and functioning of the RCA, see Goldberg, 2011.)

In the second part of the analysis, we used multivariate multinomial logistic regression to model the probability of belonging to each group as a function of an individual's socio-demographic characteristics. The aim was to understand if group segmentation also entailed a means of social stratification.

Finally, in the third part, we used multivariate logistic regression to establish whether individual characteristics and perceptions correlated differently with vaccine acceptance in each group.

4. Results

4.1 Relational Class Analysis: Convinced, Skeptics, and Agnostics

Applying RCA to the data resulted in a partition of respondents into seven groups, but four were removed from the analysis because they contained only one participant. The three main groups represented, respectively, 27 % % (n = 267), 46 % (n = 450), and again 27 % (n = 267) of the sample. We labeled the three groups Convinced, Skeptics, and Agnostics, respectively. The belief network for each group is represented in Figure 2.1.

Since RCA increases within-group covariances, correlation matrices are an informative way to represent and interpret groups' belief networks with respect to variables involved in the analysis. Looking at correlation matrices. it is possible to deduct three different qualitative patterns of association between issue domains. The Convinced group has a decoupled position between the issue domain measuring perceived risk with vaccination on one side and risk perception without vaccination and confidence on the other. We labeled this group Convinced because they seemed to organize their representation of the vaccination issue along a line drawn in the literature between individuals in favor versus those against vaccination. This group contains, in fact, individuals who show lower perceived risk with vaccination and higher confidence and risk perception without vaccination, or vice-versa. For individuals at the extreme of this group's continuum, we argue, vaccination can be interpreted as a protective or endangering practice, an element that reduces or increases perceived risk. For this reason, individuals in this group appeared to be firm in their belief about the positive or negative effects of vaccination. In the second group, Skeptics, respondents frame their representation of the vaccination issue as revolving around the contraposition between confidence in vaccination and the presence of side effects.

There exists, in fact, a strong negative correlation between variables assessing confidence in vaccination and three specific variables measuring the probability and severity of side effects and the anticipated regret for the side effects. Skeptics could be seen as a blurred version of the Convinced group, where individuals might apply cost/benefit reasoning, driven by the perceived level of the vaccine's side effects. At the extremes of this group are individuals with higher confidence, higher perceived risk without vaccination, and lower perceived risk for side effects, and vice-versa. Therefore, the heterogeneity between individuals seems driven by a different

perception of collateral effects together with an unclear position about vaccination

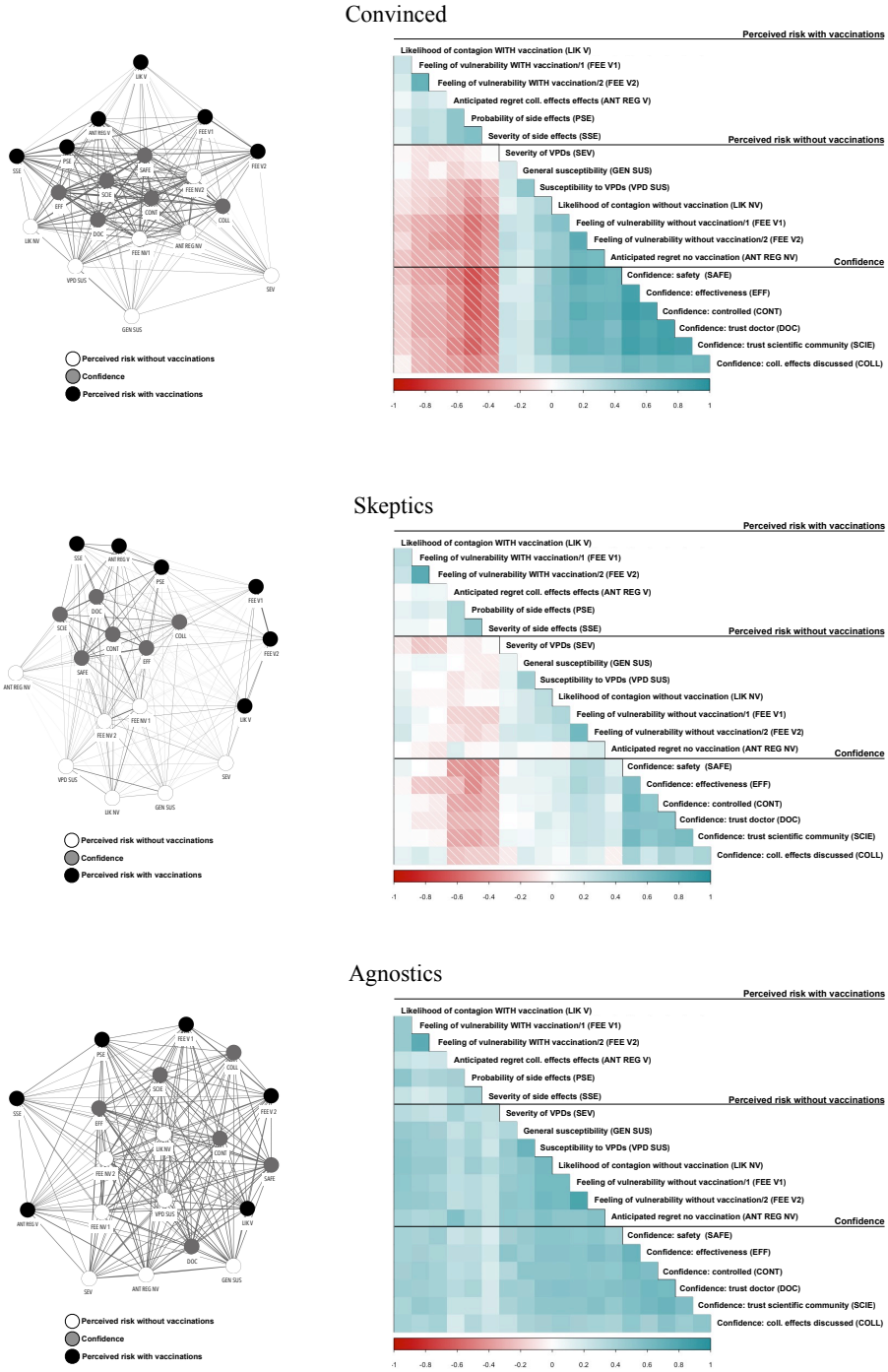

Figure 2.1 – Belief networks in each group detected by RCA. In left-side network plots, each node corresponds to one variable, and each line connecting two nodes to the correlation between them, only if significant at a $p \leq 0.05$. Line shades and widths are proportional to the strength of the correlation. Given the complexity of the graph, only positive correlation lines are drawn. Networks are drawn using Fruchterman-Reingold algorithm, so that distances between the nodes inversely correspond to the edge weights connecting them. On the right side, the respective correlation matrices are reported. Light blue squares represent positive correlations and red-shaded squares negative correlations. The correlation coefficient is proportional to the intensity of the respective color.

effectiveness in reducing the risk of VPDs. This is shown by the unclear pattern between the first three variables in the correlation matrix and the remaining ones.

The third group, Agnostics, has a significantly different pattern. The three issue domains are positively correlated with each other. At the extremes of this group's continuum are individuals with higher confidence and higher risk perception with or without vaccination, and vice-versa. Individuals in this group appear not to recognize vaccination as a useful tool whether they perceive VPDs as dangerous and whether they trust vaccination.

Based on core predictors of vaccine acceptance, RCA revealed three different ways individuals framed their understanding of the vaccination issue, and that different cognitive schemas were indeed shared by individuals in our sample. However, the different ways perceived risk and confidence correlate in each group do not necessarily imply a difference in the levels of the variables. In other words, relational networks tell us the story about the structure of cognitive schemas, but they say little about the levels of each predictor in each group.

To understand if cognitive segmentation also identifies groups with different levels of perceived risk and confidence, we generated three standardized indexes by averaging the respondents' opinions on the variables in each issue domain. We excluded individuals' perceived severity of diseases, given that the severity of disease is independent of any protective measure. The indexes for confidence, risk perception without vaccination, and risk perception with vaccination show a Cronbach's alpha scale reliability coefficient of .91, .79, and .77, and each one represented a unidimensional scale, tested through exploratory factor analysis (see Appendix).

Figure 2.2 plots the average levels of each index in each group detected by RCA.

The three groups showed significantly different levels of confidence, risk perception without vaccination, and risk perception with vaccination. The Convinced group had, on average, the highest levels of confidence in vaccination and perceived risk of VPDs without vaccination and the lowest levels of perceived risk with vaccination. This suggests that the Convinced group appeared to trust vaccines and the vaccination process, and they saw vaccination as a means to reduce perceived risk. The Skeptics showed significantly lower levels on the three indexes. Compared to the

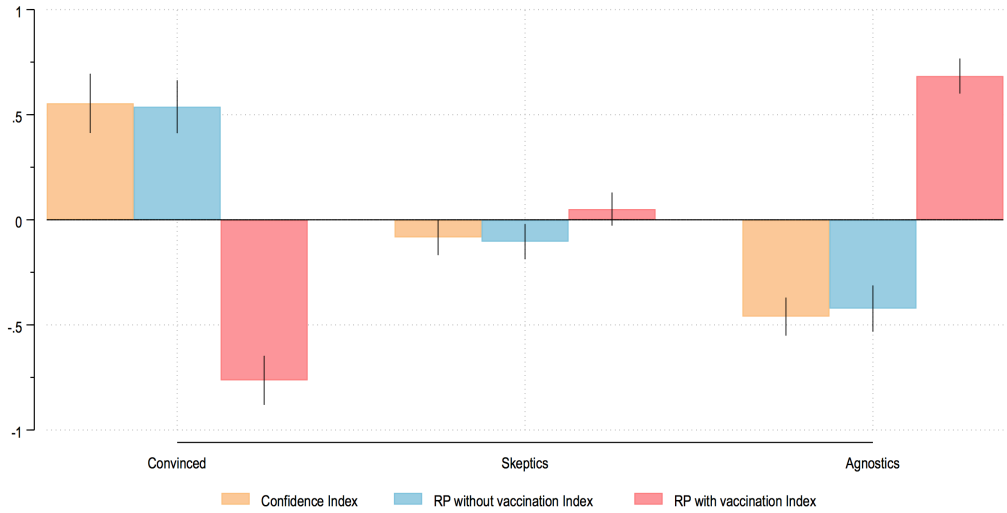

Figure 2.2 – Average levels of confidence and risk perception with and without vaccination in each group detected by RCA. All standardized coefficients, 95 % CIs.

Convinced group, the Skeptics showed lower confidence in vaccination, lower perceived risk of VPDs without vaccination, and a significantly higher perceived risk with vaccination. Given the overlapping confidence intervals for perceived risk with and without vaccination, it appears that vaccination had little or no ability to reduce how this group perceived risk. Complementing RCA, a likely explanation is that for this group, fear of side effects might limit the propensity to see vaccination as an effective tool in reducing the risk of VPDs. Finally, the Agnostic group, which already appeared to answer to a very different logic, showed, on average, the lowest levels of confidence and perceived risk without vaccination. In this group, the perceived risk with vaccination was significantly higher than without, suggesting that vaccination seems not to reduce risks, but instead was a factor that contributed to defining them.

Prior research often treated vaccine hesitancy as if all individuals saw vaccination with the same eyes. RCA, on the contrary, allowed us to appreciate three systematic differences in the way individuals frame this issue by showing that individuals differ not only in "what" they think but also in "how" they think, revealing different interpretative and epistemic frameworks of the same social object. In addition, as Figure 2.2 points out, representational mechanisms are tied, on average, to

systematically different levels in the predictors of vaccine hesitancy. This suggests that an individual's cognitive schemas might also represent different levels of support for vaccination.

4.2 Socio-Demographic Predictors of Cognitive Schemas

Do cognitive schemas embody principles of evaluation that demarcate different social groups? If group segmentation also represents a mean of social distinction or stratification, we should expect socio-demographic attributes to correlate with belonging to one group rather than another. On the contrary, if cognitive segmentation cuts across socio-demographic characteristics, no individual characteristic should be significantly associated with being assigned to a specific group. Using multinomial logistic regression, we analyzed the extent to which socio-demographic characteristics predicted the relative risk of belonging to each RCA group. Figure 2.3 plots the results of this model for statistically significant associations.

A limited number of socio-demographic characteristics were significantly associated with group belonging. Importantly, though, individuals with the highest educational level had a lower relative risk ratio of belonging to the Skeptics group or

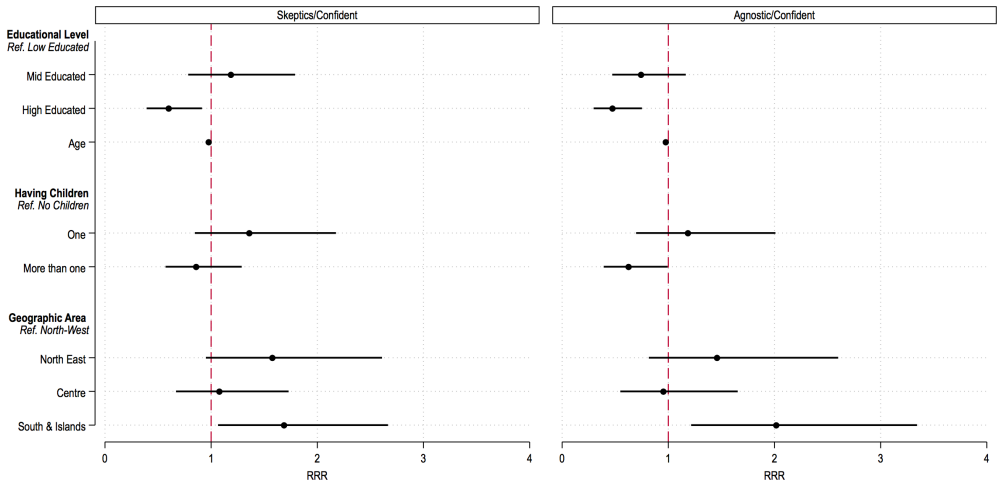

Figure 2.3 – Multinomial logistic regression predicting the probability to belong to each RCA group as a function of individuals' sociodemographic characteristics. Predictor variables include: educational level, age, gender, whether respondents have children, religious affiliation, geographic area of residence and rural or urban area of residence. Relative Risk Rations, 95 % CIs, weighted coefficients.

the Agnostic group, compared to the Confident group. Figure 2.2 showed that, on average, the three groups appeared to be in descending order of their confidence in vaccination and its ability to reduce the perceived risk of VPDs. So, it appears that a higher educational level is associated with a cognitive schema where vaccination is valued more highly. Interestingly, we also found a negative association between having more than one child and the relative risk of being in the Agnostics versus the Convinced group. This might suggest, we argue, that for Agnostics, having had one child and seeing no relevant side effects might have fostered a more favorable understanding of vaccinations. Finally, we find a geographical gradient, where individuals living in the southern regions of Italy were also more likely to be in the Skeptics and Agnostics group than the reference group.

Could these results suggest that different cognitive schemas also entail a means of social distinction or stratification? On one hand, only a few socio-demographic characteristics were significantly associated with group belonging. On the other hand, it seems important to stress that the way individuals exhibit a certain understanding of the vaccination issue is stratified by their educational level and geographical area. This might partially explain the mixed findings in the literature concerning the role of educational level. Although further research is needed here, it could be the case that the association between educational level and vaccine hesitancy might be mediated by different individual cognitive schemas and that these are distributed differently in different contexts. Overall, it is important to note that different epistemologies appear to also providing a means of social stratification, highlighting the importance of education in favoring a worldview that supports vaccine acceptance.

4.3 Predictors of Vaccine Hesitancy in Each Group

In the third part of the analysis, we explored whether cognitive segmentation entailed a different association between predictors of vaccine hesitancy and vaccine hesitancy in each group. Figure 2.4 plots the average marginal effects of three binomial logistic regressions that investigated the association between the standardized indexes of issue domains and vaccine hesitancy, controlling for individuals' socio-demographic characteristics. Figure 2.4 suggests that the association between confidence, perceived risk with and without vaccination, and the likelihood of being vaccine-hesitant is

articulated differently in each group. In the Confident group, higher levels of confidence are associated with a lower probability of being vaccine-hesitant.

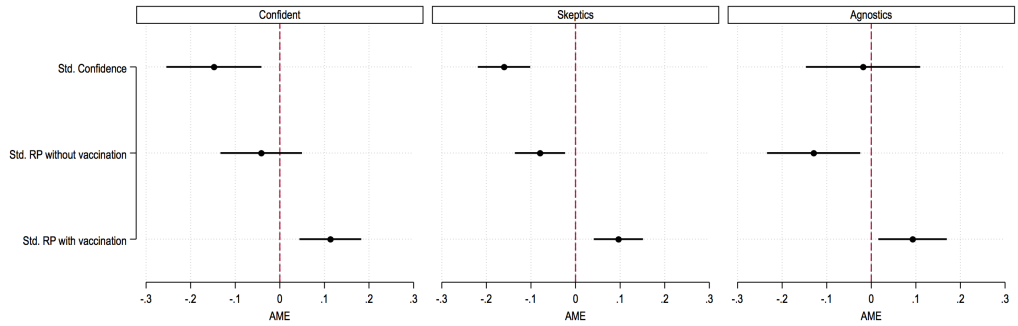

Figure 2.4 – Average marginal effects of multivariate binomial logistic regression models predicting the probability to be vaccine hesitant (0= no hesitancy; 1=hesitancy). Models are controlled for individuals' sociodemographic characteristics. All standardized coefficients. 95% CIs, weighted coefficients.

The perceived risk of VPDs in the absence of vaccination, on the contrary, was not significantly associated with a change in the probability of being vaccine-hesitant, whereas higher levels of perceived risk after vaccination are positively associated with a higher likelihood of vaccine hesitancy. The Skeptics group had a very similar scenario, but for Skeptics, higher levels of perceived risk of VPDs without vaccination were associated with a lower likelihood of being vaccine-hesitant. Finally, in the Agnostics group, confidence in vaccination, one of the main constructs analyzed in vaccine hesitancy research, appeared not to be significantly associated with the probability of being vaccine-hesitant.

This result suggests that cognitive segmentation also reveals that core predictors of vaccine acceptance are associated differently with vaccine hesitancy following individuals' cognitive schemas. This shows the centrality of an individual's epistemology in evaluating the dimensions of vaccine acceptance. In line with previous steps of the analysis, these findings suggest the importance of considering an individual's cognitive characteristics in vaccine hesitancy research and in developing strategies to increase vaccine acceptance. If systematically different worldviews

underpin the recognition of different elements as relevant in one's propensity to be vaccinated, developing effective strategies to increase vaccine acceptance might require diversifying interventions based on the articulation of elements in different subgroups of the population.

5. Discussion and Conclusion

Vaccines are safe and effective measures to prevent infectious diseases, but reaching a sufficient and stable coverage rate has proven to be more difficult than predicted. One major challenge recent research on vaccine hesitancy is facing is the recognition of the complexity and heterogeneity of the positions of individuals and the need for relevant ways to analyze them. In this chapter, we argued that this heterogeneity might be investigated by exploring whether individuals show different epistemologies on the same social object by treating beliefs as relational systems.

By using fine-grained measures of predictors of vaccine hesitancy and RCA, a method tailored to identify shared cognitive structures (Goldberg, 2011), we identified three different groups of individuals, characterized by different patterns of closeness and opposition on 19 core predictors of vaccine acceptance.

Substantively, these results appear to be relevant from methodological, theoretical, and public policy perspectives. Methodologically, it tests the feasibility and usefulness of studying individuals' opinions as relational structures on a topic such as vaccine acceptance. They revealed different patterns of association that might have gone unnoticed without such partition. In addition, the results support the idea that beyond socio-demographic and attitudinal variables, cognitive differences are a significant source of variance that should be considered when analyzing individuals' attitudes (Veltri, 2021). This also suggests the relevance of developing new strategies to disentangle individuals' attitudes, such as RCA. Theoretically, building on the recent bridge between sociology and cognitive sciences, it highlights the importance, advantages (and complexities) of including individuals' cognitive characteristics in the analysis of vaccine hesitancy. This is even more important in the light of the fact that we showed how cognitive segmentation identified groups with different levels of perceived risk of VPDs and confidence in vaccination (see Figure 2.2). Furthermore,

we argue, they are different ways to recognize vaccination as a means to reduce the risk of VPDs. Further research is needed in this liminal field, where sociology can benefit from cognitive sciences, and vice versa. From a public policy perspective, increased attention to cognitive segmentation might be another key for addressing vaccine hesitancy. Effective communication strategies to foster vaccine acceptance should take into account that the ways people interact and react to public policy interventions might be conditioned not only by people's socio-demographic profiles but also by their cultural and cognitive schemas (Veltri, 2021).

In the second part of the chapter, we explored whether cognitive segmentation also represented a logic of social distinction and stratification. We found that an individual's educational level was significantly associated with being in the Convinced group, versus the Skeptics and Agnostics groups (see Figure 2.3). Therefore, it appears that the level of education is a powerful indicator of individuals' worldviews, where vaccination is a trustworthy tool against VPDs. We argued in the theoretical section that there are mixed results in vaccine hesitancy research concerning the role of educational level in predicting vaccine acceptance. This is especially the case after recognizing that even highly educated individuals rely on information of questionable origin or validity (Kirkland, 2012). This analysis, on the contrary, points toward the direction where more educated individuals are more likely to develop worldviews favorable to vaccine acceptance. This, of course, does not necessarily imply that the educational level is always a relevant predictor of vaccine hesitancy. As we pointed out, vaccine acceptance is context-specific, and given this study offers only a limited window on one European country, it is not possible to generalize results to different contexts. Nevertheless, the more nuanced result—that education is a significant predictor of a worldview where vaccination is more positively conceived—underlines that an individual's location in our societies' structure is still a relevant factor for vaccine acceptance. Research has noted many times that vaccine acceptance is socially stratified, where subgroups in the population are systematically less likely to accept vaccination (Dryhurst et al., 2020; Robertson et al., 2021). Our results point toward this direction, emphasizing that to address vaccine hesitancy it is important to address deeper issues concerning our societies' social stratification.

Finally, in the third part, we explored whether core predictors of vaccine acceptance were associated differently with vaccine hesitancy in each group. We found that higher perceived risk of VPDs with vaccination unanimously identified higher levels of vaccine skepticism. However, we did not find a significant association between the perceived risk of VPDs without vaccination in the Convinced groups and confidence in vaccination for the Agnostic group (see Figure 2.4). This result is important because, to increase vaccine acceptance, it is of paramount importance to identify a set of predictors on which to focus attention.

On a methodological level, this result suggests that when surveying vaccine hesitancy, conditioning perceived risk of VPDs in a scenario where vaccines have already been taken might yield hold more consistent results independently of a source of variance such as cognitive schemas. Further research should be conducted to develop valid and reliable predictors of vaccine acceptance, to make empirical results more easily comparable in and between contexts. Finally, reconstructing belief networks might help to understand the relative importance of specific predictors in different groups of individuals, a relevant toll in developing more tailored interventions.

Some limitations of this study must be considered. First, the sampling method limits the robustness of the results, and further efforts should be invested in collecting representative data to get a clearer analysis and cleaner estimates. For this reason, we strongly suggest avoiding any causal interpretation of the results and considering this exploratory study as a first step toward more ample investigations. Second, RCA is a relatively new method and its consistency should be further explored. Third, as underlined by Baldassarri and Goldberg (2014), mechanically grouping individuals does not provide a straightforward interpretation of the underlying psychological mechanisms that generate this division, and this remains to be tested empirically.

The contributions of this chapter are threefold. First, it empirically tackled the problem of individuals' heterogeneity on vaccine hesitancy, theoretically postulated but rarely addressed empirically. We did so by a) highlighting the importance of cognitive-based differences in the population, b) using an empirical way to address them, and c) showing how cognitive segmentation might also represent a means of social distinction. Second, it highlighted the importance of individuals' cognitive characteristics in vaccine hesitancy research, and it advocated for a tighter connection

between neighborly disciplines. Third, it contributed to the literature on measuring risk and trust in a health-related situation, recurring to an extensive set of measures that, to the best knowledge of the authors, have never been surveyed together systematically.

Further research is needed in the liminal field between social and cognitive sciences, and in developing empirical methods to further analyze vaccine hesitancy. In this chapter, an exploratory analysis showed that cognitive segmentation was indeed a relevant source of variance between individuals. It also suggested that the ways people acquire, interpret, and use information might be an additional key to understanding peoples' worldviews and fostering vaccine acceptance.

CHAPTER III

DO COGNITIVE STYLES AFFECT VACCINE HESITANCY? A DUAL-PROCESS COGNITIVE FRAMEWORK FOR VACCINE HESITANCY AND THE ROLE OF RISK PERCEPTIONS[1][2]

Abstract

In this chapter, we consider cognitive differences in vaccine hesitancy and whether perceived risks intervene in this relationship. Researchers have identified two cognitive processes, intuitive and analytic cognition. Different individuals lean toward one of these processes with varying degrees of strength, influencing their day-to-day behavior, perceptions, and decisions. The implications of individuals' cognitive differences for vaccination uptake have seldom been addressed from a sociological standpoint. In this chapter, we bridge this gap by investigating whether thinking styles have a direct association with vaccine hesitancy and an indirect one through perceived risks. We use data from original surveys carried out between September and November 2019 on a sample of Italian citizens, and use Karlson, Holm, and Breen (KHB) decomposition to compare coefficients of nested nonlinear models, separate the direct and indirect association of cognitive processes with vaccine hesitancy, and disentangle the contribution of each measure of risk perception. Results show that, net of individual characteristics, the direct association is as important as the indirect one. In addition, affective risk perceptions account for over half of the indirect association, underlining the centrality of affective versus probabilistic approaches to risk perception. This chapter underlines the importance of including cognitive characteristics in vaccine hesitancy research, and it empirically shows individuals' qualitatively complex perceptions of risks. Results might inform policy development, suggesting that effective communication to contain vaccine hesitancy should consider an individual's preferred cognitive style and develop messages that reassure individuals about their affective concerns, rather than using probabilistic data.

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[1] This chapter was co-authored with Prof. Giuseppe A. Veltri
Mauro Martinelli: Conceptualization, Methodology, Formal analysis, Writing – original draft, review and editing, Visualization.
Giuseppe A. Veltri: Conceptualization, Methodology, Supervision, Resources, Funding acquisition.

[2] A revised version of this chapter has been published as:
Martinelli, M., Veltri, G. A., (2021). Do cognitive styles affect vaccine hesitancy? A dual-process framework for vaccine hesitancy and the role of risk perceptions. *Social Science & Medicine*, 289, 114403.

1. Introduction

Vaccine prophylaxis is one of the most successful preventive techniques in 20th-century healthcare. The World Health Organization (WHO) estimates that routine vaccination of infants, children, and adults prevents around 2 to 3 million deaths every year (WHO, 2013). Despite strong public support for vaccination, vaccine hesitancy is re-emerging as an issue, especially in those contexts where vaccination's most beneficial effects have been seen (Larson et al., 2014). In addition, vaccine acceptance is fundamental to resolving the COVID-19 pandemic, but early results suggest that "distrust is likely to become an issue" (Peretti-Watel et al., 2020, p. 1). A large-scale study involving 67 nations has found Italy to have the second-highest rate of vaccine-relates skepticism, after Russia and before Azerbaijan (Larson et al., 2016). Research in different fields has explored the drivers of vaccine hesitancy, finding that "similar determinants of vaccine acceptance or refusal emerged, including contextual, organizational and individual ones" (Dubé et al., 2015, pp. 99–100). This chapter focuses on individual-level determinants of vaccine hesitancy.

Given that "being motivated to get vaccinated is in many ways the result of deliberation by individuals" (Brewer et al., 2017, p. 158), several behavioral theories have been used to explain vaccination intentions, such as the "Health Belief Model and Sick Role Behavior" (Becker, 1974), "Protection Motivation Theory" (Rogers, 1975), the "Theory of Planned Behavior" (Ajzen, 1985) and the "Theory of Reasoned Action" (Fishbein and Ajzen, 2011). The main limitation of key models of health behavior is that they consider individuals to be rational actors, pursuing the best outcome for themselves and maximizing expected utility. The model behind these theories—the "rational choice theory'—was long considered a baseline, but since the work of Simon (1955), it has increasingly been suggested that individuals are not fully rational actors. It is more likely that individuals take decisions with limited information, limited time, and limited cognitive capacity and ability, and they display bounded rationality. In this framework, cognitive science, together with sociology and social psychology, has elaborated complex models to consider the way cognition can inform a theory of action. The most widely supported view of how our cognition works, the "dual systems of cognition model" (Evans and Stanovich, 2013; Kahneman, 2011; Sloman, 1996), postulates the existence of two systems of thought, with different capacities and

processes. System 1 (S1) is fast, intuitive, and automatic, whereas System 2 (S2) is slow, deliberative, and reflective (Stanovich, 1999). Furthermore, in decision-making, "people rely on a limited number of heuristic principles which reduce the complex task of assessing probabilities and predicting values. ... In general, these heuristics are quite useful, but sometimes they lead to severe and systematic errors" (Tversky and Kahneman, 1974, p. 1124). For example, the availability heuristic (Nisbett and Ross, 1980; Tversky and Kahneman, 1974) expects individuals to give greater weight to evidence they can easily recall. Thus, it may be easier to recall sporadic but salient media accounts of allegedly adverse effects, although these are far less frequent than cases in which vaccine uptake has no significant side effects, which are rarely reported. In conclusion, individuals are rational but within limits, and these limits might be generated by the way our cognition works.

Individuals' cognitive differences in viewing vaccination uptake have seldom been addressed, but as Frederick (2005) notes, "a neglected aspect does not cease to operate because it is neglected, and there is no good reason for ignoring the possibility that ... various ... cognitive abilities are important ... determinants of decision making" (p. 25). From a sociological standpoint, this notion is even more important if we recognize that specific cognitive traits can be both individual and socially distributed. Different individuals, distant in time and space, might show similar cognitive characteristics associated with the same preferences (Brekhus, 2015; Vaisey, 2009).

We address this gap by adopting a dual-process cognitive framework, which suggests that, compared to analytical thinking, intuitive thinking might be a source of vaccine hesitancy, and that several risk perceptions can indirectly intervene in this association.

We used data from original surveys carried out between September and November 2019 in Italy. The surveys assessed individuals' ability to overcome intuitive thinking, and they collected fine-grained measures of risk perceptions. We rely on Karlson, Holm, and Breen (2012) decomposition (henceforth KHB decomposition) to measure the total, direct, and indirect association of cognitive styles with vaccine hesitancy and to disentangle the contribution of each element od perceived risk.

Results are important not only to improve our understanding of vaccine hesitancy but also to suggest where or how future research might be directed to develop effective strategies to increase vaccination coverage.

2. Theoretical Framework

2.1 Two Systems of Cognition

The distinction between two kinds of thinking, one fast, intuitive, and heuristic, the other slow, effortful, and deliberative, has its origins in the 1970s and 1980s (Evans and Stanovich, 2013). It has recently seen wide application to a variety of processes, especially in psychological research (Gervais, 2015). "Dual-process modes of cognition" have been studied extensively by cognitive neuroscientists, and research has shown that cognition is characterized by two systems—System 1 and System 2 (Stanovich and West, 1998). These systems generate two basic types of cognitive processing. Different names are given to these structures and processes: fast/slow (Kahneman, 2011), practical/discursive (Vaisey, 2009), intuitive/deliberate (Evans and Stanovich, 2013). In this chapter, we refer to System 1 processes as automatic cognition and to System 2 processes as analytic cognition. The most important distinction "is the principle that there are two different types of cognitive processing, one being autonomous ... and the other requiring controlled attention" (Leschziner, 2019, p. 4). Automatic cognition is "effortless, immediate, universalized and subconscious thought" (Brekhus, 2015, p. 29), which we process efficiently without much review. Automatic cognition allows us to rely on a sort of "automatic pilot", quickly responding to stimulus without conscious effort. Analytic cognition "involves slow, deliberate, conscious, verbalized thought processes" (Brekhus, 2015, p. 29), implying a different neural experience. When engaged in analytic thinking, individuals may reject or override their previous assumptions from automatic cognition and put active effort into cognitive activities (Cerulo, 2002). It could be said that analytic cognition is our deep-level cognitive method, but several studies on these dual processes have shown that automatic cognition is often the system in charge (Vaisey, 2009).

The relationship between the two systems has been the object of several investigations (for a partial review, see Evans and Stanovich, 2013). One widely

accepted view maintains that System 1 oversees most of our day-to-day decisions, while System 2 is primarily concerned with developing justifications for decisions already made by System 1 (Moore, 2017). In this view, the two systems work sequentially. On the other hand, some sociological formulations suggest that in many situations, decisions are made using either System 1 or System 2 (Brekhus, 2015; Vaisey, 2009), with the two systems working in parallel. In this chapter, we treat System 1 and System 2 as parallel but interactive systems, where both are assumed to contribute to behaviors with a shifting degree of strength (Epstein, 2014), and this strength varies as a function of the individual's characteristics and the situation. Crucially, evidence has suggested that different people employ and rely on each of these systems with varying degrees of strength: Epstein (2014) elaborated a comprehensive theory, the "Cognitive-Experiential Theory", in which he suggests that some people favor the use of System 1 (the "experiential system", in Epstein's words), while others tend to use System 2 more (the "rational" system). An individual's characteristics and context affect the way they process information, more experientially or more rationally, and the overall orientation between this dichotomy affects day-to-day tasks, such as behaviors and decision-making (Anderson, 2016). This suggests that different individuals show different thinking dispositions (Stanovich and West, 1998), some leaning toward a more "intuitive style", characterized by the prevalent use of automatic cognition, others toward a more "analytic style", where analytic cognition is more often in charge. This orientation has been supported by several empirical contributions (Chaiken and Trope, 1999; Epstein, 1994; Evans, 2008) (for a different interpretation of thinking styles, see Evans and Stanovich, 2013).

A dual processes framework of cognition has several implications for a theoretically informed analysis of vaccine hesitancy. The most important consequence of the existence of a non-deliberative processing system is that it must be considered as an important corrective to theories of rational action which dominated health models. Furthermore, looking at dual systems of cognition not only as cognitive systems but also as cognitive styles, allows us to explore whether vaccine hesitancy is a product, not just of people's beliefs, but also of the way individuals process, store, retrieve, and use information.

2.2 Styles of Cognition and Vaccine Hesitancy

Although vaccine hesitancy has only recently begun to be examined by considering styles of cognition, several studies have looked at individual differences in the degree to which people operate in the two modes and how intuitive thinking relates to various unscientific beliefs (Evans and Stanovich, 2013; Greene et al., 2001; Kahneman, 2011; Petty and Cacioppo, 1986; Sloman, 2014). The analytic style has been positively associated with a higher level of acceptance of scientifically verifiable beliefs, and the intuitive style to several beliefs united by their varying absence of verification (Anderson, 2016). These include religion, pseudo-sciences, supernatural phenomena, the paranormal, and conspiracy theories (Aarnio and Lindeman, 2005; Browne et al., 2014; Genovese, 2005; Gervais, 2015; Gervais and Norenzayan, 2012; Pennycook et al., 2013). For example, while cognitive styles are almost certainly not the sole cause of religious belief or disbelief, research has found that individuals leaning toward a more intuitive style rely more frequently on epistemologies that value insights of a spiritual, metaphysical, or revelatory nature, devaluing more "rationalist" approaches to knowledge (Browne et al., 2014; Pennycook, 2014). Conversely, analytic thinking strategies are a source of religious disbelief (Gervais and Norenzayan, 2012, but see Camerer et al. (2018) on the failure to replicate the original experiment). Intuitive thinking facilitates belief in supernatural agents, such as supernatural creation stories as an explanation for diversity on Earth (Gervais, 2015), while "individuals who are better able to analytically control their thoughts are more likely to eventually endorse evolution's role in the diversity of life and the origin of our species" (Gervais and Norenzayan, 2012, p. 320). Intuitive thinking is positively associated with paranormal beliefs (Aarnio and Lindeman, 2005), a kind of belief related to poor critical thinking and limited rationality (Gray and Mill, 1990; Musch and Ehrenberg, 2002). Analytic thinking, on the other hand, "is assumed to be a generative mechanism that, through education, decreases paranormal beliefs" (Aarnio and Lindeman, 2005, p. 1228). Along the same lines, Genovese (2005) has shown that the lowest levels of paranormal belief are found among analytical thinkers and that a person's thinking style contributes, alongside other individual characteristics, in shaping that individual's beliefs.

Although only a few studies have investigated this specific association in cases of vaccine hesitancy (see Anderson, 2016; Schindler et al., 2020; Tomljenovic et al., 2019; Tomljenovic et al.,2020), research has shown that, under incomplete information, individuals might stumble across heuristic cognitive flaws that support several vaccine misconceptions (Jacobson, 2007). Poland et al. (2014) reviewed several heuristics, finding that their use is associated with automatic processing and greater vaccine skepticism. Intuitive thinking is characterized using heuristics, and individuals who lean toward an intuitive thinking style have been found to share various misconceptions about vaccination (Poland et al., 2014). Therefore, intuitive thinking might hide a certain level of vaccine hesitancy. Recent research by Schindler et al. (2020) underlines how the perception of the low prevalence of VPDs, combined with prominent accounts of vaccine side effects, might have generated an intuitive response that disparages the safety and usefulness of vaccines. Tomljenovic et al. (2020) show that parents who rely more on intuitive reasoning were more likely to endorse invalid statements, advocate vaccine avoidance, or even support conspiracy theories about vaccinations.

2.3 Vaccine Hesitancy, Cognitive Styles, and Risk Perception

Prior research has allowed us to hypothesize the existence of a direct association between thinking styles and vaccine hesitancy, where support for unscientific claims and vaccine hesitancy are connected to the use of heuristics, a typical feature of automatic thinking.

At the same time, it must be recognized that being vaccine-hesitant is also the result of complex processes. Vaccine hesitancy is, in fact, one outcome of a broader contemporary debate about modernity and risk: dangers might be real, but risks are socially constructed (Slovic, 2005). Beck (1992) described modernity as a “risk society”, a time when rapid technological development has reduced the perception of dangers as inevitable. This has encouraged individuals to minimize risks to make their future secure (Giddens, 1999). As a result, perceived hazards increasingly belong to the category of “manufactured uncertainties” (Beck, 1992). They are the direct but unintended consequences of scientific progress. This is particularly true for health, which has become a “super value” (Price et al., 2016). In a very specialized

environment, where individuals must delegate knowledge in many fields, fear of unintended consequences may lead to a lack of trust not only in a product but also in the technology, science, and institutions that stand behind it. This associates several "hot-button issues such as pandemics, GMO foods, [and] stem-cell research, [that] raised the fears and consciences of Western industrial nations" (Price et al., 2016, p. 59). Vaccinations clearly have not escaped this process (Peretti-Watel et al., 2015). Empirical research has shown multiple times that the way individuals perceive risks is a strong predictor of vaccine endorsement (Brewer et al., 2017; Floyd et al., 2000;). This appears to apply also to the COVID-19 pandemic, where several studies underlined the importance of perceived risks of the disease in driving the decision to immunize (Attema et al., 2020; Caserotti et al., 2020, in the Italian context; Dryhurst et al., 2020). Most research has categorized risks in the way classic models of health behavior did, assuming that people pay close attention to likelihood and odds. Nevertheless, a systematization of dimensions involving risk perception (Slovich et al., 2005) has found that people have a conception of risk that is broad, qualitative, and complex, and it calls into play individuals' cognitive systems. Recent literature has shown, in fact, that a series of circumstances can lead individuals to neglect probability and that, more generally, individuals are not very good judges of probability (Kahneman, 2011). Kahan (2014) suggested that individuals' assessments of the risk of vaccination are guided not solely by the calculus of objective risks and benefits, but also by an affective dimension. "In potentially risky scenarios, people tend to judge the options that feel right to them as the safest, often completely failing to calculate objective odds of risk" (Anderson, 2016, p. 4). In this view, people base their assessments of an activity or technology—such as vaccination—not merely on what they think about it, but also on the way they feel about it. This strategy has been referred to as "affect heuristic" (Finucane et al., 2000). Although several researchers have investigated the relationship between cognitive styles and support for unscientific claims, we know little about the association between cognitive styles and risk perception. As Frederick states, "in the domain of risk preferences, there is no widely shared presumption about the influence of cognitive ability" (2005, p. 32). Nevertheless, that author has shown how these two elements are strongly tied together. Individuals may, in fact, differ in the extent to which the intuitive or analytic style

influences their perceptions of risk. “For example, whereas a medical professional’s understanding of risk as statistical probability may be more heavily influenced by the deliberative system, a lay understanding may rely on more experiential ways of knowing” (Reventlow et al., 2001, in Slovic et al., 2005, p. 37). For example, in the COVID-19 pandemic, contact with individuals affected by the virus resulted in an engagement of the intuitive system, closely connected to the affective processing of risk (Dryhurst et al., 2020). In this chapter, we aim to explore the possibility that individuals’ thinking styles show a direct association with vaccine hesitancy and an indirect one through risk perceptions.

Three research questions drive this chapter:

Q1: Are thinking styles directly associated with vaccine hesitancy?

H1: We hypothesize that, if there are qualitative differences in individuals’ ability to inhibit or override intuitive thinking, individuals characterized by an intuitive thinking style may show a greater probability of being vaccine-hesitant, net of other individual characteristics.

Q2: Are thinking styles associated with risks perception?

H2: We hypothesize that, on average, individuals characterized by an intuitive thinking style differ from individuals characterized by an analytic thinking style in the way they articulate risks perception.

Q3: Does risks perception intervene in the relationship between cognitive styles and vaccine hesitancy?

H3: We hypothesize that the overall degree of association between thinking styles and vaccine hesitancy, if any, can be decomposed into a direct association and an indirect one acting through risk perceptions.

Understanding whether individual thinking styles correlate with vaccine acceptance should help us expand our knowledge of the determinants of vaccine hesitancy. This would be a first step toward including these elements more frequently in analyses of vaccine hesitancy. In addition, as previous research has advocated, determining which cognitive styles individuals lean toward could help provide more tailored information (Poland et al., 2014). Understanding whether individuals characterized by different thinking styles and perceptions of risk tend to accept

vaccination could invite further research into the usefulness of including these characteristics in developing effective strategies to decrease vaccine hesitancy.

3. Data, Variables, and Methods

3.1 Data[1]

We used a dataset obtained from two collections of primary data. The first was a survey administered in September and October 2019, and the second was a follow-up questionnaire circa 15 days after the completion of the main questionnaire, in November 2019. We used a non-probabilistic quota-sampling method and interviewed 1008 Italian citizens taking part in an online panel run by a major Italian survey company. The response rate to the follow-up questionnaire was 94.4 %, reducing the total sample size to 952 respondents. To compute cell sizes in the first survey, respondents were stratified by gender, age, geographical location, and educational level. The number of individuals in the gender and age classes, and the geographical location strata, was proportional to the 2018 Italian population, as surveyed by ISTAT, the Italian National Institute of Statistics. Educational levels (low, medium, high) were distributed equally in the sample population. To account for this sampling characteristic, probability weights were applied in the analysis. Quota sampling, although being far from an ideal probabilistic sampling method, was chosen after careful consideration of the research funds available, the research goals, and the need to obtain accurate data in the Italian context. For this reason, point estimates in the following analysis should be carefully considered, always taking the limitations of this method into account. On the other hand, the opportunity to collect primary data on this theme gave us access to a qualitatively complex dataset. It combined measures that, to the best knowledge of the authors, have not been surveyed together before.

3.2 Variables

[1] Data and code to replicate the analysis is available on OSF.io: https://bit.ly/3kjkIdQ

Variables used in the analysis, with one exception (described below), were all covered in the first survey. A complete description of survey questions, variables, and coding can be found in Table 1 in the appendix. Our outcome variable was whether the respondent would hesitate to administer to a hypothetical child the mandatory and recommended vaccinations in Italy, indicating the degree of hesitancy on a scale from 0 to 10. Given the skewed distribution (*M:* 3.05; *SD:* 3.5; *Mdn:* 1), we re-expressed the variable as a dichotomy: 0 indicated no hesitancy and 1 indicated hesitancy.

Our main predictor variable was the individual's thinking style. To assess this, we relied on an extended version of the Cognitive Reflection Test (CRT) (Frederick, 2005) proposed by Primi et al. (2015), containing the three original CRT questions and three additional questions suited for a less highly educated sample (CRT-Long). The three original CRT questions were presented as the first question in the first questionnaire, and the three additional CRT-L items were the first question of the follow-up questionnaire. We combined the six items, obtaining the full CRT-L test. The CRT-L test is relatively simple, and the solution to each problem is easily understood once explained. The difficulty consists in overriding a heuristic answer that immediately springs to mind and looking for the correct answer by engaging in analytic thinking. Frederick (2005) has shown how, among all the incorrect answers, the heuristic one dominates. This suggests that it is indeed possible to distinguish individuals who engage in analytical thinking from those who answer intuitively. To clearly distinguish individuals leaning toward a more intuitive thinking style from those in whom an analytic style dominated, we recoded our main predictor variable to four categories. Individuals who gave the correct answer to four or more questions were assigned to the analytic style, as were individuals giving three correct answers, one heuristic answer, and two incorrect answers (or two heuristic and one incorrect). Conversely, individuals who gave the clearly heuristic answer to four or more questions were assigned to the intuitive style, as were individuals giving three intuitive answers, one correct answer, and two incorrect answers (or two correct and one incorrect). The first residual category comprised individuals who gave the most incorrect answers, constructed with the same rationale of the two previous categories. They were classified as incorrect. The second residual category comprised individuals who gave an equal number of correct, incorrect, and heuristic answers (for example, two correct, two

heuristic, and two incorrect answers, or three correct and three heuristic answers). They were categorized as unassigned. For the sake of clarity and given the scope of this study, throughout the chapter, we compare only individuals showing an intuitive style with those showing an analytic style. In the appendix section, we report full tables including the incorrect and unassigned categories, and we also show that, despite differences in point estimates, our main results are robust to different CRT-L scoring methods.

To survey indicators of risk perception (RP), questions were preceded by asking respondents to imagine they must take care of a child, today, in Italy. We measured four distinct risk perception concepts: severity of a disease, likelihood of contagion, susceptibility to illness, and feeling at risk. The severity of disease was represented by the perceived magnitude of an adverse event (Becker, 1974), such as a VPD. The likelihood of contagion was defined as the perceived "probability of being harmed by a hazard under certain behavior conditions" (Brewer et al., 2007, p. 137). Therefore, this was a probability assessment. Perceived susceptibility was articulated both as a general property of the hypothetical child—a "constitutional" vulnerability to diseases—and as perceived risk, specifically from VPDs. The fourth dimension, "feeling at risk," followed the intuitions of Slovic et al. (2005) and Kahan (2014), who suggested that "one can define risk as an 'analysis' (e.g., a probability judgment) or risk as a 'feeling'" (Weinstein et al., 2007, p. 147). In this interpretation, risk can be defined as an affective state, distinct from cognitive judgment. To measure the perceived likelihood of contagion and feeling at risk, we presented two hypothetical scenarios, asking respondents to imagine that the child has not been vaccinated, and the converse. We named the corresponding variables Conditioned on vaccination and Not conditioned on vaccination. Most empirical studies use only unconditioned questions, returning answers that may be biased by the individual's memory of having (or not having) received a treatment (Brewer et al., 2007). Additional questions investigated the perception of probability and severity of side effects. Following Weinstein et al. (2007), we asked participants to answer using a seven-point Likert scale, an approach found to be more balanced across individuals' demographic characteristics. Respondents were also allowed to say that they don't know their position on a question. Given the limited sample size and the small number of individuals choosing this option,

"don't know" responses were treated as "having a mixed opinion", corresponding to a value of four on the seven-point scale. All RP indicators were standardized to have $M = 0$ and $SD = 1$. Control variables were respondent's educational level (lower: up to 8 years of education; medium: up to 13 years of education; higher: more than 13 years of education), gender, age, whether respondents have children (categorized as 0 = no, 1 = one, 2 = more than one), and geographic area of residence (northeast, northwest, center, and south and islands).

3.3 Methods

The empirical analysis was divided into four logically consequent steps investigating 1) the association between thinking styles and vaccine hesitancy; 2) the relationship between thinking styles and measured RP; 3) the association between measured RP and vaccine hesitancy; and 4) the total, direct, and indirect association of cognitive styles with vaccine hesitancy, assessing the contribution of each RP measure to the indirect association.

In the first step, we measured the association between cognitive styles and vaccine hesitancy, first bivariate (m1) then controlling for individual characteristics (m2). This step assessed the existence of a relationship between thinking styles and vaccine hesitancy, estimated the strength of the total association, and measured its change after controlling for individual characteristics. Given the known difficulties in comparing coefficients of nested nonlinear models (Mood, 2010), we use KHB decomposition (Karlson et al., 2012) rescaling (m1) and (m2) based on the final-most saturated model (m12). KHB decomposition compares a full model containing additional variables with a reduced model, where the variables not required are replaced with their residuals after a linear regression of those variables on the key predictor variable (Triventi, 2013). This method let us disentangle the change in coefficients based on confounding and the change from rescaling, which is of no substantive interest (Kohler et al., 2011; Triventi, 2013). In other words, KHB allow us to interpret the coefficients of direct and indirect associations of nonlinear models as is commonly done for linear regression models, estimating coefficients of additional variables while considering the problem of rescaling (Connelly et al., 2016; Kohler et al., 2011).

The full model is:

$$(m12): \left(\frac{PrVh}{1-PrVh}\right) = \alpha + \beta_{1F}TStyle + \beta_{2F}RP + \beta_{3F}C + \epsilon$$

where $TStyle$ represents the individual's thinking style, RP represents eight measures of risk perception, and C summarizes several individual characteristics.

The reduced models (m1) and (m2)—before rescaling—are:

$$(m1): \left(\frac{PrVh}{1-PrVh}\right) = \alpha + \beta_{1R}TStyle + \epsilon$$

$$(m2): \left(\frac{PrVh}{1-PrVh}\right) = \alpha + \beta_{1R}TStyle + \beta_{2R}C + \epsilon$$

KHB extracts the information not contained in X by calculating the residuals of a linear regression of βRP on $\beta TStyle$, to obtain the indirect association given by $\beta_R - \beta_F$, net of confounding attributable to rescaling:

$$R = \beta RP - (\alpha + \beta TStyle)$$

where α and $\beta TStyle$ are estimated coefficients of the linear regression. R is then used in the reduced models (m1) and (m2):

$$(m1): \left(\frac{PrVh}{1-PrVh}\right) = \alpha_R + \beta_{1R}TStyle + \beta_{2R}R + \epsilon$$

$$(m2): \left(\frac{PrVh}{1-PrVh}\right) = \alpha_R + \beta_{1R}TStyle + \beta_{2R}R + \beta_{3R}C + \epsilon$$

To compute indirect associations, the difference between the estimated coefficients is:

$$\beta_R - B_F = \frac{\beta_R}{\sigma_R} - \frac{\beta_F}{\sigma_F} = \frac{\beta_R - \beta_F}{\sigma_F}$$

Because R and RP differ only in the part of RP that is correlated with $TStyle$, the difference between coefficients is divided by some common value. This ensures the existence of a common standard deviation σ_F between models, allowing their magnitude to be compared (Kohler et al., 2011).

The second step examined the relationship between thinking styles and measures of RP through eight different linear regressions, controlling for individuals' characteristics:

$$(m3 - m10): RP = \alpha + \beta_1 TStyle + \beta_2 C + \epsilon$$

This step allowed us to verify whether, following Frederick (2005), thinking styles were related to the way individuals perceived risks and, more deeply, with which specific risk perception measures they have an association.

The third step investigated the association between RP measures and vaccine hesitancy, using multivariate logistic regression and controlling for individual characteristics. The model is:

$$(m11): \left(\frac{PrVh}{1 - PrVh}\right) = \alpha + \beta_3 RP + \beta_2 C + \epsilon$$

This analysis is important for verifying which risk perception measures were correlated with the outcome.

In the fourth and last step, we a) estimated the total, direct, and indirect association of thinking styles with vaccine hesitancy and b) decomposed the indirect relationship to estimate the contribution of each RP indicator, controlling for individual characteristics.

The equation for the full model is:

$$(m12): \left(\frac{PrVh}{1 - PrVh}\right) = \alpha + \beta_{1F} TStyle + \beta_{2F} RP + \beta_{3F} C + \epsilon$$

4. Results

4.1 Association of Thinking Styles with Vaccine Hesitancy

The first step examined the relationship between thinking styles and the probability of being vaccine-hesitant. Figure 3.1 reports average marginal effects for a bivariate logistic regression (the dark grey bar) predicting the probability of vaccine hesitancy, comparing the intuitive thinking style with the analytic thinking style, and

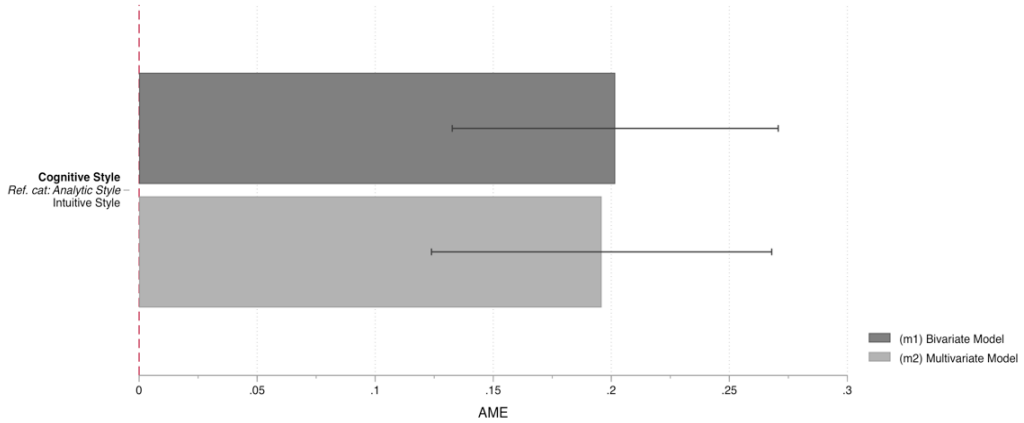

Figure 3.1 – Bivariate Logistic regression (m1) and multivariate logistic regression (m2) predicting vaccine hesitancy: average marginal effects (AME) of intuitive style versus analytic style. In (m2) AME controlled for individuals' sociodemographic characteristics (educational level, gender, age, number of children, geographical area of residence) and general susceptibility to disease. Weighted coefficients, 95 % CIs.

the same model controlling for individuals' sociodemographic characteristics and individuals' general susceptibility to disease (the light grey bar).

In model 1, individuals who showed an intuitive style were, on average, 20.2 percentage points (pp) more likely to be vaccine-hesitant than those showing an analytic style. Controlling for individual characteristics, the average marginal effect decreased to 19.6 pp. Contrary to previous studies in the Italian context (Anello et al., 2017), we found a positive relationship between educational level and the probability of accepting vaccination. This was in line with recent multi-country analysis (Makarovs and Achterberg, 2017). In addition, respondents with more than one child were

generally less likely to be vaccine-hesitant. To interpret this result, we argued that where one child had been immunized and did not suffer severe side effects, this promoted vaccine acceptance. Finally, we found a significant divide between the southern Italian region and the rest of the country. Individuals living in the south were more likely to be vaccine-hesitant (see Table 2 in the Appendix).

This result suggests two considerations. First, it shows empirically that cognitive styles do indeed correlate with vaccine hesitancy, after controlling for individuals' sociodemographic characteristics. It also shows that individual characteristics, although certainly relevant, reduce this association only slightly. In other words, the relationship between cognitive styles and vaccine hesitancy appears not to be significantly stratified according to individual characteristics. This is an important result, since few studies have investigated the relationship between cognitive styles and vaccine hesitancy, and here we showed how this correlation existed even where individual characteristics were held constant.

4.2 Association of Cognitive Styles with Risk Perception Measures

In the second part of the analysis, we examine whether cognitive styles were associated with measures of RP, and if so, how. Figure 3.2 reports coefficients of eight multivariate linear regressions where the outcome variable was a risk perception measure and the main predictor variable was thinking style, controlling for individual characteristics.

Overall, a clear pattern emerged: compared to the analytic style, the intuitive style was associated with a decrease in RP (questions not conditioned on vaccination) and, conversely, with an increase in RP (questions conditioned on vaccination). More specifically, compared to the analytic style, the intuitive style was associated with a decrease in the perceived severity of VPDs, the perceived susceptibility to VPDs, the perceived likelihood of contagion, and the feeling of vulnerability where not vaccinated.

Conversely, it was associated with increases in the perceived likelihood of contagion, the feeling of vulnerability, and the perceived probability of side effects. Individuals who exhibit an intuitive thinking style, therefore, seem to see vaccination

as increasing perceived risk. It is important to note that thinking styles are strongly associated with affective perceptions over assessments of probability.

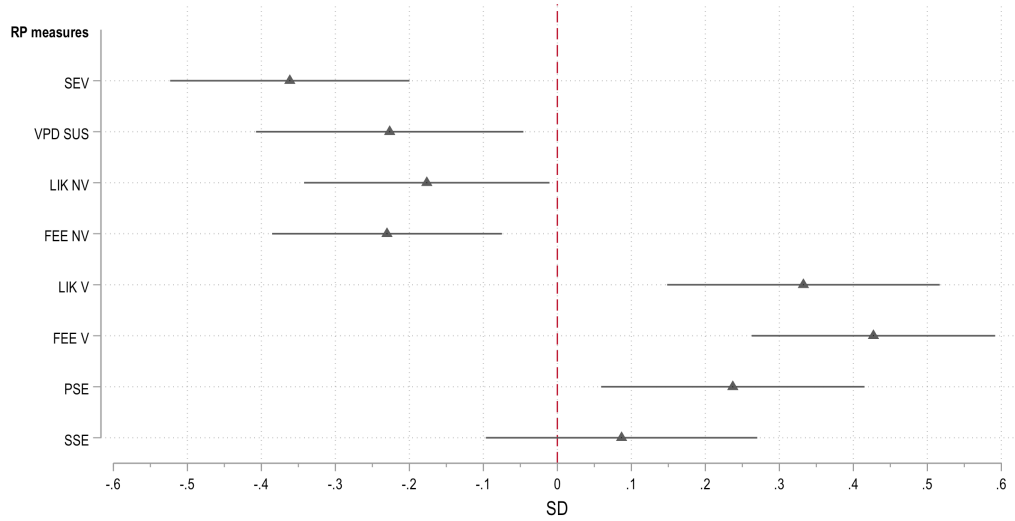

Figure 3.2 – Multivariate linear regression (m3–m10) estimating the association of intuitive thinking versus analytic thinking style on measures of risk perception. All indicators have been standardized. All models are controlled for individuals' sociodemographic characteristics (educational level, gender, age, number of children, geographical area of residence) and general susceptibility to disease. Weighted coefficients, 95 % CIs.
SEV = Perceived severity of VPDs; VPD SUS= Susceptibility to VPDs; LIK NV= Perceived likelihood of contagion conditioned on no vaccination; FEE NV=Perceived feeling of vulnerability conditioned on no vaccination; LIK V=Perceived likelihood of contagion conditioned on vaccination; FEE V=Perceived feeling of vulnerability conditioned on vaccination; PSE= Probability of side effects; SSE=Severity of side effects.

4.3 Association of Risk Perception Measures with Vaccine Hesitancy

Figure 3.3 reports the average marginal effects for a logistic regression where measures of risk perception were regressed on vaccine hesitancy, controlling for individual characteristics.

Surveying a wide range of theoretically driven measurements of perceived risk, the results pointed toward a complex scenario. The likelihood of contagion, whether conditioned on vaccination, was not significantly associated with a change in the probability of vaccine hesitancy. This result is particularly important, given that extensive literature has found an association between the likelihood of contagion and

the propensity to support vaccination. Our analysis suggested, on the contrary, that an

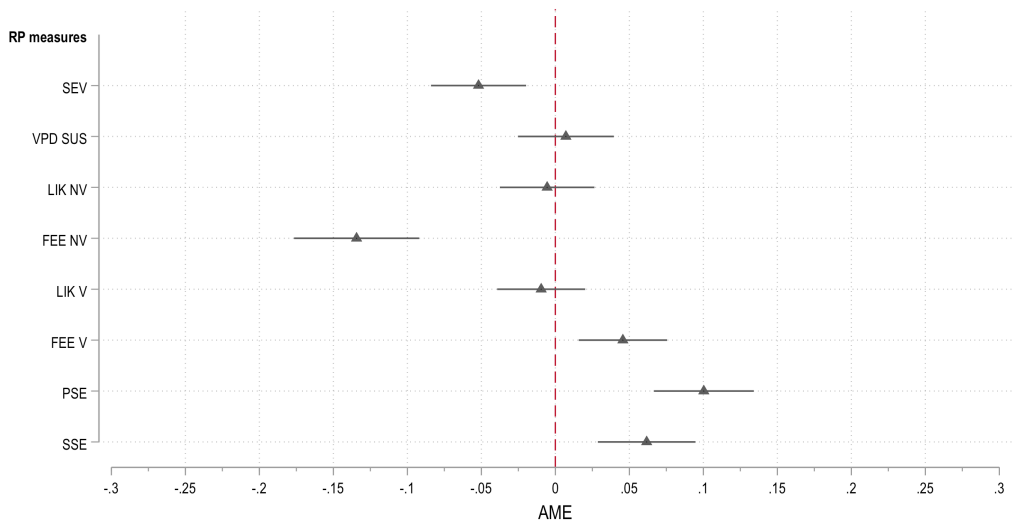

Figure 3.3 – Logistic regression (m11) predicting vaccine hesitancy by risk perception measures. AMEs controlled for individuals' sociodemographic characteristics (educational level, gender, age, number of children, geographical area of residence) and general susceptibility to disease. All indicators have been standardized. Weighted coefficients, 95 % CIs.

assessment of probability was not associated with the outcome, whereas we found a strong association between vaccine hesitancy and perceived feelings of vulnerability. Conditioned on no vaccination, an SD increase in the feeling of vulnerability to VPDs was associated with a 13.4 pp decrease in the likelihood of being vaccine-hesitant. At the opposite end of the spectrum, conditioned on vaccination, an SD increase in feelings of vulnerability to VPDs was associated with a 4.6 pp increase in the likelihood of being vaccine-hesitant. In other words, without vaccinations, individuals who felt vulnerable to VPDs were less likely to be vaccine-hesitant, whereas, after vaccinations, individuals who felt more vulnerable to VPDs were more prone to be vaccine-hesitant.

This suggests that emotional judgments have a higher impact on subjects' understanding of the protective effects of vaccinations, while probability-based cognitive judgments are not associated with vaccine hesitancy. In line with prior research, an increase in the perceived severity of diseases was associated with a

decrease in the probability of vaccine hesitancy, whereas perceived susceptibility to VPDs was not. Finally, as expected, increases in both the probability and the severity of side effects were associated with increases of 10.0 pp and 6.2 pp, respectively, in the likelihood of vaccine hesitancy. Individuals perceiving vaccination as carrying frequent or harsh side effects were, therefore, more prone to be vaccine-hesitant.

4.4 Total, Direct, and Indirect Association of Cognitive Styles and the Role of Risks Perception

In this final section we relied on KHB decomposition to 1) estimate the total, direct, and indirect association of cognitive styles with vaccine hesitancy, and 2) understand how perceptions of risk are called into play in this relationship, disentangling the contribution of each RP measure.

Table 3.1 reports average marginal effects of total, direct, and indirect association between intuitive versus analytic thinking style and vaccine hesitancy.

Table 3.1 – KHB decomposition predicting the probability to be vaccine hesitant. AMEs of total, direct, and indirect association of intuitive style, compared with analytic style, and corresponding significance levels. Robust SE in parentheses.

	Dependent variable: Probability to be vaccine hesitant		
	Total effect (reduced model) (m2)	**Direct effect** (full model) (m11)	**Indirect effect** (est. difference)
Cognitive style *Ref category: Intuitive style*			
Analytic style	0.1959***	0.1006**	0.0953***
	(0.0368)	(0.0372)	.
Confounding ratio	1.9153		
Confounding percentage	47.79		
Rescaling factor	1.4175		

**** p<0.001, ** p<0.01, * p<0.05;* robust standard errors in parentheses

Note: SE not available for AME of indirect association. A table reporting odds ratios, SE, and significance levels for the estimated difference is available in the Appendix.

We also report the confounding ratio between the reduced model (m2) and the full model (m12), the percentage reduction attributable to risk perception variables (the confounding percentage), and the rescaling factor applied to (m1) and (m2), based on the most saturated model (m12). Controlling for individual characteristics, individuals

leaning toward an intuitive rather than an analytic thinking style showed an increase, on average, of 19.6 pp in the likelihood of vaccine hesitancy, as shown in (m2). After controlling for risk perceptions, the direct association of intuitive style with vaccine hesitancy declined to an average of 10.0 pp greater than the analytic style. This left an indirect positive association through risk perceptions of 9.5 pp. In other words, as reported in the second part of Table 3.1, the total association was 1.92 times the direct association, and 47.8 % of the total association was attributable to all RP measures combined.

Substantively, this suggests that there was indeed a direct relationship between thinking styles and vaccine hesitancy and that this association was at least as strong as the indirect association through the risk perceptions we measured. The intuitive thinking style led to lower perceived risk without vaccinations and higher risk perception with vaccination. This translates, on average, into a 9.5 pp greater probability of being vaccine-hesitant. At this point, the question moves to which of the risk perception variables contributes most to the indirect association. Figure 3.4 reports the percentage contribution of each RP variable to the difference between the full (m12) and the reduced model (m2).

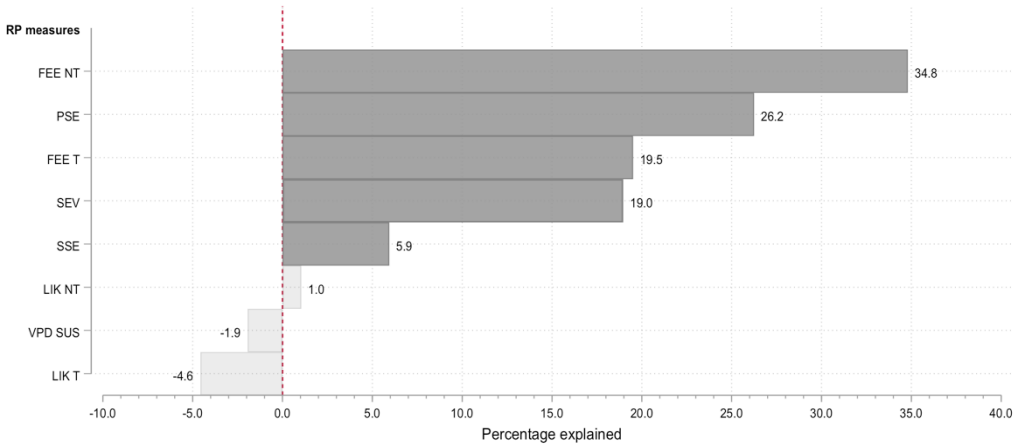

Figure 3.4 – Percentage contribution of each risk perception variable to the indirect association of intuitive style on the probability of vaccine hesitancy, compared with analytic style. Dark gray bars indicate statistically significant associations at $p < 0.05$.

As Figure 3.4 shows, five out of eight measures of risk perception were significantly associated with vaccine hesitancy.

Feelings of vulnerability conditioned on no vaccination accounted for almost 35 % of the indirect association, where an *SD* increase resulted in the probability of vaccine hesitancy decreasing by 13.6 pp. In descending order, the perceived probability of side effects followed, accounting for 26.2 % of the indirect association (−9.9 pp on the probability of vaccine hesitancy), then feelings of vulnerability conditioned on vaccination (19.5 % of indirect association, −4.1 pp on the probability of vaccine hesitancy), perceived severity of diseases (19 % of indirect association, −4.7 pp on the probability of vaccine hesitancy), and, last, the perceived severity of side effects (5.9 % of indirect association, −6.1 pp on the probability of vaccine hesitancy).

KHB decomposition results pointed toward three considerations. First, controlling for individual characteristics and measures of risk perception, the cognitive style had a direct, surveyable association with the probability of vaccine hesitancy. Individuals leaning toward an intuitive thinking style were more prone than those leaning toward an analytic style to be vaccine-hesitant. Second, part of this total relationship was spurious, and it operated indirectly by influencing individuals' risk perceptions. Third, the indirect association of cognitive styles with vaccine hesitancy through risk perceptions revealed a more complex picture than the one depicted by most research on the theme. Feelings of vulnerability counted for more than 54 % of the indirect association of thinking styles with the probability of vaccine hesitancy. This showed the centrality of this sometimes-neglected concept.

5. Discussion and Conclusion

Understanding beliefs, motives, and reasons behind vaccine hesitancy is an important task from both an academic and a very pragmatic public policy perspective. Discussions of cognitive differences in vaccine hesitancy do not appear often in academic literature, with the remarkable exceptions (Anderson, 2016; Schindler et al., 2020; Tomljenovic et al., 2019; Tomljenovic et al., 2020). Nonetheless, an extensive set of contributions based on the dual process of cognition framework has shown how cognitive characteristics play a significant role in shaping human perceptions,

decisions, and behavior. Importantly, recent research has shown that individuals appear to use one style more frequently than the other, preferring intuitive or analytic processes (Chaiken and Trope, 1999; Epstein, 1994, 2014; Evans, 2008; Pacini and Epstein, 1999, in Anderson, 2016) and thus revealing different thinking styles. In this chapter, we investigated how thinking styles correlated with vaccine hesitancy and tested a mechanism by which the relative magnitude of the total association between intuitive cognitive style and vaccine hesitancy could be decomposed into both a direct and an indirect association, through several measures of risk perception.

In the first part of the analysis, we showed how the intuitive style was associated with an increase in the probability of vaccine hesitancy, even after controlling for individual characteristics. In the second part, we showed that the intuitive style was associated with more perceived risks of VPDs conditioned on vaccination. This suggested that vaccination was perceived as a factor that increased vaccine hesitancy. In the third part of the analysis, we evaluated how perceptions of risk were associated with the probability of vaccine hesitancy, showing the importance of including affective perceptions in the analysis. In the last part of the analysis, we showed empirically that, overall, the association of the intuitive thinking style, compared to the analytic thinking style, can be decomposed into two approximately equal, direct, and indirect associations through measures of risk perception. Disentangling the contribution of each RP measure, we once again found that affective feelings accounted for over half of the indirect association with perceived risk, together with the important contribution of perceptions of the probability and severity of side effects.

The importance of considering cognitive characteristics to explain how individuals make decisions has a long-standing tradition in psychology and social psychology. On the other hand, sociologists interested in vaccine hesitancy have often emphasized the role of individual sociodemographic characteristics, contextual socioeconomic factors, and perceptions. With the seminal paper of DiMaggio (1997) and the work of Cerulo (2002), a more interdisciplinary approach developed to understand how mechanisms of cognition are used to interpret culturally specific dynamics (Brekhus and Ignatow, 2019). In this chapter, we aimed at contributing to

this cognitive sociology approach by showing how embedded cognitive characteristics were indeed correlated with the way individuals develop

opinions and form preferences about vaccine hesitancy. In addition, while sociology often underlined the importance of perceived risks, applied to vaccine hesitancy, this often happened through the lenses of classic models of health behavior. In this chapter, we instead exploited several theoretically distinct concepts that revealed a complex pattern of associations in the empirical analysis, both directly between measures of risk perception and vaccine hesitancy and indirectly in the association between cognitive styles and vaccine hesitancy.

Three main contributions can be drawn from this analysis.

First, incorporating what we now know about human cognition into sociological discourse can provide a better understanding of motives, beliefs, and attitudes behind human behavior. In this specific case, we showed that thinking styles are associated with the outcome we examined, even after controlling for individual characteristics. This showed the importance of taking this dimension into account. Second, we believe this exploratory study could be a starting point for developing more specific knowledge about the importance of including individual cognitive characteristics in strategies to increase vaccine acceptance. For example, recent research (Schindler et al., 2020) suggested that, in face-to-face settings, increasing participants' awareness of their intuitive feelings and suggesting how to monitor them could be valuable. Third, individuals' concerns about VPDs and the risks of vaccination are legitimate anxieties that should be addressed attentively by understanding the exact points they insist on. This chapter has shown how individuals' risk perceptions are less concerned with assessments of probability and more with affective states and emotional perceptions. Previous studies have underlined how, to favor vaccine acceptance, existing strategies often emphasize individuals' and parents' perceptions of the risk a disease presents (Gilkey et al., 2020). Given that a consistent body of research has revealed that individuals might fail to calculate objective probabilities and be drawn to choices that *feel* the safest to them (Anderson, 2016; Kahan, 2014; Slovic, 2005), to address vaccine hesitancy, it might be important to focus on individuals' affective concerns, rather than issue messages based on frequencies and probabilities. Further research could therefore explore the importance of taking these dimensions into

account when creating messages about the safety of vaccines and vaccination procedures.

This work has some limitations that should be addressed. First, quota sampling means point estimates should be carefully considered, although, in this study, a primary survey allowed us to collect detailed data not available before. Future researchers should attempt to collect more accurate data using a probabilistic sampling method to get more reliable estimates. Second, in this chapter, we tested the possibility that perceived risks indirectly intervened in the association between thinking styles and vaccine hesitancy, but it must be stressed that an empirical assessment is necessary but not sufficient to imply this is a true underlying mechanism (Fielder et al., 2010). Several methodological contributions, in fact, warn about the infeasibility of distinguishing between different theoretical models through a statistical test in a correlational design (Bullock et al., 2010; Fielder et al., 2010; Lemmer and Gollwitzer, 2017). Furthermore, given the cross-sectional nature of our data, omitted variable bias and measurement errors make it extremely complicated to test equally plausible models against each other (Lemmer and Gollwitzer, 2017). Therefore, we recommend avoiding any causal interpretation of the results. Third, since applying decomposition analysis to nonexperimental data is likely to bias estimates upward (Bullock et al., 2010) and, given the importance of the theme in the light of the COVID-19 pandemic, further efforts should be made to get experimental data that could greatly benefit vaccine hesitancy research by exploring causality more cleanly. Unfortunately, at least in the Italian case, this was not practical. So, this exploratory study was a first step toward the collection of more accurate data that would allow for better designs and further-reaching results. Last, we take a position in the current debate about the relationship between two cognitive processing mechanisms, by considering them a feature of individuals that remain stable through a specific period. More research is needed in this field, where sociology could greatly benefit from cognitive research and vice versa.

CHAPTER IV

COVID-19 VACCINE ACCEPTANCE: A COMPARATIVE LONGITUDINAL ANALYSIS OF THE ASSOCIATION BETWEEN RISK, CONFIDENCE AND THE ACCEPTANCE OF A COVID-19 VACCINE[1]

Abstract

Following the outbreak of COVID-19, scientists rushed to develop vaccines to protect individuals and ferry the world out of the health crisis. Unfortunately, recent research suggests that vaccine acceptance has been declining over time. Vaccine hesitancy research on previous pandemics highlighted the perceived risk of infectious diseases and confidence in the vaccination process as core determinants of vaccine acceptance. Research on COVID-19 is less conclusive, and frequently it relies on only one point in time, cross-sectional data. In this chapter, we analyzed the association between perceived risk, confidence, and vaccine acceptance cross-sectionally at individual and country levels. Then we longitudinally explored whether a within-country variation in perceived risk and confidence was correlated with a variation in vaccine acceptance. We used data from a large-scale survey on individuals in 23 countries and for 19 time-point between June 2020 and March 2021. We used comparative longitudinal multilevel models to estimate the association of perceived risk and confidence at individual, country-time, and country levels simultaneously. The results showed the existence of cross-sectional relationships at the individual level, where levels of perceived risk and confidence were positively associated with vaccine acceptance. We found no significant association within countries over time, but we found a positive association between confidence levels and willingness to vaccinate at country-level. This chapter contributes to our understanding of vaccine hesitancy by underlining that reasons behind vaccine acceptance might differ at diverse levels of analysis. So, to foster vaccine acceptance it might be important to simultaneously address individual concerns while considering persisting contextual characteristics.

[1] This chapter was co-authored with Prof. Giuseppe A. Veltri
Mauro Martinelli: Conceptualization, Methodology, Formal analysis, Writing – original draft, review and editing, Visualization.
Giuseppe A. Veltri: Conceptualization, Supervision, Resources.

1. Introduction

Following the explosion of the COVID-19 global pandemic, scientists rushed to develop safe and effective vaccines. Less than a year later, vaccination campaigns started all over the world, but the vaccination process, a major tool to ferry the world out of the pandemic (Karlsson et al., 2020), could turn out to be less straightforward than anticipated. Researchers immediately identified vaccine hesitancy as a major threat to the success of the vaccination campaigns (Dubé and MacDonald, 2020; Peretti-Watel et al., 2020). Recent contributions suggest, in fact, that whereas most of the population would accept a COVID-19 vaccine (Daly and Robinson, 2021; Freeman et al., 2020; Karlsson et al., 2021; Lazarus et al., 2021; Peretti-Watel et al., 2020), a consistent number of individuals expresses refusal or hesitancy. The share of individuals unwilling to be vaccinated varies greatly between countries and time points but, perhaps more importantly, early results indicated that this percentage appears to be increasing over time (Daly and Robinson, 2021).

Vaccine acceptance is a complex issue standing at the intersection of individual decisions and societal needs, and it is heavily influenced by social, cultural, political, and historical factors (Brunson, 2013; Dubé and MacDonald, 2020; Dubé et al., 2021). The way individuals perceive risk and the trust they put in health professionals, authorities, and institutions are central theoretical concepts in vaccine acceptance (Brewer et al., 2017; Schmid et al., 2017; Verger and Dubé, 2020). Empirical research has shown multiple times the existence of a positive association between levels of perceived risk and trust and willingness to be vaccinated (Brewer et al., 2017; Floyd et al., 2000; Larson et al., 2014; Oster, 2018). This is also true in the case of COVID-19 (Attema et al., 2021; Freeman et al., 2020; Karlsson et al., 2021). Nevertheless, one issue of most recent papers investigating this association is that they rely on one point in time, cross-sectional data. This is understandable. In the face of an unprecedented, rapidly changing situation, gathering time-sensitive information to understand the evolution of a pandemic is an invaluable asset. However, the sociological analysis of society is also the investigation of change over time, and as Siegrist (2013) emphasized, in the case of natural hazards, relying only on cross-sectional estimates might make it more difficult to unveil important associations.

In this chapter we aim to address this gap, investigating if higher levels of perceived risk and trust are associated with higher vaccine acceptance at individual and country levels, but also whether a within-country change in the perceived risk and trust levels are correlated with a change in the willingness to be vaccinated.

We relied on a large-scale dataset collected by a joint effort of Facebook Inc. and the Massachusetts Institute of Technology (MIT), and we used comparative longitudinal multilevel models (Fairbrother, 2014) to investigate these associations between 23 countries over 19 time points from July 2020 to March 2021.

Understanding why people feel hesitant about COVID-19 vaccines is a fundamental tool for successfully implementing a large-scale vaccination program. Investigating whether core elements of vaccine acceptance are important predictors of a *change* in willingness to be vaccinated is a further step to inform public policies and target individual concerns more accurately.

2. Theoretical Framework

2.1 The Risk–Vaccination Link in Cross-Sectional, Longitudinal, and COVID-19 Scenarios.

The way individuals perceive the risk of an infectious disease and trust a valid coping mechanism are core determinants of vaccine acceptance (Dubé et al., 2021). From an empirical perspective, higher perceived risk of disease has repeatedly been associated with higher engagement with health-protective behaviors and vaccine acceptance, although with noteworthy contextual variability (Brewer et al., 2017). For example, in a large-scale study on the acceptance of the MMR vaccine, Larson et al. (2016) showed significant country variability in acceptance rates. They suggested that the perception of a low risk of measles contributed to coverage gaps in several contexts. It is also interesting to note that the efficacy of vaccination programs might have had the unintended consequence of generating a lack of concerns about VPDs, undermining vaccine acceptance in those contexts that more than others have seen vaccination's beneficial effects (Larson et al., 2014; Kahn and Luce, 2006).

With an emerging infectious disease like COVID-19, it might be complex to understand the specificity of perceived risks, mainly because there hardly is any

measure to compare them to (Dryhurst et al., 2020). Research on previous pandemics, such as the 2009 H1N1 swine flu pandemic (Gidengil et al., 2012) and the Ebola outbreak (Vinck et al., 2019; Yang and Chu, 2018), underlined the positive association between levels of perceived risks of disease and willingness to be vaccinated. Moreover, research has suggested that the perceived risks of COVID-19 are high across different contexts (Dryhurst et al., 2020) and positively correlated with vaccine acceptance (Attema et al., 2021; Freeman et al., 2020; Karlsson et al., 2021). However, it has shown noteworthy between-country differences in the specific dimension of risk correlated with vaccine acceptance. Ward et al. (2020) and Glockner et al. (2020) investigated, respectively, French and German respondents. They found that willingness to be vaccinated was significantly associated with respondent's perceived likelihood of contagion, whereas Faasse and Newby (2020) showed only a marginal association between the likelihood of contagion, the severity of disease, and the willingness to be vaccinated in a sample of Australian respondents, On a parallel line, Karlsson et al. (2021), studying three samples of Finnish respondents, concluded instead that only the perceived risk for the community, and not the risk for the respondent individual, was associated with intentions to be vaccinated. These slightly different results, although supporting previous findings, might indicate the existence of longstanding social, cultural, and historical characteristics that affect vaccine acceptance in a heterogeneous way between contexts. In addition, it must be considered that the cross-sectional nature of the data and the rapidly changing pandemic situation might be relevant factors in explaining contextual specificities.

This notion, not an issue per se, raises the question of whether similar conclusions can be reached longitudinally. Scholars have observed that risks are perceived as more salient when they are uncommon, catastrophic, or involve a high number of deaths and that a decrease in novelty could diminish their saliency (Slovic, 2002). Change in perceived risk could, therefore, show high saliency at the beginning of the pandemic and then steadily decline, in parallel with the evolution of the pandemic, or even be influenced by preventive measures that limit physical and social interactions, such as lockdowns (Attema et al., 2021). In the case of the H1N1 pandemic, support for medical intervention steadily declined over time in the U.S., but the perceived risk either paralleled the influenza activity (Gidendil et al., 2012) or

increased over time (Ibuka et al., 2010). With the COVID-19 pandemic, a similar result was obtained in France by Attema et al. (2021), whereas in Italy both perceived risk and willingness to be vaccinated appeared to be increasing over time (Caserotti et al., 2020). To the best of the authors' knowledge, the only study using a panel of U.S. respondents (Fridman et al., 2021), has shown that individual attitudes toward vaccination became less favorable over time, while the perceived risk increased, although only for participants who identified as democrats.

Although perceived risk and willingness to be vaccinated appear to be positively associated in cross-sectional studies, their covariation over time should be further explored.

2.2 The Confidence-Vaccination Link in Cross-Sectional, Longitudinal, and COVID-19 Scenarios

In research on vaccine hesitancy, the second core element of vaccine acceptance, trust, has often been associated with the word confidence. It has been recognized as one of the main determinants of vaccine acceptance (Verger and Dubé, 2020), although there have been mixed results in the literature, mainly because of conflicting definitions of the concept. In this chapter, we define confidence as trust in healthcare professionals, healthcare systems, science, and the socio-political context (MacDonald, 2015; Verger and Dubé, 2020). Confidence plays a fundamental role in supporting individuals' decision to be vaccinated (Yaqub et al., 2013), while distrust in pharmaceutical companies, physicians, government, and researchers has been repeatedly connected with vaccine hesitancy (Majid and Ahmad, 2020). Hesitant individuals might think that pharmaceutical companies push a profit-oriented pro-vaccine agenda (Dubé et al., 2016), that physicians might receive financial incentives to support vaccination (Attwell et al., 2017; Blaisdell et al., 2016; Vandenberg and Kulig, 2015), that governments could push policy-interventions to favor vaccine uptake because of their ties with pharmaceutical companies (Helps et al., 2018), or that researchers could have withheld research results unfavorable to a pro-vaccine agenda (Attwell et al., 2017). Confidence levels have been positively associated with vaccine acceptance (Schmid et al., 2017) while showing a relevant contextual variability, and the European region has displayed significantly lower confidence than other areas of

the world (Larson et al., 2016). Research on previous pandemics has supported these findings. High institutional trust was a fundamental component of vaccine acceptance during the 2018 Ebola outbreak (Vinck et al., 2019) and the H1N1 pandemic (Fabry et al., 2011; Rönnerstrad, 2016). This positive cross-sectional relationship seems to hold for COVID-19 as well. Trust in information from the government and health authorities (Lazarus et al., 2020), institutions (Kreps et al., 2020), and researchers (Latkin et al., 2021) has been a strong predictor of willingness to be vaccinated.

As for risk perception, however, the confidence–vaccination link over time does not appear to be equally clear. Theoretical contributions have suggested that, in a pandemic, confidence is likely to decline over time because institutional competence is hardly tested when managing an unprecedented health crisis (Bangerter et al., 2012). During the 2009 H1N1 influenza outbreak, confidence peaked at the beginning of the pandemic and steadily declined over time. This change was correlated with growing public mistrust in the competence of governments and health authorities (Bangerter et al., 2012). Along the same line, Perett-Watel et al. (2013) showed that distrust and vaccine hesitancy peaked at the end of the H1N1 pandemic, a situation that increased vaccine skepticism among the French population for several years (Verger and Dubé, 2021). Similar results have been found for the more recent 2018–2019 Ebola outbreak (Vinck et al., 2019). To the best knowledge of authors, empirical contributions on the contextual covariation over time of confidence measures and willingness to be vaccinated do not seem to be extremely frequent. As Verger and Dubé (2021) suggested, for COVID-19, we might assume that variation in vaccine acceptance might be correlated with variation in confidence following the evaluation of the pandemic management by healthcare personnel, systems, and governing bodies, but whether a change in trust levels is associated with a change in vaccine acceptance appears to need further investigation.

It is perhaps an understatement to suggest that the COVID-19 pandemic has challenged the way individuals and societies deal with new risks, since they were asked to trust unprecedented measures to contain the coronavirus. The literature seems to agree on the direction of the association between perceived risk, confidence, and willingness to be vaccinated, and the existence of significant contextual variability. At the same time, in a pandemic, including the study of how these dimensions covariate

over time can be of great relevance, and not many studies have exploited these dimensions and the analytical possibilities they open.

In this chapter, we aimed to investigate these issues further by adopting a more extensive approach. The research questions driving this chapter are threefold.

Q1: Is there a cross-sectional relationship between levels of perceived risk, confidence, and willingness to be vaccinated?

H1: Based on theoretical contributions and previous empirical results, we hypothesize the existence of a significant positive association between levels of risk and confidence and individual willingness to be vaccinated.

Q2: Are between-country differences in levels of perceived risk and confidence associated with different country levels of willingness to be vaccinated?

H2: We hypothesize the existence of a positive between-countries association between perceived risk, confidence, and willingness to be vaccinated, reflecting persistent contextual, social, and historical differences.

Q3a: Is a within-country change in the levels of risk and confidence associated with a change in willingness to be vaccinated?

H3a: Following theoretical considerations and previous empirical results, we hypothesize the existence of a significant, positive association between a change in perceived risk and confidence and a change in within-country willingness to be vaccinated.

Q3b: Does the association between a within-country change in the average level of risk perception depend on the within-country pandemic evolution?

Hb3: Regarding the concept of saliency, we hypothesize perceived risk and interest for vaccination to covary over time as a function of the objective saliency of the pandemic.

3. Data, Variables, and Methods

3.1 Data

[1]We relied on the Global Survey on COVID-19 beliefs, behaviors, and norms (Collis et al., 2021), a large-scale dataset collected by Facebook, Inc., and the Massachusetts Institute of Technology (MIT), and advised by the Johns Hopkins Center for Communication Programs (CCP) and the World Health Organization Global Outbreak Alert and Response Network (GOARN). Using the Facebook app, users in 67 countries and aged 18 years and older were asked to take part in an off-platform survey on several topics related to COVID-19. For 23 countries with a sufficient pool of users, every two weeks a new sample of respondents was invited to participate. The selection of participants was based on individuals' sociodemographic characteristics and engagement with the platform by Facebook, which developed a sampling frame to decide who to administer the survey. The survey began on July 7, 2020, and ended on March 29, 2021. It consists of 23 countries, 19 waves, and 437 country-waves. The surveyed countries were: Argentina, Bangladesh, Brazil, Colombia, Egypt, France, Germany, India, Indonesia, Italy, Japan, Malaysia, Mexico, Nigeria, Pakistan, the Philippines, Poland, Romania, Thailand, Turkey, Great Britain, the United States, and Vietnam.

The questionnaire had several blocks of questions that investigated different aspects, attitudes, and behaviors toward COVID-19. At the beginning of the questionnaire, participants were shown the same four blocks of questions, investigating, among others, socio-demographic information and willingness to be vaccinated. Each respondent was subsequently shown four random blocks from the others in the survey. For this reason, only a random subset of respondents provided answers that were useful for this analysis. The Facebook team computed a diverse set of probability weights for each person, based on demographic information and the engagement pattern with the platform. For this chapter, we used probability weights developed for the individuals who completed at least the socio-demographic block of the questionnaire and having as reference population the 18 years and older population of each country. For a more extensive explanation of the survey's sampling selection,

[1] The code to replicate this chapter's analysis is available on OSF.io: https://bit.ly/3kjkIdQ.
Data from 'Our World in Data' are freely available at ourworldindata.org.
Data from the 'Global Survey on COVID-19 beliefs, behaviors, and norms' (Collis et al., 2021) are available upon request.

weights design, and use, and the full questionnaire, see Collis et al. (2020) and Barkay et al. (2020).

We have complete information on the outcome variable, demographics, and probability weights for 142,264 individuals that constituted our analytical sample.

To include in the analysis a time-varying indicator of the change of the pandemic, we relied on official governmental sources, collected in the publicly available dataset "Our World in Data" elaborated by the University of Oxford (Ritchie et al., 2020). To include data on the level and variation of containment policies in each country over time, we used the publicly available data collected in the "Oxford COVID-19 Government Response Tracker" (OxCGRT) (Hale et al., 2021), elaborated by the Blavatnik School of Government at the University of Oxford. The dataset collects a wide range of indicators on governments' policies and interventions during the pandemic, elaborated from publicly available data such as news articles and government press releases.

3.2 Variables

In this section, we describe the main variables used in the analysis. A complete description of variable questions and coding can be found in the appendix section. The main outcome variable was a dichotomic variable measuring the willingness to be vaccinated, represented by the question: "If a vaccine for COVID-19 becomes available, would you choose to get vaccinated?" (Yes = 1; No, Don't Know = 0). Starting from wave 12 (December 7–21, 2020), individuals who already received a vaccine were coded as "Yes."

On the individual level, the main predictor variables, the perceived risk of COVID-19 and confidence were standardized indexes constructed by saving individual predicted scores of principal component analysis, with unrotated factors and using OLS to predict individuals' values. The perceived risk index was constructed using three questions: "How dangerous do you think the COVID-19 risk is to your community?"; "How likely is it that someone of the same age as you in your community becomes sick from COVID-19?" and "How serious would it be if you become infected with COVID-19?" The index's Cronbach's alpha was .61. The confidence index was constructed using four items in this question: "How much do you trust each of the following as

information source on COVID-19?" Selected items investigated trust in four sources: local health workers, clinics, and community organizations; scientists, doctors, and health experts; the WHO; government health authorities and other officials. Cronbach's alpha for the confidence index was .68.

Individual-level controls included gender (Male, Female), Age (18–30, 31–40, 41–50, 51–60, and over 60), educational level (low, medium, high), characteristics of the residential area (city, town and village, or rural area), perceived health status (poor, fair, good) and the self-reported level of exposure to COVID-19 information during the previous week (low, high).

To generate the average perceived risk and confidence variables for country-waves, for each of the two indexes, we computed a weighted mean in each country-wave from individual data. We subsequently aggregated country-wave values to compute country means. In this way, the country-level mean was insensitive to wave sample sizes, and each wave had the same relative weight in the analysis.

As an indicator of the saliency of the pandemic, we used a variable from the "Our World in Data" dataset: the officially reported daily number of new deaths per million inhabitants, for each day in each country, from July 7, 2020, to March 29, 2021. We recoded, using the average value between the previous and the subsequent day, nine negative occurrences with values ranging from –0.15 to –0.513, derived from official country corrections of historically inaccurate data. No updates were available for Vietnam from July 22 to 30, 2020, and we imputed these cells with the average value between the previous and subsequent officially reported values.

We computed the average daily number of new deaths per million inhabitants for each country and country-wave. In the latter, we included values of days in the first week of each wave and the week before the beginning of the wave. In this way, the values represented the average number of daily new deaths per million inhabitants with a one-week lag. This was to have a better approximation of the situation where all respondents in a wave had been exposed to a similar pandemic scenario in the previous weeks. To consider the level and change of containment measures, we used the stringency index (Hale et al., 2020), considering eight indicators: school closing, workplace closing, canceled public events, restrictions on gatherings, limitations on public transport, stay-at-home requirements, restrictions on internal movements, and

restrictions on international travel. We computed the mean stringency index for each country and country-wave.

3.3 Methods

We began with a descriptive analysis, two different bivariate linear probability models (LPMs) that predicted the willingness to be vaccinated as a function of the perceived risk of COVID-19 or confidence, to assess the existence of cross-sectional and longitudinal associations. We pooled all the observations, included an interaction between an index and wave dummies, and computed the average marginal effect of each index at each time point. Between- and within-country associations were bivariate OLS models. These separate models, although they could be greatly improved, could not consider the complex structure of the data, where observations are nested in country-waves and nested in countries; simultaneously control for compositional effects at the individual level, and fully exploit the longitudinal nature of observations. A solution proposed by Fairbrother (2014) is to treat data as non-repeated observations of a large random sample of micro-level units (individuals) nested in a small sample of repeated observations for each country, such as in time-series–cross-sectional (TSCS) data. The basic idea is therefore to treat individuals as random cross-sectional observations, nested in a dataset with a panel structure, with multiple observations over time of the same countries, a revised version of a hybrid model for panel data analysis, applied to multilevel longitudinal data. In this way, it is possible to:

a) estimate the individual cross-sectional effects of an x on y;

b) decompose the within- and between-country effects of a time-varying country-level variable, and

c) control for individual-level compositional effects.

The basic model we adopted for this chapter was a random-intercept model structured as follows:

$$Y_{itj} = \beta_0 + \beta_1 X_{itj} + \beta_k X_{itj} + \gamma_{WE}\left(Z_{tj} - \bar{Z}_j\right) + \gamma_{BE}\bar{Z}_j + \sum_{t=1}^{T} \delta_t D_t + \upsilon_j + u_{tj} + e_{itj}$$

This model has the usual multilevel longitudinal structure, where individuals (i) are nested in country-time (t), nested in countries (j) and where:

- Y_{itj} is the dependent dichotomic variable, assessing the willingness to be vaccinated;
- β_1 is a vector of coefficients identifying the individual-level association of risk perception and confidence on Y_{itj} across all waves and countries;
- β_k is a vector of control variables;
- γ_{WE} represents within-country effects of perceived risk and confidence. These coefficients are the result of the difference between the aggregated country-wave average of perceived risk and confidence, and the respective country-level means. This coefficient captured the effect of a within-country change in the average perceived risk and confidence on a change in Y_{itj}.
- γ_{BE} are the between-country effects, the average country-level mean of perceived risk and confidence, capturing enduring cross-national differences;
- $\sum_{t=1}^{T} \delta_t D_t$ is a set of dummies to control for potential simultaneous but unrelated time trends in Z_{tj} and $\bar{Z}_j$. In other words, wave fixed effects guaranteed that within-country estimates were not biased because of a common time-trend in the data.

Given that Z_{tj} and $\bar{Z}_j$ are orthogonal, the within-country coefficients do not suffer from omitted variable bias because of any time-constant country-level characteristics (Schmidt-Catran et al., 2019). They are identical to fixed-effects estimates of a balanced pane data. Nevertheless, they might be affected by time-varying heterogeneity. For this reason, we included in the model a variable that measured the saliency of the pandemic and the change in containment measures. These elements have been theoretically identified as possible time-varying confounders correlated with the perception of risk and confidence. Given the complexity of the model, we used a linear probability model (LPM) and maximum likelihood estimation with robust standard errors and clustering observations at the country level. LPMs, besides allowing for a simpler interpretation and comparison of coefficients (Mood, 2010), avoid convergence problems that are frequent in complex multilevel models and are further burdened by using probability weights.

4. Results

We begin our analysis by describing between-countries differences and the existence of variation over time in main predictors and outcomes.

The top row of Figure 4.1 shows the weighted averages of vaccine acceptance,

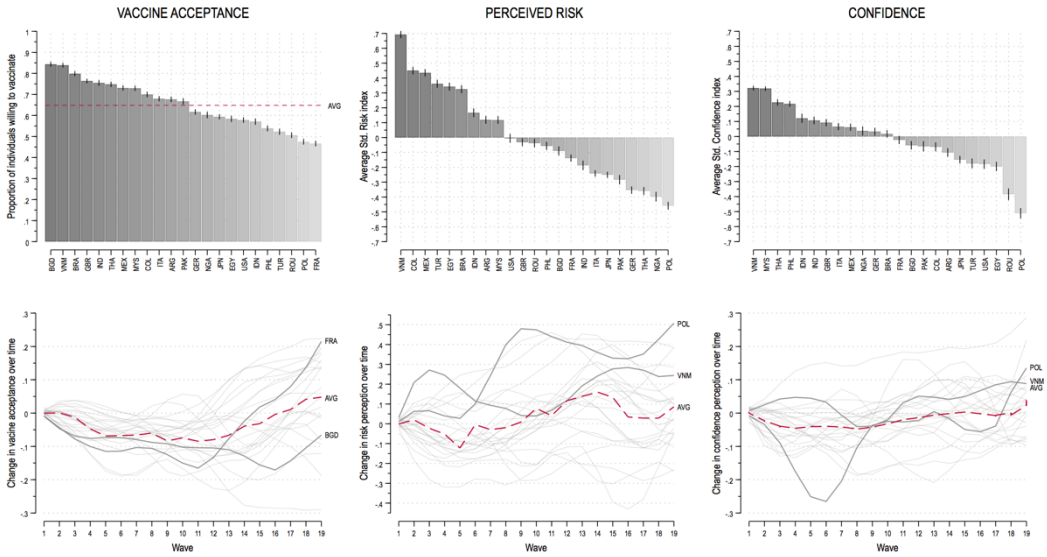

Figure 4.1 Top-row graphs report vaccine acceptance, perceived risk and confidence weighted average levels in each country with 95 % Cis, sorted by levels magnitude. Bottom-row graphs reports weighted within-country change in vaccine acceptance, perceived risk, and confidence. Country-lines and average country lines are set to an initial value of 0.

perceived risk, and confidence in each country, pooling all individual observations. The bottom row shows the change in weighted average levels, setting for each country an initial value of 0.

Given the high number of countries, we highlighted the trend of those countries that showed the highest and lowest average values in the top row. On average, slightly less than 65 % [63.9 %–66.2 %] of survey respondents declared they would accept a vaccine once available, a percentage below the suggested threshold to reach herd immunity (Daly and Robinson, 2021; Sanche et al., 2020). Average vaccine acceptance had significant variability between countries, from Bangladesh, where over 84 %

[83.3 %–85.3 %] of respondents declared they would accept a vaccine, to France, where, across all waves, less than 46 % [45.4 %–46.6 %] of respondents declared they would accept a COVID-19 vaccination. These results appear to be in line with previous findings on country-levels of vaccine acceptance, where southern and eastern European regions performed poorly in terms of vaccine acceptance, way below countries in southeast Asia and South America, with France consistently showing the lowest level of vaccine importance (Larson, 2016).

The graphs on the bottom row show there was significant variability over time, and that exploring between- and within-country relationships can point toward different scenarios. France, for example, presented a significant upward trend from wave 11 and on. Bangladesh, on the contrary, despite having the highest vaccine acceptance, saw this proportion constantly decrease over time, with a slight recovery only in the last three waves. A similar picture is depicted in the center panel. A country such as Poland, with the lowest average perceived risk, presented, over the course of almost nine months, half an *SD* increase in the average perceived risk index, an increase stronger than any other observed country. Confidence seemed to exhibit, on average, a more limited variation over time. We will further test whether this variation over time is significant. These descriptive results suggest, we believe, the usefulness of investigating the relationship between perceived risk and confidence from different angles, at both the cross-sectional and the longitudinal levels.

In Figure 4.2 we move, in fact, to investigating the bivariate relationship between willingness to be vaccinated, risk perception, and trust at three different levels: individual, between countries, and within countries over time. Graphs in the left column plot the average marginal effect of perceived risk and confidence on the probability of accepting a COVID-19 vaccine in each of the 19 waves. These results were obtained from a bivariate LPM, pooling all observations, and interacting a wave-dummy with each index. The two graphs show a significant positive association between individual levels of perceived risk confidence and willingness to be vaccinated, respectively. Whereas the former seemed to be somewhat stationary over time, the latter has an upward trend, suggesting a strengthening of the relationship between confidence and vaccination. These results are in line with most of the existing

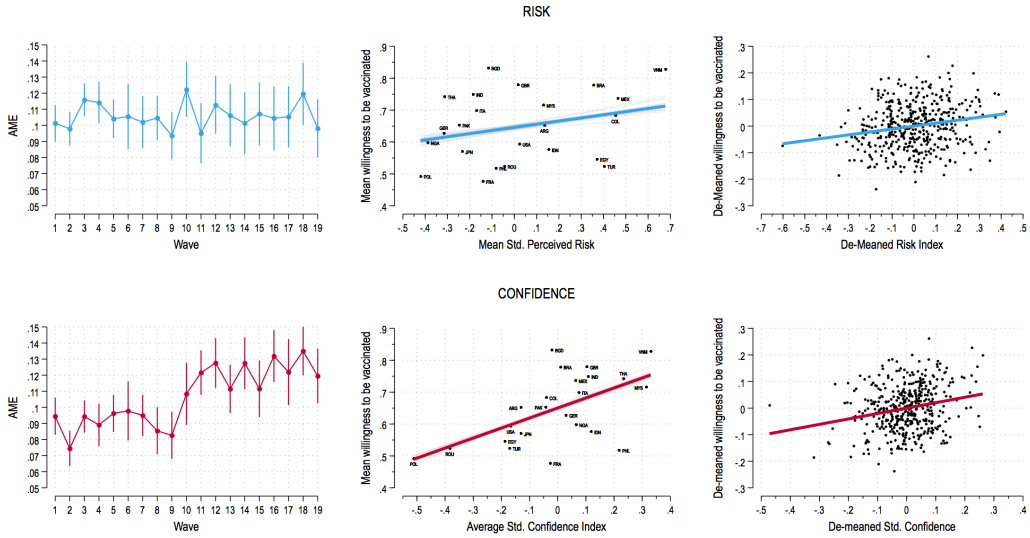

Figure 4.2 – Bivariate associations at individual level (left-column graphs), between countries (center-column) and within-countries over time (right column). Graphs in the left column report the AME of a LPM pooling all observations together (n = 142,264) and interacting a wave dummy with the predictor variable. Graphs in the center column report average weighted country levels of risk perception and confidence and the average weighted country-level of vaccine acceptance, and the fitted OLS line pooling country-level observations together (n=23). Graphs in the right column report the relationship between the de-meaned weighted country-wave average level of confidence, risk perception and de-meaned weighted average vaccine acceptance, and the itted OLS line pooling all observations together (n=437).

literature on vaccine acceptance and with more recent investigations of the COVID-19 pandemic.

In the center panels, we explored the between-county relationships using a bivariate OLS model, regressing the average country-level perceived risk and confidence on the average willingness to be vaccinated. Visually, slopes of the linear regression lines are positive, indicating that between-country differences in levels of perceived risk and confidence are associated with different average levels of vaccine acceptance. The association appears to be stronger in the bottom graph. This result, obtained by pooling 19 waves, suggests the existence of persistent differences between countries over the course of the pandemic. In the last part of the analysis, we test whether these differences are significant when controlling for possible confounders.

Finally, in the right column panels, we assess whether there were longitudinal relationships that would justify investigating the covariation over time in each country.

We pooled all country-waves and, in a bivariate OLS model, regressed the de-meaned perceived risk and de-meaned confidence indexes on the de-meaned vaccine acceptance proportion. The graph represents therefore the association between a change in x on a change in y. In both cases, there appears to be a positive association over time, although especially for the bottom-right graph, the beta coefficient seems to be significantly smaller than the one for between-country differences.

This descriptive analysis, suggesting the existence of positive relationships at different levels of analysis, calls for a more precise investigation. We do this through a series of multilevel longitudinal random intercept models, simultaneously estimating cross-sectional and longitudinal associations, controlling for compositional effects and for possible unrelated time-trends in the data. Table 4.1 reports the results of the multilevel analysis.

Model 0 is an empty model with no covariates other than the constant term. It substantially reproduces the results of the top left panel of Figure 4.1, taking into account the structure of the data. The grand mean is the average willingness to be vaccinated across all individuals. The variance at the individual level was 0.211; at the country-wave level, it was 0.0064, and at the country level, it was 0.0112. The intraclass correlation (Hox, 2010, p. 34, eq. 2.18–2.19) at the country level was 0.049, and at the country-wave level, it was 0.028. Overall, about 8 % of the variance was not located at the individual level. Z-test scores indicated that variance was significant at each of the three levels ($p < .001$). This suggested there was significant variability at the country and country-wave levels that can be explained.

In model 1, we added individual-level variables. Individual characteristics reduced the variance components at the country level by 21 % and at the country-wave level by 5 %. Compositional effects can, therefore, explain only a limited fraction of the variance at the two higher levels, This leaves the variance at the country and country-wave levels substantially unexplained. In model 2, we included wave-fixed effects. Compared to the null model, the explained variance at the country-wave level was reduced by 30 %, suggesting the existence of unrelated time-trends in the data and the usefulness of including time-fixed effects.

In model 2, the coefficients of perceived risk and confidence were both positive; a standard deviation increase was correlated, respectively, to increases of

Table 4.1 – Multilevel longitudinal models. All models are random intercept models, estimated using a Linear Probability model (LPM) on a dichotomic outcome. SE clustered at country-level. Weighted coefficients. [WE] = Within; [BE] = Between. N=142.264.

	Null	M1	M2	M3	M4	M5
	b/(se)	b/(se)	b/(se)	b/(se)	b/(se)	b/(se)
Individual level variables						
Gender *(Ref. = Male)*						
Female		-0.085***	-0.085***	-0.085***	-0.085***	-0.085***
		(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Age *(Ref. = 18-30)*						
31-40		-0.032***	-0.032***	-0.032***	-0.032***	-0.032***
		(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
41-50		-0.034***	-0.034***	-0.034***	-0.034***	-0.034***
		(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
51-60		-0.019*	-0.019*	-0.019*	-0.019*	-0.019*
		(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Over 60		0.023	0.023	0.023	0.023	0.023
		(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Educational Level *(Ref. = Lower Educated)*						
Mid Educated		0.007	0.007	0.007	0.007	0.007
		(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Higher Educated		0.041***	0.041***	0.041***	0.041***	0.041***
		(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Area *(Ref. = City)*						
Town		-0.005	-0.005	-0.005	-0.006	-0.005
		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Village or rural area		-0.010	-0.010	-0.010	-0.010	-0.010
		(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Self-reported health status *(Ref. = Poor)*						
Fair		0.007	0.007	0.007	0.006	0.006
		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Good		-0.002	-0.002	-0.002	-0.002	-0.002
		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Information exposure *(Ref. = Low)*						
High		0.039***	0.039***	0.039***	0.039***	0.039***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Perceived Risk Index		0.084***	0.085***	0.085***	0.085***	0.085***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Confidence Index		0.073***	0.073***	0.073***	0.073***	0.073***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Country and country-wave level variables						
Perceived Risk [WE]				0.015	-0.054	-0.054
				(0.033)	(0.033)	(0.033)
Perceived Risk [BE]				-0.016	-0.051	-0.053
				(0.047)	(0.053)	(0.054)
Confidence [WE]				0.053	0.056	0.059
				(0.050)	(0.043)	(0.043)
Confidence [BE]				0.222**	0.226*	0.228*
				(0.072)	(0.093)	(0.093)
New deaths per million [WE]					0.010***	0.010***
					(0.003)	(0.003)
New deaths per million [BE]					0.003	0.003
					(0.013)	(0.013)
Stringency Index [WE]					0.001	0.001
					(0.001)	(0.001)
Stringency Index [BE]					0.003	0.003
					(0.003)	(0.003)
New deaths per million [WE] * Perceived Risk [WE]						-0.010
						(0.008)
Constant	0.649***	0.653***	0.689***	0.690***	0.490**	0.492**
	(0.023)	(0.022)	(0.023)	(0.023)	(0.173)	(0.173)
		+ Wave FEs	*+ Wave FEs*	*+ Wave FEs*	*+ Wave FEs*	*+ Wave FEs*
Variance Components						
Country	0.0112	0.00881	0.00891	0.00705	0.00615	0.00621
Country-Wave	0.00641	0.00609	0.00447	0.00445	0.00380	0.00379
Individual	0.211	0.193	0.193	0.193	0.193	0.193
Log Likelihood	-91724.599	-85526.665	-85472.253	-85468.422	-85441.050	-85440.526
AIC	183457	171089	171016	171017	170970	170971
BIC	183497	171267	171372	171412	171404	171415

Robust standard errors in parentheses, *** p<0.001, ** p<0.01, * p<0.05

8.4 % and 7.3 % in the probability of accepting a vaccination. Also considering the diverse set of countries and time points analyzed, this result corroborates our hypothesis H1, providing further support to recent results that stressed the importance of the relationships between levels of confidence, perceived risk, and vaccine acceptance.

Females and, surprisingly, individuals above 30 years old were less likely to be willing to be vaccinated. On the contrary, more-educated individuals were, on average, more willing to be vaccinated. Despite multiple accounts of the fact that vaccine-hesitant individuals include people with high education attainments (Kirkland, 2012), our analysis points toward the idea that, on average, a higher educational level is a protective factor against vaccine hesitancy. While we do not find significant differences between individuals health status or residential area, we do find that more exposure to information is correlated with higher levels of vaccine acceptance.

In model 3, we introduced the main predictors at the country-wave and the country levels, decomposing the between-country association (BE) from the one within-country association over time (WE). Model fit significantly improved after introducing these two indexes, as indicated by AIC and BIC measures. We do not find a significant between-country association among average levels of perceived risk and willingness to be vaccinated. We do find, on the contrary, a significant relationship between countries' average level of confidence and willingness to be vaccinated. We, therefore, found only partial support for hypothesis H2, claiming the existence of persisting contextual differences in the relationship between perceived risk, confidence, and vaccine acceptance. This appears to be valid for confidence levels, but not for perceived risk.

In hypothesis H3, we suggested a possible within-country association over time, where a change in average perceived risk and confidence might have been associated with a change in average willingness to be vaccinated. After controlling for compositional effects and time trends and decomposing between and within associations, our results did not support hypothesis H3. They did not show any significant relationship between perceived risk, confidence, and willingness to be vaccinated within countries over time. It should be noticed that, in the random part of the model, there was no decrease in country-wave variance. This suggests that within-

country change in vaccine acceptance might not be correlated with within-country changes in perceived risk and confidence.

As we underlined in the methodology section, within-country associations are not sensitive to time-constant unobserved heterogeneity, but not to time-varying one. For this reason, in model 4, we introduced the variable measuring pandemic saliency, the officially reported new number of deaths per million inhabitants, and the stringency index. We found a significant association for the within-country change in the number of new deaths per million inhabitants. An increase of one additional death per million inhabitants was correlated with a 10 % increase in the willingness to be vaccinated, a rather large effect. Our model suggested that this relationship is not based on a change in perceived risk and confidence. Rather, it is connected to unexplained unobserved within-country heterogeneity.

Finally, in the last model (M5) we tested hypothesis H3b. It suggested that the association of perceived risk with willingness to be vaccinated could vary according to the level of the saliency of the pandemic. We tested this hypothesis by interacting the within-country change in perceived risk with the within-country change of the pandemic's saliency while controlling for the changes and levels of containment policies. We did not detect a significant association, hence we found no support for hypothesis H3b. Our model suggested that the association between perceived risk and willingness to be vaccinated does not depend on a change in pandemic saliency. Furthermore, introducing the interaction term caused the model fit to worsen, suggesting that introducing the interaction term was unwarranted.

5. Discussion and Conclusion

In this chapter, we investigated the relationship between risk perceptions, confidence, and willingness to accept a vaccine against COVID-19. In the last decade, numerous studies have addressed the primary role of individuals' perceptions in vaccine acceptance, an effort that accelerated greatly after the COVID-19 pandemic erupted. We argued that one main issue of prior studies was that they relied on one point in time cross-sectional studies. This limit is almost unavoidable, given the sudden nature of a pandemic. We further maintained that, beyond the relationship between

levels of perceived risk, confidence, and willingness to be vaccinated, it might be of primary importance to look at the association between changes in perceived risk and confidence and changes in the willingness to be vaccinated. Our results further illuminated the complexity of vaccine acceptance, suggesting the existence of different relationships at each level of analysis.

In the first part of the analysis, descriptive results indicated significant between-country variability in the proportion of individuals willing to be vaccinated and in the average levels of perceived risk and confidence. This result was in line with previous, pre-pandemic studies. It showed how differences between countries might persist (Larson, 2016), and how they might affect the acceptance of a vaccine for COVID-19. At the same time, we showed that over the course of the 19 waves observed in this study, there was significant variation within each country.

For this reason, we explored the existence of an association between individual perceptions and vaccine acceptance at both individual and country levels, both cross-sectionally and longitudinally. We found, in the initial exploratory analysis, a positive relationship in all three cases, although the within-country longitudinal relationship appeared to be weaker than the between-country one.

To assess the existence and magnitude of these associations more precisely, we used a series of multilevel longitudinal random intercept models (Fairbrother, 2014). The aim was to disentangle the relationships between three levels of analysis, controlling for individual compositional effects and unrelated time trends. We found that higher individual levels of perceived risk and confidence were correlated with higher levels of vaccine acceptance. This result was consistent with the most recent research (Attema et al., 2021; Freeman et al., 2020; Karlsson et al., 2021) and with previous research on vaccine acceptance in pandemic scenarios (Gidengil et al., 2012; Vinck et al., 2019). By using a large-scale survey with a diverse sample of countries and a large time-span (at least, relative to the pandemic activity), results further supported these findings. Although recent research has shown some variability in the strength and specificity of this relationship (Faasse and Newby, 2020; Karlsson et al., 2021), we argued that one reason behind this variability might be correlated to the difficulty of conceptualizing and measuring individual perceptions. For example, we stressed that there is no consensus on the concept of confidence (see, for example,

Larson, 2015; MacDonald, 2015; Verger and Dubé, 2020) or that risk perception might be disentangled in various components, each with specific characteristics (Brewer et al., 2017; Weinstein, 2007). Furthermore, many recent contributions insisted on very different contexts, and their results might be connected to underlying unobserved contextual determinants. Further studies might be directed toward developing a clearer, shared definition of concepts and measurement models, to increase the comparability of research. On the other hand, our analysis suggested that these individual-level associations appeared to be stable across contexts and time. The individual-level analysis also revealed the important associations between sociodemographic characteristics and vaccine acceptance, with a particular reference to the role of educational level. Although there are mixed results in the literature (Kirkland, 2012), our findings suggested that, on average, a high educational level was a protective factor against vaccine hesitancy.

We did not find a significant correlation between a change in perceived risk and confidence, and a change in vaccine acceptance within countries over time. Previous longitudinal investigations (Bangerter et al., 2012; Gidengil et al., 2012; Vinck et al., 2019) showed how risk, confidence, and vaccine acceptance might not have followed the same trend, and our analytical strategy tested this covariation in a more robust way. We believe this result, different from those at the individual level, is not contradictory. Rather, this further illuminates the complexity of vaccine hesitancy, and it illustrates the importance of disentangling associations between levels and change and how they might prove to be significantly different. At the same time, this result is open to a variety of interpretations. In fact, we found a positive relationship between within-country changes in the saliency of the pandemic and willingness to be vaccinated, an association independent from levels of risk perception. Further research is needed to understand any additional effects of a pandemic to extend our understanding of vaccine acceptance. From the perspective of public policy, these results suggest that, whereas it is important to increase people's awareness about COVID-19 characteristics and foster individuals' confidence in vaccines and the vaccination process, this strategy might not be sufficient to increase overall vaccine acceptance.

Finally, we found a significant association between country levels of confidence and vaccine acceptance. This association, computed using a time span of over nine months, could represent persisting differences between countries. Research has shown several times that vaccine acceptance is socially stratified. That is, significant subgroups in the population are systematically less likely to accept vaccination. These include less-educated individuals (Dryhurst et al., 2020) and ethnic and racial minorities (Dryhurst et al., 2020; Robertson et al., 2021). This shows that contextual, social, and historical motives are factors of primary importance in coping mechanisms involving an unprecedented and clearly disruptive event such as a global pandemic.

This work has some limitations that must be addressed. First, the sampling method suggested that point estimates should be considered carefully, looking at the direction and significance of relationships rather than the magnitude of the coefficients. Although in comparative studies, it might be complicated to obtain uncorrelated country samples, a selection of countries based on the availability of a sufficient pool of social media users might be correlated with common unobserved heterogeneity, limiting the external validity of our results. For the same reason, a selection bias is naturally induced by excluding individuals that do not have a social media account. On the other hand, the diversity of counties surveyed, the sample size, and the wide range of time points allowed us to gain valuable insights that, to the best knowledge of the authors, are still underdeveloped in the literature. Future research should consider the possibility of collecting representative samples to increase external validity, as well as repeated observations of the same individuals. Second, our main indexes cannot capture the wide range of components of perceived risk and confidence as depicted in the literature The availability of more refined dimensions could increase the ability to capture all the faceted dimensions of these concepts. Third, the variable we used as a proxy for change in pandemic saliency, the official daily number of new deaths per million inhabitants, is likely to underestimate the real number of COVID-19 casualties. Furthermore, this issue is likely to be unevenly distributed across the analyzed counties. Unfortunately, for the time being, and to the best knowledge of the authors, there appears not to exist an equally time-sensitive, comparable, and publicly available indicator for such a large number of countries. Finally, between-country associations

were computed on a very limited number of cases, as for every country-level cross-sectional estimate. This strongly limits the possibility of controlling for confounders, and it always leaves open the possibility that significant between-country associations are due to unobserved heterogeneity.

The contributions of this chapter are threefold.

First, we addressed a gap in the empirical literature that frequently uses one point in time cross sectional data. Indeed, we showed that, in the analysis of a complicated issue such as vaccine acceptance in a pandemic scenario, disentangling relationships at diverse levels of analysis can produce significantly different results. This deserves to be further addressed.

Second, our results suggested that fostering the COVID-19 vaccine might require different and simultaneous strategies. To increase individual acceptance, it might be important to increase awareness of COVID-19 characteristics and promote trust in a diverse set of actors. However, at the country level, a change in willingness to be vaccinated might be correlated with different dimensions. Harrison et al. (2021) suggested that increasing public acceptance of vaccines might require a re-imagination of the culture of public health that focuses more on the social, contextual, and moral enhancements that vaccines might bring to the entire community.

Third, our analysis showed that there are longstanding contextual effects involving vaccine confidence. Fostering vaccine acceptance might be a long-term commitment, and addressing differences and inequalities deeply rooted in our societies might prove to be important for vaccine acceptance as well.

CONCLUDING REMARKS

This thesis investigated the issue of vaccine hesitancy by looking at different and interrelated ways the perceptions and characteristics of individuals can be associated with their willingness to accept vaccinations. Although independent, all the chapters are united by the investigation of common elements to enlighten vaccine acceptance from different standpoints. The aim was to provide a whole that is hopefully a little greater than the mere sum of its parts.

Why should we discuss vaccine hesitancy? And why do it in an academic and sociological frame?

The answer to the first question is very pragmatic. As I hope I conveyed in the Introduction, vaccine acceptance has never been a smooth process (Hausman, 2019). Moreover, in recent years, delaying or refusing to be vaccinated is a resurging issue in high-income countries, with severe effects on peoples' health (Larson et al., 2014). In addition, during the COVID-19 pandemic, vaccine acceptance is a controversy at the center of our everyday activities and conversations. It is, therefore, of paramount importance to discuss a topic with severe public health consequences.

To answer the second question, it is important to discuss vaccine hesitancy in an academic frame because of the need to find solutions that help people recognize vaccines' safety and efficacy. It is of primary importance to analyze the conditions and mechanisms behind vaccine acceptance. Within this frame, a sociological approach can provide strong roots for the analysis of a subject intertwined with core characteristics of modern societies, which that sociological analysis had the ability to recognize and describe.

At the beginning of this manuscript, I stressed two points. First, that although the scientific community agrees on vaccines as safe and effective measures to prevent infectious diseases, the concerns of vaccine-hesitant individuals should be considered legitimate. On a first level, when a technological solution involves a risk, albeit infinitesimal, the legitimacy of concern is somehow mechanical. On a second level, people's perceptions do not always respond to completely rational dynamics (Tversky

and Kahneman, 1974), but this does not appear to be a legitimate reason to demean peoples' fears or doubts.

The second point I stressed in the Introduction was the distinction between vaccine hesitancy, vaccine activism, and vaccine refusal (Dubé et al., 2021). Vaccine hesitancy does not represent the activity of committed "novax" individuals or the activity of those who include vaccine refusal as peripheral to their core interests. Vaccine hesitancy is not necessarily the opposite of vaccine acceptance (Dubé et al., 2021; Dubé and MacDonald, 2015). It lies in that gray area where people express concerns, doubts, and fears about a medical procedure—a phase where hesitancy might turn into refusal.

In Chapter II, I discussed the evolution of vaccine hesitancy research, how to frame it in a wider sociological framework, and which theoretical models could be promising if applied to the empirical analysis of this topic.

Growing academic efforts have been directed toward the understanding of vaccine hesitancy and the disentangling of its predictors, with an exponential growth following the COVID-19 outbreak. Although this effort comes from different disciplines, the research community has recognized similar determinants of vaccine acceptance (Dubé, 2013), including the case of COVID-19 (Attema et al., 2021; Dubé et al., 2021 Freeman et al., 2020; Karlsson et al., 2021; Kreps et al., 2020; Latkin et al., 2021; Lazarus et al., 2020). This effort promptly pointed toward the recognition of two key elements for individual vaccine acceptance: the individuals' perception of the risk of infectious disease and the trust people have in a valid coping response—labeled "confidence" in vaccine hesitancy research (Brewer et al., 2017; Larson et al., 2016). These elements, stemming from a public health perspective, also stand at the center of a wider sociological analysis of the consequences of modernization in contemporary societies. This work mainly comes from the theoretical contributions of Beck (1992) and Giddens (1990; 1999). It has shown how modernization has minimized everyday natural risks while increasing the perceptions of the risks of technological solutions—the unintended consequences of scientific development (Beck, 1992). Peoples' concerns became more oriented toward minimizing manufactured uncertainties, while societies' growing complexity and hyper-specialization forced individuals to trust systems they did not fully understand. This generated a reflexive process that left

individuals less prone to accept risk, and it created a crisis about the legitimacy of people and institutions who are required to control them (Giddens, 1999). Vaccinations did not escape this process (Peretti-Watel et al., 2015).

Within this theoretical framework, I delineated empirical strategies that have been used to analyze individual vaccine hesitancy. Most such efforts investigated how perceived risk and confidence were correlated with willingness to be vaccinated, and they are based on models of health behavior developed in behavioral economics (Ajzen, 1985; Becker, 1974; Rogers, 1975). According to these models, the individual propensity to accept a medical intervention is a function of the perceived risk of the infectious disease and the availability of a valid coping response. The underlining idea of these models stands at the center of contemporary vaccine hesitancy research and to some extent of this thesis as well. While the usefulness of these models is undeniable, I pointed out some limitations that should be addressed.

First, the assumption of humans as completely rational actors has been widely criticized (Simon, 1955). Second, together with the recognition of the extreme relevance of emotional and affective judgments (Brewer et al., 2017; Weinstein, 2007), in the last 15 years, research has shown in convincing ways that how our cognition works might affect our behaviors and intentions in complex ways (Kahneman, 2011). This stream of research, where cognitive sciences came into touch with sociological research (DiMaggio, 1997), has provided an additional key to address the puzzle of vaccine hesitancy, the way the study of cognition could inform a theory of action.

Cognitive research, in fact, has recognized that our cognition also works in unconscious ways (Epstein, 1994), resulting simultaneously in a corrective to a rational actor's perspective and helping to explain how individuals—distant through space (and time?)—could develop similar ideas on a certain social object. Each conscious and unconscious experience, in a specific cultural framework, helps to define our worldviews by forming recurring cognitive schemas (Cerulo, 2010; 2021), the representational mechanism of our brain. Since individuals can occupy similar positions at the complex intersection of contextual standpoints and individual experiences, it might be the case that distant individuals develop similar cognitive schemas. These groups of individuals are known as thought communities (Fleck,

1936[1986]), and they might be considered different 'lenses' through which people see the world.

Starting from this framework, in the following chapters, I developed three empirical analyses where some of these tools have been used to analyze different features of vaccine hesitancy.

In Chapter III, I investigated whether it was possible to uncover individuals' cognitive schemas through a wide set of predictors investigating individuals' perceived risk of VPDs and confidence in vaccines, the vaccination process, and institutions. I used data from an original survey conducted on a sample of Italian citizens that used a wide array of measures that, to my best knowledge, had not been surveyed together. Using a method specifically designed to reveal individuals' cognitive structures, I uncovered three different ways people understand the issue of vaccine acceptance to be structured. This result was independent of respondents' individual characteristics. It was derived by using only attitudinal variables. Three groups were shown to have qualitatively complex understandings of perceived risk and confidence, and they were also shown to have different average levels of confidence and perceived risk, with and without vaccinations. This is a relevant result, since it highlights, in a simple way, that how people understand an issue to be structured can be correlated with their support for a certain health procedure. I later analyzed within-group characteristics, showing that cognitive segmentation also was a means of social stratification, where people with a lower educational level were less likely to be part of a thought community that sees vaccinations as a significant tool in reducing the risk of VPDs. I finally showed that, beyond average levels, predictors of vaccine hesitancy were articulated differently in each group. This revealed a more complex scenario than prior research suggested. I believe the results of this first empirical chapter are relevant in that they showed that the way people organize their beliefs can be correlated with differential support for vaccination. They also showed that the approach to organizing beliefs assigned different levels of importance to issue-specific predictors. In addition, the fact that distant people might share similar and surveyable worldviews suggested the existence of three additional challenges: first, that the analysis of such controversial issues might be oriented toward the conceptualization of preferences as relational systems; second, that there might be a need to develop additional tools to address such complexity, and

third, that addressing vaccine hesitancy might require the development of targeted interventions that resonate with different peoples' understanding of the structure of a certain issue.

In Chapter IV, I turned attention to how a specific individual cognitive characteristic could be correlated with willingness to be vaccinated, both directly and indirectly, through several measures of perceived risk. In this chapter, I referred to theories of dual systems of cognition (Evans, 1989). Then, by using an appropriate test, I classified individuals according to their tendency to use either intuitive or analytic thinking. I reviewed empirical research that showed how intuitive thinking was associated with pseudo-sciences, supernatural phenomena, the paranormal, and belief in conspiracy theories (Aarnio and Lindeman, 2005; Browne et al., 2014; Genovese, 2005; Gervais, 2015; Gervais and Norenzayan, 2012; Pennycook et al., 2012). Then I showed that individuals who leaned toward using intuitive thinking were more likely to be vaccine-hesitant. This relationship can be decomposed into two equally sized associations: a direct one, and an indirect one through measures of perceived risk of VPDs. This last channel showed how the affective and emotional dimensions of perceived risk were more relevant for defining this association, compared to probability judgments, which are frequently used in vaccine hesitancy research. In this chapter, I highlighted how considering individuals' cognitive characteristics, a longstanding tradition of psychological research, could and should be more frequently considered in sociological empirical discourse and even more so in analyzing vaccine hesitancy. By using social-psychological themes in a wider sociological framework, I hoped to convey that our understanding of vaccine hesitancy, and perhaps related issues, could benefit from this disciplinary collaboration. By disentangling motives and cognitive processes, it could be possible to tailor public policy interventions that resonate more clearly with individuals' differential ways of acquiring, interpreting, and using information. This chapter also stressed how, for human beings who are, at best, poor judges of probability and odds (Tversky and Kahneman, 1974), affective and emotional perceptions are powerful elements that shape human intentions. This last result also strengthened the idea of vaccine hesitancy's concerns to be legitimate. Being vaccine-hesitant might be less of a conscious and determined decision and more of an unconscious, emotional perception, a "gut feeling" that cannot be resolved with

numerical information. This suggests that, when developing strategies to increase vaccine acceptance, it could be fruitful to address peoples' anxieties and insecurities, focusing on the safety of vaccinations with a less curing and more caring approach.

Finally, in Chapter V, I turned the attention to the recent COVID-19 case. I used the core theoretical concepts of this thesis, the perceived risk of infectious disease, and confidence in vaccines and the vaccination process, and I analyzed their association with willingness to accept a COVID-19 vaccine.

Applying general concepts of vaccine hesitancy to an unprecedented and threat-specific case appeared to be a way to test again whether more general theoretical concepts are relevant in different scenarios. Furthermore, I tested the importance of these associations not only in the Italian context, as in the previous chapters, but between different countries and within countries over a relatively large time span during the pandemic. Previous chapters focused on the relationship between the levels of variables. In this chapter, I expanded the analysis to test whether similar associations occurred between individuals and countries, but also within countries over time. In this way, I disentangled these relationships at different levels, where each level called into play different but complementary elements. I found that, on the individual level, across all the observations gathered in 23 countries and over 19 time-points, there was a clear association between the perceived risk of COVID-19, confidence, and willingness to be vaccinated. This confirmed that predictors of vaccine hesitancy could be applied to COVID-19 as well and that this specific threat responds, on many levels, to classic dynamics of vaccine hesitancy. Second, I tested this relationship within countries over time, to understand whether changes in perceived risk and confidence were correlated with changes in the willingness to be vaccinated. I did not find evidence of such a relationship. This is an interesting result because it shows how vaccine hesitancy can be complex and different at varying levels of analysis, and that increasing perceived risk and confidence levels in vaccination might not be the only or best option to foster a change in vaccination rates in countries. Finally, I analyzed the relationships between countries, and I found a significant association between countries' confidence levels and the willingness to be vaccinated, representing longstanding social, historical, and contextual country characteristics associated with vaccine acceptance.

This result concludes this thesis. It underlines, in fact, that beyond what I identified as relevant predictors of vaccine acceptance, increasing vaccination rates also rely on deeper societal issues. Previous research has shown, in fact, that vaccine acceptance is stratified along important lines, such as gender, ethnicity, and educational levels (Dryhurst et al., 2020; Robertson et al., 2021). Addressing the differences, divisions, and inequalities in our societies is probably the cornerstone of any strategy to increase vaccine acceptance.

Taken together, the chapters of this thesis provide several contributions: the importance of the different ways individuals acquire, interpret, and use information; the complexity of people's worldviews; the importance of affection and emotions; the usefulness of disentangling issues at different levels, and finally, the importance of addressing our societies divisions.

At the same time, they revealed that much more must be researched, analyzed, addressed. What I initially thought was a weakness of this very specific research field, its fragmentation, now appears to me to be its strength. Together with similar controversial issues of contemporary societies, this topic can and should be analyzed from different standpoints, using different theoretical frameworks, methods, and research questions. I hope in this thesis I showed how, together with more typical approaches, expanding and blending research fields might open different perspectives and enlighten further pieces of this puzzle.

In this historical moment, in the quest to get our old normality back, increasing vaccine acceptance is a crucial means, and theory-driven empirical research its key.

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APPENDIX TO CHAPTER II

Relational Class Analysis

In the first section of the paper we use Relational Class Analysis (RCA) to cluster respondents on the basis of their shared understanding of a social object. For a complete description of RCA see Goldberg (2011). In this section, we provide a brief description of RCA characteristics and functioning.

At the core of RCA are relational theories of meaning, sustaining that the meaning of symbols in a cultural system rests not in symbols themselves, but in the relationship between them (Boutyline, 2017). For example, the concept of "big" or "small" for whichever object – say, a house -, is in part defined by the relationship between the size of that object with similar ones – for example, houses in a certain neighborhood or city. Similarly, a more abstract concept such as musical taste (as in Goldberg's original example) is partly generated by the relationships between individual's appreciation or dislike for several music genres.

RCA uses this notions to 1) detect individuals "mental schemas" (Converse, 1964), 2) measure the extent to which each pair of respondents employ the same mental schema, and 3) create groups by minimizing and maximizing differences within and between groups, respectively.

To measure the extent to which two individual respondents follow the same logic or, in other words, show a similar mental schema, Goldberg (2011) uses a metric he calls "Relationality".

Relationality R_{ij} between two individuals is computed as follows:

1. A row vector containing individual's responses on a series of items is taken into account.

2. Differences between respondent's values are pairwise calculated, by subtracting them from one another.

3. Each survey row i results at this point in a matrix X_i of pairwise arithmetic differences between variables in that row.

4. R_{ij} between two respondents i and j is computed as the element-wise difference between absolute values of the respective matrices X_i and X_j. Each element of the resulting matrix $X_{ij}$is given a sign based on whether the corresponding matrix values were in the same or opposite directions.

5. The elements of matrix X_{ij} are summed together. This results in R_{ij} value, which is rescaled ranging from -1 to 1. R_{ij} values close to the extremes suggest that vectors of responses between the two individuals i and j are similar, whereas values in between indicate that respondents present different patterns of response, showing different mental schemas (Baldassarri&Goldberg, 2014).

Relationality is then computed between each pair of individuals in the dataset, resulting in a matrix of absolute relationalities between pairwise individuals. "This matrix can be thought of as a complete non-directional weighted graph, in which each node corresponds to one observation and each edge weight is the magnitude of schematic similarity between the two observations it connects" (Goldberg, 2011:1408).

Finally, RCA uses a modularity-maximization algorithm (Newman, 2006) to partition this network into groups of respondents who have relatively high absolute relationalities, clustering together groups of respondents characterized by a similar mental schema

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Table 1 – Variables description. Survey questions in table 1 are a translation from the original Italian version. All risk perception and confidence variables included a "don't know" option, recoded with the intermediate value.

Variable	Survey question	Coding/Recoding
Risk perception variables		
Perceived severity (SEV)	In your opinion, how dangerous vaccine preventable diseases are? Indicate your answer in a scale from 1 to 7, where 1 corresponds to "Absolutely harmless" and 7 to "Absolutely harmful". **Imagine you have to take care of a child, today, in Italy.**	(1) Absolutely harmless (7) Absolutely harmful (88) Don't Know
General Susceptibility (GSUS)	Could you indicate, in a scale from 1 to 7, where 1 corresponds to "Completely disagree" and 7 to "Completely agree", how much you agree or disagree with these statements? Generally, the child would easily get sick	(1) Completely Disagree (7) Completely Agree (88) Don't Know
VPDs Susceptibility (VPD SUS)	Generally, the child would be exposed in this period to get a vaccine preventable disease	(1) Completely Disagree (7) Completely Agree (88) Don't Know
Likelihood of contagion without vaccines (LIK NV)	Imagine the child would have NOT received any vaccination: How likely do you think it is that the child would get a vaccine preventable disease?	(1) Absolutely Unlikely (7) Absolutely likely (88) Don't Know
Feeling of vulnerability without vaccination (FEE NV1) (FEE NV2)	How much do you agree or disagree with this sentence? 1) Without any vaccination, I feel the child could contract a vaccine preventable disease 2) Without any vaccination, I feel the child would be vulnerable to vaccine preventable diseases.	(1) Completely Disagree (7) Completely Agree (88) Don't Know
Likelihood of contagion with vaccines (LIK V)	Imagine now that all mandatory and recommended vaccinations had been administer to the child: How likely do you think it is that the child would get a vaccine preventable disease?	(1) Absolutely Unlikely (7) Absolutely Likely (88) Don't Know
Feeling of vulnerability with vaccination (FEE V1) (FEE V2)	How much do you agree or disagree with this sentence? 1) Having received all vaccinations, I feel the child could contract a vaccine preventable disease. 2) Having received all vaccinations, I feel the child would be vulnerable to vaccine preventable diseases	(1) Completely Disagree (7) Completely Agree (88) Don't Know

Probability of side effects (PSE)	How likely do you think it is that vaccinations might cause collateral effects?	(1) Absolutely Unlikely (7) Absolutely Likely (88) Don't Know
Severity of side effects (SSE)	How severe you think that vaccination's collateral effects could be?	(1) Absolutely Mild (7) Absolutely Severe (88) Don't Know
Anticipated regret (ANT REG NV)	Could you indicate, in a scale from 1 to 7, where 1 corresponds to "Completely disagree" and 7 to "Completely agree", how much you agree or disagree with these statements? 1) If I would vaccinate the child, and he/she would develop side effects, I would regret my decision to vaccinate him/her.	(1) Completely Disagree (7) Completely Agree (88) Don't Know
Anticipated regret 2 (ANT REG V)	2) If I would not vaccinate the child, and he/she would develop a vaccine preventable disease, I would regret my decision not to vaccinate him/her.	(1) Completely Disagree (7) Completely Agree (88) Don't Know

Confidence Variables

	Could you indicate, in a scale from 1 to 7, where 1 corresponds to "Completely disagree" and 7 to "Completely agree", how much you agree or disagree with these statements?	(1) Completely Disagree (88) Don't Know (7) Completely Agree
Safety (SAFE)	Vaccines are safe	
Effectiveness (EFF)	Vaccines are effective	
Controlled (CONT)	Vaccines are adequately controlled before being commercialized	
Trust doctors (DOC)	I trust my doctor's indications on vaccines	
Trust Scien. Community (SCIE)	I trust the scientific community about vaccinations	
Coll. Effects (COLL)	Information about collateral effects are openly discussed by official authorities	

Vaccine hesitancy variable

	If you would have to decide for a child you take care of, today, in Italy, would you hesitate to administer her/him all the mandatory and recommended vaccinations indicated in the Italian vaccination plan?	(0) No hesitancy (10) Max hesitancy

Socio-demographic variables		
Gender		(0) Male; (1) Female
Educational level		(0) Low: up to 9 years of education (1) Medium: 9-13 years of education (2) High: more that 13 years of education
Age		Years of age
Having children		(0) Childless (1) One child (2) More than one child
Religion	Would you say you belong to a specific religion or religious denomination?	(0) No (1) Yes (88) I don't know
Urban/Rural Area	Would you say you live in:	(1) Metropolitan Area (2) City/Urban centre (3) Rural Area (88) I don't know
Geographic area of residence		(0) North-West (1) North-East (2) Centre (3) South and Islands

Table 2 – Variables description, original language.

Variable	Survey question	Coding/Recoding
Risk perception variables		
Perceived severity	Secondo lei, quanto solo pericolose le malattie per le quali possono essere somministrati dei vaccini? Indichi la sua risposta in base ad una scala da 1 a 7, dove 1 rappresenta "Assolutamente innocue" e 7 "Assolutamente pericolose"	(1) Assolutamente innocue (7) Assolutamente pericolose (88) Non so
	Immagini di doversi prendere cura di un bambino o una bambina piccolo/a, oggi, in Italia.	
General Susceptibility (GSUS)	Mi può dire, su una scala da 1 a 7, dove 1 corrisponde a " Completamente in disaccordo" e 7 a "Completamente d'accordo", quanto lei è d'accordo o in disaccordo con le seguenti affermazioni? In generale, il bambino tenderebbe ad ammalarsi facilmente.	(1) Completamente in disaccordo (7) Completamente d'accordo (88) Non so
VPDs Susceptibility (VPD SUS)	In generale, il bambino sarebbe esposto in questo periodo a contrarre una malattia per la quale può essere somministrato un vaccino	(1) Completamente in disaccordo (7) Completamente d'accordo (88) Non so
Likelihood of contagion without (LIK NV)	Immagini che il bambino NON abbia ricevuto alcuna vaccinazione. Quanto ritiene probabile che possa contrarre in questo periodo una malattia per la quale può essere somministrato un vaccino?	(1) Assolutamente improbabile (7) Assolutamente probabile (88) Non so
Feeling of vulnerability without vaccination (FEE NV1) (FEE NV2)	Quanto è d'accordo o in disaccordo con le seguenti affermazioni? 1) Senza alcuna vaccinazione, sento che il bambino potrebbe contrarre una malattia per la quale può essere somministrato un vaccino 2) Senza alcuna vaccinazione, sento che il bambino sarebbe vulnerabile alle malattie per le quali può essere somministrato un vaccino	(1) Completamente in disaccordo (7) Completamente d'accordo (88) Non so
Likelihood of contagion with (LIK V)	Immagini invece che al bambino siano state somministrate tutte le vaccinazioni obbligatorie e raccomandate. Quanto ritiene probabile che contragga una malattia per la quale può essere somministrato un vaccino?	(1) Assolutamente improbabile (7) Assolutamente probabile (88) Non so

Feeling of vulnerability with vaccination (FEE V1) (FEE V2)	Quanto è d'accordo o in disaccordo con le seguenti affermazioni? 1) Avendo ricevuto tutte le vaccinazioni, sento che il bambino potrebbe contrarre una malattia per la quale può essere somministrato un vaccino. 2) Avendo ricevuto tutte le vaccinazioni, sento che il bambino sarebbe vulnerabile alle malattie per le quali può essere somministrato un vaccino.	(1) Completamente in disaccordo (7) Completamente d'accordo (88) Non so
Probability of side effects (PSE)	Quanto ritiene probabile che le vaccinazioni possano causare effetti collaterali o complicazioni?	(1) Assolutamente improbabile (7) Assolutamente probabile (88) Non so
Severity of side effects (SSE)	Quanto ritiene che possano essere gravi gli effetti collaterali delle vaccinazioni?	(1) Assolutamente lievi (7) Assolutamente gravi (88) Non so
Anticipated regret (ANT REG NV)	Mi può dire, su una scala da 1 a 7, dove 1 corrisponde a " Completamente in disaccordo" e 7 a "Completamente d'accordo", quanto è d'accordo o in disaccordo con le seguenti affermazioni? 1) SE NON VACCINASSI il bambino e contraesse una malattia, mi pentirei della mia decisione di non averlo vaccinato	(1) Completamente in disaccordo (7) Completamente d'accordo (88) Non so
Anticipated regret 2 (ANT REG V)	SE VACCINASSI il bambino e sviluppasse degli effetti collaterali mi pentirei della mia decisione di averlo vaccinato	(1) Completamente in disaccordo (7) Completamente d'accordo (88) Non so
Confidence Variables		
	Mi può dire, su una scala da 1 a 7, dove 1 corrisponde a " Completamente in disaccordo" e 7 a "Completamente d'accordo", quanto lei è personalmente d'accordo o in disaccordo con le seguenti affermazioni?	(1) Completamente in disaccordo (7) Completamente d'accordo (88) Non so
Safety	I vaccini sono sicuri	
Effectiveness	I vaccini sono efficaci	
Controlled	I vaccini sono adeguatamente controllati prima di essere immessi sul mercato	
Trust doctors	Mi fido delle indicazioni del medico in tema di vaccinazioni	
Trust Scien. community	Mi fido delle indicazioni della comunità scientifica in tema di vaccinazioni	

Coll. Effects	Le informazioni sugli effetti collaterali dei vaccini sono discusse apertamente dalle autorità ufficiali	
Vaccine Hesitancy variable		
	Se oggi dovesse decidere per un bambino di cui si prende cura, esiterebbe nel somministrare tutte le vaccinazioni obbligatorie previste dal piano vaccinale nazionale? Me lo indichi, per favore, su una scala da 0 a 10, dove 0 rappresenta nessuna esitazione e 10 massima esitazione.	(0) Nessuna esitazione (10) Massima esitazione

Table 3 – Descriptive statistics for variables used in RCA analysis. The first two columns report the sample size and mean for each variable before recoding all the 'Don't Know' answers. The following columns are computed including missing cases recoded with the intermediate value of 4, for a total sample size of N=988. Weighted values.

Variable	Pre-recoding N	Pre-recoding Mean(sd)	mean(sd)	median	min	max
LIK V	977	3.83 (1.78)	3.83 (1.76)	4	1	7
FEE V1	963	3.40 (1.69)	3.43 (1.65)	4	1	7
FEE V2	961	3.25 (1.66)	3.29 (1.63)	3	1	7
ANT REG V	956	4.25 (1.82)	4.23 (1.77)	4	1	7
PSE	963	3.94 (1.47)	3.94 (1.43)	4	1	7
SSE	891	4.06 (1.58)	4.05 (1.49)	4	1	7
SEV	972	5.54 (1.39)	5.49 (1.39)	6	1	7
GSUS	972	4.54 (1.50)	4.52 (1.48)	4	1	7
VPD SUS	940	4.92 (1.46)	4.85 (1.43)	5	1	7
LIK NT	980	5.24 (1.45)	5.21 (1.44)	5	1	7
FEE NV1	979	5.56 (1.36)	5.51 (1.36)	6	1	7
FEE NV2	983	5.63 (1.39)	5.59 (1.40)	6	1	7
ANT REG NV	977	5.65 (1.59)	5.60 (1.59)	6	1	7
SAFE	974	5.21 (1.46)	5.16 (1.45)	5	1	7
EFF	986	5.66 (1.27)	5.62 (1.28)	6	1	7
CONT	951	5.37 (1.48)	5.29 (1.47)	6	1	7
DOC	985	5.44 (1.35)	5.40 (1.36)	6	1	7
SCIE	978	5.33 (1.42)	5.29 (1.42)	6	1	7
COLL	931	4.66 (1.62)	4.61 (1.56)	5	1	7

Table 4 – Weighted descriptive statistics for the analytical sample and each RCA group.

	Analytical sample (n=984)					Confident (n=267)					Skeptics (n=450)					Agnostics (n=267)				
Variable	**n(%)**	**mean(SD)**	**median**	**min**	**max**	**n(%)**	**mean (SD)**	**median**	**min**	**max**	**n(%)**	**mean(SD)**	**median**	**min**	**max**	**n(%)**	**mean(SD)**	**median**	**min**	**max**
Hesitancy																				
No	402 (40,6%)					189 (70,8%)					174 (38,5%)					44 (16,3%)				
Yes	587(59.4%)					79 (29,2%)					277 (61,5%)					224 (83,7%)				
Std. R.P. without vacc.		-0.03 (1.00)	-0.08	-4.24	1.75		0.54 (1.04)	0.76	-3.91	1.75		-0.10 (0.89)	-0.08	-3.24	1.75		-0.42 (0.91)	-0.58	-4.24	1.75
Std. R.P. with vacc.		0.01 (0.98)	0.05	-2.48	2.89		-0.76 (0.96)	-0.84	-2.48	2.74		0.05 (0.84)	0.05	-2.33	2.44		0.68 (0.68)	0.50	-2.48	2.89
Std. Confidence		-0.02 (1.01)	0.06	-3.62	1.47		0.55 (1.16)	0.77	-3.62	1.47		-0.08 (0.90)	0.06	-3.62	1.47		-0.46 (0.74)	-0.65	-3.62	1.47
Std. Knowledge Index		-0.02 (0.98)	0.17	-2.03	1.27		0.58 (0.89)	0.90	-2.03	1.27		-0.06 (0.91)	0.17	-2.03	1.27		-0.52 (0.87)	-0.57	-2.03	1.27
Age		43.73 (11.97)	44.00	20.00	64.00		46.45 (11.85)	48.00	21.00	64.00		42.95 (12.05)	43.00	20.00	64.00		42.69 (11.52)	43.00	20.00	64.00
Gender																				
Male	489 (49.5%)					126 (46.9%)					214 (47.4%)					149 (55.6%)				
Female	500 (50.5%)					142 (53.1%)					237 (52.6%)					119 (44.4%)				
Educational level																				
Low	352 (35.6%)					90 (33.6%)					148 (32.9%)					114 (42.6%)				
Medium	440 (44.5%)					104 (38.8%)					225 (49.8%)					108 (40.3%)				
High	198 (20.0%)					74 (27.6%)					78 (17.3%)					46 (17.1%)				
Having children																				
No	396 (40.1%)					95 (35.3%)					178 (39.4%)					123 (45.7%)				
Yes	593 (59.9%)					173 (64.7%)					273 (60.6%)					145 (54.3%)				
Religious																				
No	449 (45.4%)					120 (44.7%)					205 (45.3%)					126 (46.9%)				
Yes	540 (54.6%)					148 (55.3%)					246 (54.7%)					142 (53.1%)				
Geographical area																				
North-West	259 (26.1%)					86 (32.1%)					108 (24.0%)					63 (23.5%)				
North-East	184 (18.6%)					43 (16.1%)					91 (20.2%)					50 (18.4%)				
Centre	204 (20.6%)					67 (24.7%)					92 (20.4%)					47 (17.3%)				
South + Islands	344 (34.7%)					73 (27.0%)					160 (35.4%)					109 (40.8%)				
Area type																				
Metropolitan area	184 (18.6%)					59 (22.1%)					81 (18.0%)					45 (16.7%)				
City/Urban centre	526 (53.2%)					136 (50.6%)					246 (54.6%)					143 (53.2%)				
Rural area	279 (28.2%)					73 (27.3%)					124 (27.5%)					81 (30.1%)				

Table 5 – Multinomial logistic regression predicting the relative risk ratio of belonging to "Skeptics" and "Agnostics" groups, compared to the "Confident" group as a function of individuals' sociodemographic characteristics. RRR, Weighted coefficients. N= 984.

	Skeptics/Confident b/(se)	**Agnostics/Confident b/(se)**
Educational Level *Ref. Cat.: Low Educated*		
Mid Educated	1.184	0.741
	(0.250)	(0.171)
High Educated	0.599*	0.472**
	(0.129)	(0.112)
Gender *Ref. Cat.: Male*		
Female	0.979	0.712
	(0.170)	(0.138)
Age	0.975**	0.974**
	(0.008)	(0.009)
Having Children *Ref. Cat.: No*		
One	1.357	1.183
	(0.327)	(0.320)
More than one	0.857	0.624*
	(0.178)	(0.148)
Religious *Ref. Cat.: No*		
Yes	1.072	0.977
	(0.194)	(0.195)
Geographic Are*a* *Ref. Cat.: North-East*		
North-West	1.575	1.457
	(0.406)	(0.431)
Centre	1.076	0.952
	(0.261)	(0.268)
South and Islands	1.685*	2.015**
	(0.394)	(0.520)
Urban/Rural Area *Ref. Cat: Metropolitan Area*		
City/Urban Centre	1.129	1.102
	(0.255)	(0.288)
Rural Area	1.091	1.199
	(0.286)	(0.363)
Constant	3.965**	4.217**
	(1.832)	(2.196)

**** p<0.001, ** p<0.01, * p<0.05;* Robust SE in parentheses

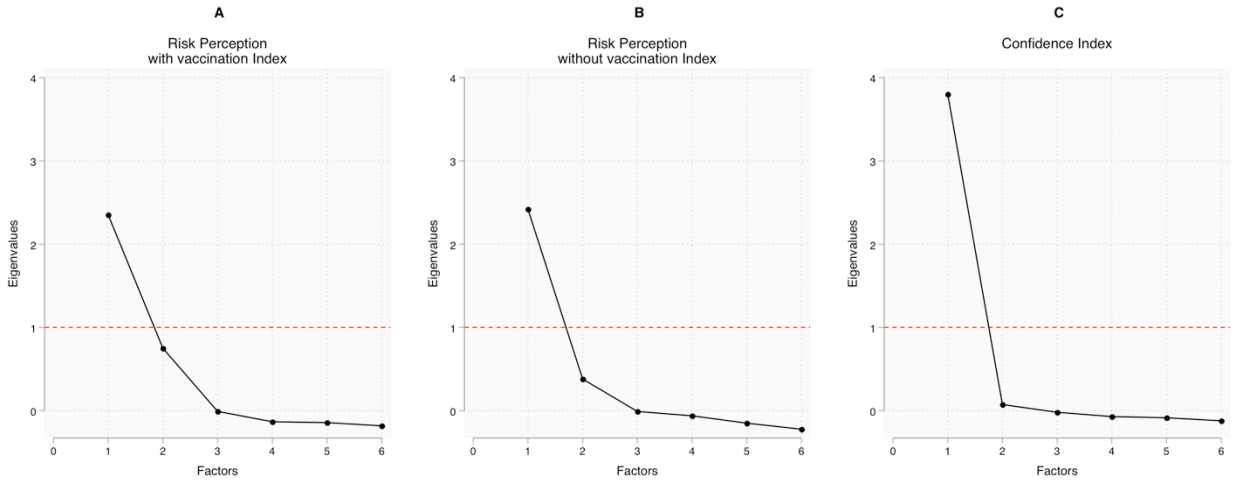
Table 6 – Binomial logistic regression predicting the probability to be vaccine hesitant in each RCA group. Odds ratios. Weighted coefficients

	Confident b/(se)	Skeptics b/(se)	Agnostics b/(se)
Issue domains Indexes			
Std. Confidence Index	0.313*	0.406***	0.845
	(0.145)	(0.076)	(0.497)
Std. Risk without vaccination Index	0.720	0.638**	0.309*
	(0.262)	(0.106)	(0.159)
Std. Risk with vaccination Index	2.434**	1.715**	2.315*
	(0.702)	(0.286)	(0.854)
Educational Level *Ref. Cat.: Low Educated*			
Mid Educated	0.410	1.098	0.522
	(0.193)	(0.320)	(0.245)
High Educated	0.879	0.708	0.960
	(0.401)	(0.235)	(0.509)
Gender *Ref. Cat.: Male*			
Female	2.029	0.675	0.283**
	(0.867)	(0.169)	(0.124)
Age	1.032	1.022	1.000
	(0.020)	(0.012)	(0.016)
Having Children *Ref. Cat.: No*			
One	0.726	1.082	0.395
	(0.434)	(0.389)	(0.194)
More than one	0.812	0.543	0.744
	(0.359)	(0.176)	(0.398)
Religeous *Ref. Cat.: No*			
Yes	0.619	1.392	1.318
	(0.259)	(0.356)	(0.548)
Geographic Are*a* *Ref. Cat.: North-East*			
North-West	0.163*	0.755	1.206
	(0.150)	(0.264)	(0.699)
Centre	1.282	1.155	0.995
	(0.630)	(0.404)	(0.639)
South and Islands	1.552	1.172	1.089
	(0.820)	(0.388)	(0.563)
Urban/Rural Area *Ref. Cat: Metropolitan Area*			
City/Urban Centre	1.027	0.895	1.415
	(0.513)	(0.300)	(0.737)
Rural Area	0.673	0.645	1.479
	(0.412)	(0.251)	(0.830)

Constant	0.724	0.980	4.910
	(0.815)	(0.618)	(4.705)
N	267	450	267
Pseudo R2	0.3444	0.2047	0.1935

**** p<0.001, ** p<0.01, * p<0.05;* Robust standard errors in parentheses

Figure 1 – Exploratory factor analysis for each issue domain index. Each scale displays only a single factor with eigenvalue above 1. This result is robust to different factor analysis specification.



APPENDIX TO CHAPTER III

Table 1 – Variables description. Survey questions in table 1 are a translation from the original Italian version. General susceptibility, although being used as a control, is included in risk perception variables as in the original sequence of the questionnaire. All risk perception variables included a "Don't know" option, recoded with the intermediate value.

Variable	**Survey question**	**Coding/Recoding**
Outcome Variable		
Vaccine Hesitancy	If, today, you would have to decide for a child you take care of, would you hesitate in administering all mandatory vaccinations as indicated in the national vaccination plan? Could you indicate it, please, on a scale form 0 to 10, where 0 represents no hesitation and 10 maximum hesitation?	(0 = 0) No (1-10 = 1) Yes
Main independent variable		
Thinking mode (CRT-L test)	**Before the beginning of the questionnaire, we would like to have you complete a little quiz.** (1) A bat and a ball cost £1.10 in total. The bat costs £1.00 more than the ball. How much does the ball cost? (2) If it takes 5 minutes for five machines to make five widgets, how long would it take for 100 machines to make 100 widgets? (3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? (4) If three elves can wrap three toys in hour, how many elves are needed to wrap six toys in 2 hours? (5) Giovanni received both the 15th highest and the 15th lowest mark in the class. How many students are there in the class? (6) In an athletics team, tall members are three times more likely to win a medal than short members. This year the team has won 60 medals so far. How many of these have been won by short athletes?	Composite variable assigning individuals to the category with the higher number of relative answers. Majority of: (0) Correct answers (Analytic Style) (1) Heuristic answers (Intuitive Style) (2) Incorrect answers (3) Equal number of correct/heuristic/incorrect answers (Unassigned)

Risk perception variables

Perceived severity (SEV)	In your opinion, how dangerous vaccine preventable diseases are?	(1) Absolutely harmless (7) Absolutely dangerous
	Imagine you have to take care of a child, today, in Italy:	
General Susceptibility (GEN SUS)	Could you indicate, in a scale from 1 to 7, where 1 corresponds to "Completely disagree" and 7 to "Completely agree", how much you agree or disagree with these statements? Generally, the child would easily get sick	(1) Completely Disagree (7) Completely Agree
VPDs Susceptibility (VPD SUS)	Generally, the child would be exposed in this period to get a vaccine preventable disease	
Likelihood of contagion not conditioned on vaccination (LIK NV)	**Imagine the child would have NOT received any vaccination:** How likely do you think it is that the child would get a vaccine preventable disease?	(1) Absolutely Unlikely (7) Absolutely likely
Feeling of vulnerabilitynot conditioned on vaccination(FEE NV)	How much do you agree or disagree with this sentence? Without any vaccination, I feel the child would be vulnerable to vaccine preventable diseases.	(1) Completely Disagree (7) Completely Agree
Likelihood of contagion conditioned on vaccination (LIK V)	**Imagine now that all mandatory and recommended vaccinations had been administer to the child:** How likely do you think it is that the child would get a vaccine preventable disease?	(1) Absolutely Unlikely (7) Absolutely Likely
Feeling of vulnerability conditioned on vaccination (FEE V)	How much do you agree or disagree with this sentence? Having received all the vaccinations, I feel the child would be vulnerable to vaccine preventable diseases	(1) Completely Disagree (7) Completely Agree
Probability of side effects (PSE)	How likely do you think it is that vaccinations might cause collateral effects?	(1) Absolutely Unlikely (7) Absolutely Likely
Severity of side effects (SSE)	How severe you think that vaccination's collateral effects could be?	(1) Absolutely Mild (7) Absolutely Severe

Socio-demographic variables

Gender	(0) Male; (1) Female

Educational level	(0) - Low: up to 9 years of education (1) - Medium: 9-13 years of education (2) - High: more that 13 years of education
Age	Years of age
Having children	(0) No children (1) One child (2) More than one child
Geographic area of residence	(0) North-West (1) North-East (2) Centre (3) South and Islands

Table 2 – Descriptive statistics, weighted. For categorical variables, frequencies have been rounded to the nearest integer.

	Analytical sample (n= 952)				
Variable	**n(%)**	**mean (sd)**	**median**	**min**	**max**
SEV		-0.03 (1.00)	0	-3	1
VPD SUS		-0.03 (1.01)	0	-3	1
LIK NV		-0.03 (1.01)	0	-3	1
FEE NV		-0.02 (1.00)	0	-3	1
LIK V		0.00 (0.99)	0	-2	2
FEE V		0.01 (0.99)	0	-1	2
PSE		0.01 (0.99)	0	-2	2
SSE		0.01 (0.97)	0	-2	2
General susceptibility		-0.02 (1.00)	0	-2	2
Age		43.91 (11.93)	44	20	64
Thinking Style					
Analytic Style	187 (19.5%)				
Intuitive Style	445 (46.7%)				
Incorrect	167 (17.5%)				
Unassigned	156 (16.3%)				
Hesitancy					
No	387 (40.6%)				
Yes	566 (59.4%)				
Gender					
Male	473 (49.6%)				
Female	480 (50.4%)				
Educational level					
Low	346 (36.3%)				
Medium	415 (43.5%)				
High	192 (20.2%)				
Having children					
Zero	384 (40.3%)				
One	207 (21.7%)				
More than one	362 (38.0%)				
Geographical area					
North-West	249 (26.1%)				
North-East	181 (19.0%)				
Center	193 (20.2%)				
South + Islands	331 (34.7%)				

Table 3 – Odds Ratios of KHB decomposition for nested logistic regression predicting the probability to be vaccine hesitant. In order to compare nested models estimates, (m1) and (m2) are rescaled on the basis of the most saturated full model (m12), as per KHB design. Robust S.E in parenthesis.

	Dependent variable: Probability to be vaccine hesitant		
	(m1) Bivariate model	(m2) Reduced Model	(m12) Full model
Cognitive style			
Ref category: Analytic style			
Intuitive Style	3.4347***	3.3243***	1.8723**
	(0.7729)	(0.7707)	(0.4314)
Incorrect	4.6693***	3.9100***	1.7001
	(1.3400)	(1.1228)	(0.4830)
Unassigned	2.5439**	2.6198**	1.6415
	(0.7687)	(0.8125)	(0.5095)
Educational Level			
Ref. Cat: Low Educated			
Mid		0.6357*	0.9902
		(0.1311)	(0.2034)
High		0.5942*	1.1229
		(0.1385)	(0.2637)
Gender			
Ref. Cat = Male			
Female		0.7483	0.7735
		(0.1334)	(0.1389)
Age		1.0044	1.0142
		(0.0082)	(0.0084)
Having children			
Ref. Cat: No children			
One child		0.9364	0.8905
		(0.2295)	(0.2206)
More than one children		0.4728***	0.7085
		(0.1060)	0.15735
Area			
Reference Cat: North-West			
North-East		1.0434	0.8246
		(0.2629)	(0.2129)
Centre		1.3790	1.3123
		(0.3445)	(0.3278)
South + Islands		1.6037*	1.1785
		(0.3823)	(0.2787)
Std. General Susceptibility		0.7193***	0.9679

		(0.0645)	(0.1041)
R.P Variables			
SEV			0.7400**
			(0.0790)
VPD SUS			1.0504
			(0.1115)
LIK NV			0.9666
			(0.0997)
FEE NV			0.4198***
			(0.0658)
LIK V			0.9242
			(0.0885)
FEE V			1.2998**
			(0.1272)
PSE			1.8878***
			(0.2205)
SSE			1.4811***
			(0.1605)
Constant	2.3259	3.2084	1.3576
	(0.3194)	(1.3735)	(0.5830)
Pseudo R2	0.0266	0.0559	0.2932
Observations	952	952	952

*** *p<0.001,* ** *p<0.01,* * *p<0.05*; Robust standard errors in parentheses

Table 4 – Linear regression (m3-m10) predicting the association between cognitive styles, compared to Analytic style, with risk perception measures. All models are controlled for individual socio-demographic characteristics and general susceptibility to diseases.

	(m3) **SEV**	(m4) **VPD SUS**	(m5) **LIK NV**	(m6) **FEE NV**	(m7) **LIK V**	(m8) **FEE V**	(m9) **PSE**	(m10) **SSE**
Cognitive style *Ref category: Analytic style*								
Intuitive style	-0.3615***	-0.2266*	-0.1764*	-0.2302**	0.3326***	0.4272***	0.2371**	0.0868
	(0.0824)	(0.0921)	(0.0845)	(0.0791)	(0.0938)	(0.0838)	(0.0907)	(0.0934)
Incorrect	-0.4366***	-0.2387*	-0.1314	-0.2724*	0.3929***	0.6459***	0.3359**	0.3066**
	(0.1079)	(0.1055)	(0.1064)	(0.1084)	(0.1138)	(0.1075)	(0.1158)	(0.1112)
Unassigned	-0.2738*	-0.1416	-0.2672*	-0.1310	0.1927	0.2567*	0.2222*	0.1933
	(0.1077)	(0.1154)	(0.1263)	(0.1030)	(0.1192)	(0.1151)	(0.1105)	(0.1117)
Educational Level *Ref. Cat: Low Educated*								
Mid	0.2196**	0.0662	0.0842	0.2205**	-0.0535	-0.1591*	-0.1525	-0.1317
	(0.0802)	(0.0724)	(0.0825)	(0.0786)	(0.0778)	(0.0758)	(0.0790)	(0.0779)
High	-0.3084***	0.0797	0.0648	0.2808***	-0.0218	-0.1458	-0.2326**	-0.2984***
	(0.0829)	(0.0776)	(0.0877)	(0.0794)	(0.0867)	(0.0849)	(0.0848)	(0.0872)
Gender *Ref. Cat = Male*								
Female	0.1113	-0.0909	-0.0579	0.1001	0.0212	-0.0432	0.1073	0.0878
	(0.0682)	(0.0633)	(0.0706)	(0.0674)	(0.0686)	(0.0670)	(0.0693)	(0.0675)
Age	0.0002	-0.0005	0.0058	0.0034	-0.0130***	-0.0071*	-0.0047	-0.0069*
	(0.0032)	(0.0032)	(0.0033)	(0.0030)	(0.0031)	(0.0031)	(0.0031)	(0.0032)

Having children								
Ref. Cat: No children								
One child	0.0569	-0.0069	-0.0281	0.0606	0.2012*	0.1436	0.0825	0.1148
	(0.0934)	(0.0853)	(0.0948)	(0.0915)	(0.0902)	(0.0901)	(0.0912)	(0.0916)
More than one children	0.2054*	0.0905	0.1422	0.2588**	0.2218**	-0.0438	-0.1580	0.0298
	(0.0801)	(0.0779)	(0.0885)	(0.0805)	(0.0832)	(0.0837)	(0.0849)	(0.0863)
Area								
Reference Cat: North-West								
North-East	0.0240	0.0012	-0.0870	-0.2581**	-0.0573	0.0320	-0.0165	0.0334
	(0.0960)	(0.0926)	(0.0984)	(0.0995)	(0.1026)	(0.0991)	(0.1044)	(0.1065)
Centre	-0.0032	0.1523	0.0030	0.0600	-0.0653	0.0353	0.0819	0.0685
	(0.1005)	(0.0913)	(0.0979)	(0.0925)	(0.1000)	(0.0969)	(0.1000)	(0.0998)
South + Islands	-0.2270*	-0.0225	0.0155	-0.0867	0.1482	0.2185*	0.1575	0.0520
	(0.0930)	(0.0832)	(0.0951)	(0.0913)	(0.0915)	(0.0910)	(0.0919)	(0.0889)
Std. General Susceptibility	0.1856***	0.5186***	0.2579***	0.2916***	0.0524	0.0491	-0.0279	0.0111
	(0.0376)	(0.0377)	(0.0417)	(0.0362)	(0.0397)	(0.0377)	(0.0386)	(0.0360)
Constant	0.0201	0.1189	-0.1906	-0.2292	0.1792	-0.0207	0.0411	0.1891
	(0.1804)	(0.1640)	(0.1750)	(0.1632)	(0.1756)	(0.1639)	(0.1759)	(0.1797)
Observations	952	952	952	952	952	952	952	952
R-squared	0.106	0.272	0.081	0.140	0.063	0.086	0.048	0.035

**** p<0.001, ** p<0.01, * p<0.05;* Robust standard errors in parentheses

Table 5 – Odds Ratios of logistic regression predicting the probability to be vaccine hesitant (m11).

Dependent variable: Probability to be vaccine Hesitant	
Risk Perception Measures	
SEV	0.7198***
	(0.0760)
VPD SUS	1.0462
	(0.1097)
LIK NV	0.9656
	(0.0997)
FEE NV	0.4270***
	(0.0648)
LIK V	0.9412
	(0.0907)
FEE V	1.3352***
	(0.1297)
PSE	1.8881***
	(0.2216)
SSE	1.4786***
	(0.1612)
Std. General Susceptibility	0.9952
	(0.1058)
Educational Level	
Ref. Cat: Low Educated	
Mid	0.9959
	(0.2049)
High	1.0145
	(0.2343)
Gender	
Ref. Cat = Male	
Female	0.7858
	(0.1396)
Age	1.0142*
	(0.0083)
Having children	
Ref. Cat: No children	
One child	0.8753
	(0.2182)
More than one children	0.6949*
	(0.1531)
Area	
Reference Cat: North-West	
North-East	0.8049
	(0.2053)
Centre	1.2498
	(0.3112)
South + Islands	1.2113
	(0.2849)

Constant	1.1729 (0.4745)
Observations	952
Pseudo R2	0.2872

*** *p<0.001,* ** *p<0.01,* * *p<0.05;*
Robust standard errors in parentheses

Table 6 – KHB decomposition predicting the probability to be vaccine hesitant. Odds ratios of total, direct and indirect associations of cognitive styles versus Analytic style and corresponding significance levels.

	Dependent variable: Probability to be vaccine hesitant		
	Total effect (Reduced model)	Direct Effect (Full model)	Indirect effect (Est. Diff.)
Cognitive style *Ref category: Analytic style*			
Intuitive Style	3.3243*** (0.7707)	1.8723** (0.4314)	1.7755 ** (0.1477)
Incorrect	3.9100*** (1.1228)	1.7001 (0.4830)	2.2999** (0.6675)
Unassigned	2.6198** (0.8125)	1.6415 (0.5095)	1.5960 (0.4522)

**** p<0.001, ** p<0.01, * p<0.05*; Robust standard errors in parentheses

Table 7 – KHB Decomposition of risk perception mediators. The first column on the left reports log odds and Robust S.E. for each mediator, in each thinking style category, compared to Analytic style. The third column expresses the percentage contribution of each mediator to the indirect effect. The fourth column reports the percentage contribution of each mediator to the total confounding effect.

	Components of Difference			
	Coef.	Robust S.E.	% Ind. Effect	% Total effect
Cognitive style *Ref category: Analytic style*				
Intuitive Style				
SEV	0.1089	(0.0458)	18.96	9.06
VPD SUS	-0.0111	(0.0244)	-1.94	-0.93
LIK NV	0.0060	(0.0184)	1.04	0.50
FEE NV	0.1998	(0.0771)	34.80	16.63
LIK V	- 0.0262	(0.0327)	-4.57	-2.18
FEE V	0.1120	(0.0472)	19.51	9.32
PSE	0.1507	(0.0636)	26.25	12.54
SSE	0.0341	(0.0376)	5.94	2.84
Incorrect				
SEV	0.1315	(0.0567)	15.78	9.64
VPD SUS	- 0.0117	(0.0259)	-1.41	-0.86

LIK NV	0.0045	(0.0140)	0.54	0.33
FEE NV	0.2364	(0.1028)	28.38	17.34
LIK V	- 0.0310	(0.0387)	-3.72	-2.27
FEE V	0.1694	(0.0691)	20.33	12.42
PSE	0.2135	(0.08299	25.63	15.66
SSE	0.1204	(0.0546)	14.46	8.83
Unassigned				
SEV	0.0824	(0.0435)	17.64	8.56
VPD SUS	-0.0070	(0.01609	-1.49	-0.72
LIK NV	0.0091	(0.0279)	1.94	0.94
FEE NV	0.1137	(0.0912)	24.32	11.80
LIK V	-0.0152	(0.0206)	-3.25	-1.58
FEE V	0.0673	(0.03919	14.40	6.99
PSE	0.1412	(0.0744)	30.20	14.66
SSE	0.0759	(0.04839	16.24	7.88

Table 8 – Summary of confounding. The first column reports the confounding ratio of each cognitive style, compared to Analytic style, between total effect and direct effect. Column two reports the relative confounding percentage. Column three reports the rescaling factor applied to the reduced model (m2) and to bivariate model (m1) in order to compare coefficients between models.

Summary of Confounding			
	Confounding Ratio	Confounding Percentage	Rescaling Factor
Cognitive style *Ref category: Analytic style*			
Intuitive Style	1.9153	47.79	1.4175
Incorrect	2.5695	61.08	1.3575
Unassigned	1.9433	48.54	1.3412

Table 9 – Odds Ratios of KHB decomposition for nested logistic regressions predicting the probability to be vaccine hesitant, computing the CRT-L score in three common alternative ways. The *CRT-L Reflective* score is computed as the sum of correct answers (correct = 1; incorrect/heuristic = 0). The *CRT-L Intuitive* score is computed as the sum of heuristic answers (heuristic = 1; incorrect/correct = 0). Finally, the *CRT-L Proportion* is computed as the proportion, for each individual, of the number of heuristic answers divided by the sum of incorrect and heuristic answers. In this case, the analytical sample numerosity decreases to 919 cases, given that 33 individuals did not answer, out of the 6 CRT-L items, with at least one intuitive or one incorrect answer.

	Dependent variable: Probability to be vaccine hesitant								
	Bivariate model (m1)			**Reduced model (m2)**			**Full model (m12)**		
	CRT-L Reflective	CRT-L Intuitive	CRT-L Proportion	CRT-L Reflective	CRT-L Intuitive	CRT-L Proportion	CRT-L Reflective	CRT-L Intuitive	CRT-L Proportion
CRT-L score	0 .7325***	1.2517***	1.7665	0.7540***	1.2596***	2.2783*	0.8943†	1.1603*	2.2603*
	(0.0418)	(0.7732)	(0.6040)	(0.0439)	(0.0802)	(0.7890)	(0.0519)	(0.0737)	(0.7910)
Educational Level *Ref. Cat: Low Educated*									
Mid				0.6687	0.6169*	0.6340*	1.0162	0.9917	0.9829
				(0.1379)	(0.1272)	(0.1302)	(0.2092)	(0.2039)	(0.2015)
High				0.5902*	0.5104*	0.5011**	1.1006	1.0793	1.0730
				(0.1390)	(0.1189)	(0.1180)	(0.2608)	(0.2535)	(0.2540)
Gender *Ref. Cat = Male*									
Female				0.7057	0.7135	0.6665*	0.7656	0.7540	0.7254
				(0.1261)	(0.1275)	(0.1198)	(0.1377)	(0.1357)	(0.1308)
Age				1.0033	1.0018	1.0005	1.0137	1.0132	1.0146
				(0.0080)	(0.0080)	(0.0081)	(0.0083)	(0.0083)	(0.0085)
Having children *Ref. Cat: No children*									
One child				0.9113	0.9228	0.9366	0.8795	0.8866	0.8965
				(0.2235)	(0.2262)	(0.2319)	(0.2185)	(0.2205)	(0.2251)

More than one child				0.4510***	0.4452***	0.4466***	0.7021	0.6964	0.6735
				(0.1021)	(0.0989)	(0.1000)	(0.1543)	(0.1534)	(0.1497)
Area									
Ref. Cat: North-West									
North-East				0.9748	0.9555	0.9190	0.8014	0.7961	0.8122
				(0.2440)	(0.2394)	(0.2330)	(0.2055)	(0.2043)	(0.2101)
Centre				1.2820	1.2493	1.0938	1.2710	1.2650	1.2178
				(0.3190)	(0.3113)	(0.2755)	(0.3169)	(0.3160)	(0.3087)
South + Islands				1.5542*	1.6920*	1.7234*	1.1717	1.1889	1.2485
				(0.3688)	(0.4040)	(0.4164)	(0.2763)	(0.2810)	(0.2987)
Std. Gen. Susceptibility				0.7352***	0.7321***	0.7197***	0.9813	0.9767	0.9698
				(0.0654)	(0.0652)	(0.0651)	(0.1053)	(0.1040)	(0.1034)
R.P Variables									
SEV							0.7366**	0.7222**	0.6971***
							(0.0776)	(0.0766)	(0.0754)
VPD SUS							1.0545	1.0504	1.0529
							(0.1105)	(0.1111)	(0.1130)
LIK NV							0.9693	0.9617	0.9488
							(0.0993)	(0.0996)	(0.0992)
FEE NV							0.4229***	0.4256***	0.4388***
							(0.0650)	(0.0646)	(0.0657)
LIK V							0.9197	0.9260	0.9575
							(0.0890)	(0.0893)	(0.0931)
FEE V							1.3096**	1.3217**	1.3326**
							(0.1279)	(0.1286)	(0.1315)
PSE							1.8856***	1.8925***	1.8444***
							(0.2215)	(0.2192)	(0.2166)
SSE							1.4765***	1.4944***	1.5013***
							(0.1605)	(0.1644)	(0.1662)
Constant	2.9960	1.0052	1.3522	4.3565	1.6888	2.2013	1.4259	1.3576	0.7366

	(0.4264)	(0.1848)	(0.3067)	(1.8264)	(0.7254)	(0.9898)	(0.1042)	(0.5830)	(0.3374)
Pseudo R2	0.0201	0.0085	0.0012	0.0440	0.0446	0.0410	0.2901	0.2921	0.2852
Observations	952	952	919	952	952	919	952	952	919

*** *p<0.001,* ** *p<0.01,* * *p<0.05,* † *p<0.1;* Robust standard errors in parentheses

APPENDIX TO CHAPTER IV

Table 1 – Variables description, English version.

Variable	Survey question	Coding/Recoding
Outcome Variable		
Willingness to vaccinate	If a vaccine for COVID-19 becomes available, would you choose to get vaccinated?	(1) - Yes (0) - No; Don't Know
Risk perception variables		
Risk: community	How dangerous do you think the COVID-19 risk is to your community?	(0) - Not at all dangerous; Slightly dangerous (1) - Moderately dangerous (2) - Very dangerous; Extremely dangerous
Risk: likelihood of contagion	How likely is it that someone of the same age as you in your community becomes sick from COVID-19?	(0) - Not at all likely; Slightly likely (1) - Moderately likely (2) - Very likely; Extremely likely
Risk: perceived severity	How serious would it be if you became infected with COVID-19?	(0) - Not at all serious (1) - Somewhat serious (2) - Very serious
Confidence variables		
Local health workers, clinics, and community organizations Scientists, doctors, and health experts World Health Organization (WHO) Government health authorities or other officials	How much do you trust each of the following as a source of COVID-19 news and information?	(0) - Do not trust (1) - Somewhat trust (2) - Trust
Control variables		
Gender		(0) Male (1) Female
Educational level	What is the highest level of education you have completed?	(0) - Less than primary school; Primary school (1) - Secondary Shool (2) - College, University, Graduate School

Age		(0) - 18-30 years (1) - 31-40 years (2) - 41-50 years (3) - 51-60 years (4) - 61-Over 60 years
Urban/Rural area	Which of these best describes the area where you are currently staying?	(0) - City (1) - Town (2) - Village or Rural Area
Health Status	In general, how would you rate your overall health?	(0) - Very poor; Poor (1) - Good (2) - Very Good; Excellent
Information exposure	In the past week, how much, if anything, have you heard or read about coronavirus (COVID-19)?	(0) - Nothing; A little (1) - A moderate amount; A lot

Table 2 – Individual-level descriptive statistics by country, Argentina-Malaysia. Weighted.

	Argentina	Bangladesh	Brazil	Colombia	Egypt	France	Germany	India	Indonesia	Italy	Japan	Malaysia
Willingness to vaccinate												
No/Don't Know'	2007 (32.35%)	813 (15.66%)	1177 (20.15%)	1807 (30.03%)	2295 (41.64%)	3740 (53.40%)	2839 (38.35%)	1283 (24.56%)	2183 (42.94%)	2323 (32.05%)	3083 (40.63%)	1662 (27.09%)
Yes	4196 (67.65%)	4375 (84.34%)	4664 (79.85%)	4208 (69.97%)	3216 (58.36%)	3265 (46.60%)	4564 (61.65%)	3941 (75.44%)	2900 (57.06%)	4926 (67.95%)	4505 (59.37%)	4472 (72.91%)
Risk Index												
Mean (SD)	0.12 (0.95)	-0.09 (1.02)	0.33 (0.95)	0.45 (0.91)	0.34 (0.92)	-0.14 (0.94)	-0.35 (0.99)	-0.19 (1.08)	0.17 (0.99)	-0.24 (0.85)	-0.25 (0.80)	0.12 (0.95)
Confidence Index												
Mean (SD)	-0.11 (1.06)	-0.06 (0.96)	0.02 (0.89)	-0.07 (1.08)	-0.20 (1.10)	-0.02 (1.08)	0.03 (1.05)	0.11 (0.86)	0.12 (1.04)	0.07 (0.94)	-0.15 (1.01)	0.32 (0.54)
Risk: Community												
Low risk	903 (14.55%)	1096 (21.12%)	508 (8.69%)	527 (8.76%)	853 (15.47%)	1091 (15.57%)	2048 (27.65%)	1148 (21.98%)	761 (14.97%)	1579 (21.78%)	973 (12.81%)	940 (15.32%)
Moderate risk	1783 (28.74%)	1449 (27.93%)	1006 (17.21%)	1153 (19.17%)	1126 (20.43%)	2656 (37.91%)	2319 (31.32%)	1267 (24.25%)	1086 (21.37%)	3154 (43.51%)	3047 (40.16%)	1116 (18.19%)
High Risk	3518 (56.71%)	2643 (50.95%)	4328 (74.10%)	4335 (72.07%)	3533 (64.11%)	3259 (46.52%)	3038 (41.02%)	2809 (53.77%)	3236 (63.66%)	2516 (34.71%)	3569 (47.03%)	4078 (66.48%)
Risk: Likelihood of contagion												
Low likelihood	916 (14.77%)	2027 (39.06%)	778 (13.31%)	803 (13.35%)	1031 (18.70%)	1743 (24.88%)	2876 (38.84%)	2381 (45.59%)	1145 (22.51%)	1934 (26.67%)	1160 (15.29%)	2569 (41.88%)
Moderate likelihood	980 (15.79%)	1571 (30.27%)	1378 (23.59%)	902 (14.98%)	1416 (25.70%)	2576 (36.77%)	3018 (40.76%)	1311 (25.09%)	1319 (25.94%)	3574 (49.30%)	4328 (57.04%)	2014 (32.83%)
High likelihood	4307 (69.44%)	1591 (30.67%)	3685 (63.10%)	4310 (71.67%)	3064 (55.60%)	2686 (38.35%)	1510 (20.39%)	1532 (29.32%)	2620 (51.54%)	1742 (24.02%)	2100 (27.67%)	1552 (25.29%)
Risk: Perceived severity												
Not at all serious	1079 (17.40%)	529 (10.19%)	1116 (19.11%)	485 (8.05%)	174 (3.16%)	1048 (14.95%)	1197 (16.17%)	778 (14.89%)	727 (14.30%)	689 (9.50%)	1912 (25.19%)	453 (7.38%)
Somewhat serious	3313 (53.41%)	1905 (36.71%)	2823 (48.32%)	2624 (43.62%)	2220 (40.28%)	3678 (52.50%)	3580 (48.36%)	2111 (40.40%)	1294 (25.45%)	4155 (57.32%)	4613 (60.79%)	2109 (34.39%)
Very serious	1811 (29.19%)	2755 (53.10%)	1902 (32.57%)	2907 (48.33%)	3117 (56.56%)	2280 (32.54%)	2627 (35.48%)	2336 (44.71%)	3062 (60.25%)	2405 (33.18%)	1064 (14.02%)	3572 (58.23%)
Confidence: Healthcare workers												
Do not trust	416 (6.69%)	648 (12.48%)	274 (4.68%)	561 (9.33%)	651 (11.80%)	370 (5.28%)	554 (7.47%)	373 (7.14%)	302 (5.94%)	326 (4.49%)	472 (6.22%)	134 (2.18%)
Somewhat Trust	2134 (34.40%)	2372 (45.72%)	2360 (40.41%)	2399 (39.88%)	2526 (45.83%)	2472 (35.29%)	3543 (47.86%)	2196 (42.04%)	1781 (35.03%)	2477 (34.17%)	4829 (63.64%)	1762 (28.73%)
Trust	3654 (58.91%)	2168 (41.79%)	3207 (54.91%)	3055 (50.79%)	2335 (42.37%)	4163 (59.43%)	3307 (44.67%)	2655 (50.82%)	3000 (59.02%)	4447 (61.34%)	2287 (30.14%)	4238 (69.09%)
Confidence: Scientists												
Do not trust	276 (4.44%)	176 (3.39%)	218 (3.73%)	288 (4.78%)	329 (5.95%)	368 (5.25%)	353 (4.76%)	172 (3.29%)	243 (4.76%)	313 (4.31%)	408 (5.37%)	107 (1.73%)
Somewhat Trust	1659 (26.74%)	1213 (23.37%)	1636 (28.00%)	1703 (28.31%)	1699 (30.83%)	2539 (36.24%)	2626 (35.46%)	1094 (20.95%)	1345 (26.46%)	2012 (27.76%)	4248 (55.99%)	1460 (23.80%)
Trust	4268 (68.81%)	3799 (73.24%)	3987 (68.27%)	4024 (66.91%)	3484 (63.21%)	4099 (58.51%)	4426 (59.78%)	3958 (75.77%)	3496 (68.78%)	4924 (67.93%)	2932 (38.64%)	4568 (74.47%)
Confidence: WHO												
Do not trust	960 (15.47%)	310 (5.96%)	757 (12.95%)	806 (13.39%)	666 (12.09%)	829 (11.82%)	922 (12.45%)	517 (9.89%)	379 (7.46%)	756 (10.43%)	1957 (25.79%)	201 (3.28%)
Somewhat Trust	2407 (38.80%)	1075 (20.72%)	1773 (30.35%)	2191 (36.42%)	1864 (33.81%)	2676 (38.20%)	2346 (31.69%)	1411 (27.00%)	1508 (29.66%)	2309 (31.85%)	3935 (51.86%)	1396 (22.76%)
Trust	2837 (45.74%)	3804 (73.32%)	3311 (56.69%)	3019 (50.19%)	2982 (54.10%)	3501 (49.98%)	4136 (55.86%)	3296 (63.10%)	3196 (62.88%)	4185 (57.73%)	1696 (22.35%)	4537 (73.97%)
Confidence: Government and health authorities												
Do not trust	1559 (25.13%)	1215 (23.42%)	1083 (18.54%)	1094 (18.18%)	1561 (28.31%)	1437 (20.51%)	799 (10.79%)	459 (8.77%)	455 (8.95%)	1100 (15.17%)	1312 (17.29%)	220 (3.58%)
Somewhat Trust	2875 (46.35%)	2120 (40.86%)	3252 (55.67%)	3024 (50.27%)	2332 (42.31%)	3293 (47.00%)	2976 (40.20%)	2083 (39.87%)	1931 (37.99%)	3354 (46.27%)	4791 (63.14%)	1466 (23.90%)
Trust	1769 (28.52%)	1853 (35.72%)	1507 (25.79%)	1898 (31.54%)	1619 (29.37%)	2276 (32.49%)	3629 (49.02%)	2683 (51.35%)	2697 (53.07%)	2796 (38.57%)	1485 (19.56%)	4448 (72.52%)
Gender												
Male	3090 (49.82%)	2813 (54.23%)	2902 (49.68%)	3050 (50.71%)	2831 (51.37%)	3236 (46.19%)	3806 (51.40%)	2812 (53.83%)	2754 (54.18%)	3524 (48.61%)	3830 (50.47%)	3045 (49.64%)
Female	3113 (50.18%)	2375 (45.77%)	2939 (50.32%)	2965 (49.29%)	2680 (48.63%)	3769 (53.81%)	3598 (48.60%)	2412 (46.17%)	2329 (45.82%)	3725 (51.39%)	3758 (49.53%)	3089 (50.36%)
Age												
18-30	1963 (31.64%)	2757 (53.14%)	1817 (31.11%)	2136 (35.50%)	2198 (39.89%)	1460 (20.84%)	1392 (18.80%)	2227 (42.63%)	1781 (35.03%)	1328 (18.31%)	856 (11.28%)	2023 (32.98%)
31-40	1258 (20.28%)	902 (17.38%)	1250 (21.39%)	1262 (20.97%)	1320 (23.94%)	1075 (15.34%)	1217 (16.43%)	1117 (21.39%)	1178 (23.17%)	1211 (16.70%)	1145 (15.09%)	1422 (23.18%)
41-50	1088 (17.53%)	748 (14.42%)	1089 (18.63%)	993 (16.50%)	963 (17.48%)	1261 (18.00%)	1347 (18.19%)	737 (14.10%)	956 (18.80%)	1470 (20.27%)	1642 (21.64%)	1224 (19.95%)
51-60	858 (13.82%)	555 (10.69%)	891 (15.25%)	947 (15.73%)	616 (11.17%)	1260 (17.99%)	1530 (20.67%)	714 (13.66%)	911 (17.91%)	1394 (19.23%)	1353 (17.83%)	825 (13.45%)
61-Over 60	1038 (16.73%)	227 (4.37%)	795 (13.61%)	679 (11.29%)	415 (7.53%)	1950 (27.83%)	1919 (25.92%)	430 (8.23%)	259 (5.09%)	1848 (25.49%)	2593 (34.17%)	641 (10.44%)
Educational Level												
Low	622 (10.02%)	90 (1.73%)	878 (15.03%)	317 (5.27%)	85 (1.54%)	329 (4.70%)	557 (7.51%)	79 (1.50%)	184 (3.61%)	462 (6.37%)	23 (0.30%)	190 (3.09%)
Mid	3195 (51.50%)	466 (8.98%)	2585 (44.26%)	2684 (44.61%)	1161 (21.06%)	2783 (39.72%)	3367 (45.48%)	523 (10.01%)	1360 (26.75%)	3720 (51.32%)	2258 (29.76%)	2339 (38.12%)

High	2387 (38.48%)	4632 (89.29%)	2378 (40.71%)	3015 (50.12%)	4265 (77.40%)	3893 (55.58%)	3481 (47.01%)	4622 (88.49%)	3540 (69.64%)	3067 (42.31%)	5307 (69.94%)	3606 (58.78%)
Urban/Rural area												
City	5041 (81.27%)	3436 (66.22%)	5479 (93.80%)	4699 (78.12%)	4036 (73.23%)	3277 (46.78%)	2949 (39.82%)	3096 (59.27%)	2072 (40.77%)	3387 (46.72%)	3787 (49.90%)	3060 (49.89%)
Town	926 (14.93%)	850 (16.37%)	127 (2.17%)	933 (15.51%)	370 (6.70%)	1807 (25.79%)	2064 (27.87%)	863 (16.51%)	932 (18.33%)	3318 (45.77%)	2971 (39.16%)	2058 (33.55%)
Village or rural area	236 (3.80%)	903 (17.40%)	236 (4.03%)	384 (6.37%)	1106 (20.07%)	1922 (27.43%)	2392 (32.31%)	1266 (24.22%)	2079 (40.90%)	545 (7.51%)	831 (10.94%)	1016 (16.56%)
Perceived Health Status												
Poor	1037 (16.71%)	864 (16.65%)	1300 (22.25%)	786 (13.06%)	1216 (22.06%)	1266 (18.06%)	1627 (21.97%)	482 (9.21%)	791 (15.55%)	964 (13.30%)	2680 (35.32%)	723 (11.77%)
Fair	1952 (31.47%)	2315 (44.62%)	1924 (32.93%)	1740 (28.92%)	2098 (38.06%)	2592 (37.00%)	2810 (37.95%)	1880 (35.98%)	3146 (61.89%)	3312 (45.68%)	3194 (42.09%)	2447 (39.89%)
Good	3214 (51.82%)	2009 (38.72%)	2618 (44.82%)	3490 (58.02%)	2198 (39.88%)	3148 (44.94%)	2967 (40.08%)	2863 (54.81%)	1147 (22.55%)	2973 (41.02%)	1714 (22.59%)	2965 (48.33%)
Information Exposure												
Low Exposure	2031 (32.74%)	3713 (71.58%)	2927 (50.12%)	2080 (34.58%)	4096 (74.33%)	1633 (23.31%)	1479 (19.98%)	2744 (52.53%)	3711 (73.02%)	3056 (42.16%)	3219 (42.42%)	2760 (44.99%)
High Exposure	4172 (67.26%)	1475 (28.42%)	2914 (49.88%)	3935 (65.42%)	1415 (25.67%)	5372 (76.69%)	5925 (80.02%)	2480 (47.47%)	1372 (26.98%)	4193 (57.84%)	4369 (57.58%)	3374 (55.01%)
N	6202	5187	5840	6014	5510	7004	7403	5223	5082	7248	7587	6133

Note: Willingness to vaccinate, perceived risk index and confidence index means differ form country means used in descriptive graphs and main model of the paper (see the following table). In this table, highlighting the individual-level distributions, country averages are computed form individual-level data, being therefore sensitive to wave sample-sizes. In the paper, as addressed in the methodological section, each country average is computed as the average of country-waves means. Means are therefore insensitive to country-waves sample sizes, and each wave has the same relative weight on the country-means.

Table 3 – Individual-level descriptive statistics by country, Mexico-Vietnam and Pooled observations. Weighted.

	Mexico	Nigeria	Pakistan	Philippines	Poland	Romania	Thailand	Turkey	Great Britain	United States	Vietnam	Total
Willingness to vaccinate												
No/Don't Know'	1667 (26.92%)	1931 (39.78%)	1608 (33.33%)	2925 (46.17%)	3621 (52.52%)	3229 (49.39%)	1503 (25.21%)	2812 (47.76%)	1739 (23.63%)	2965 (42.19%)	962 (16.11%)	50163 (35.26%)
Yes	4526 (73.08%)	2923 (60.22%)	3215 (66.67%)	3410 (53.83%)	3274 (47.48%)	3308 (50.61%)	4457 (74.79%)	3075 (52.24%)	5622 (76.37%)	4063 (57.81%)	5007 (83.89%)	92102 (64.74%)
Risk Index												
Mean (SD)	0.44 (0.89)	-0.40 (1.09)	-0.28 (1.04)	-0.06 (0.99)	-0.46 (1.00)	-0.04 (1.11)	-0.36 (0.97)	0.36 (0.96)	-0.03 (1.04)	-0.01 (1.15)	0.69 (0.86)	-0.00 (1.02)
Confidence Index												
Mean (SD)	0.06 (0.88)	0.04 (1.00)	-0.07 (1.13)	0.22 (0.71)	-0.51 (1.35)	-0.38 (1.52)	0.23 (0.77)	-0.18 (1.18)	0.09 (0.95)	-0.18 (1.23)	0.32 (0.55)	-0.02 (1.04)
Risk: Community												
Low risk	449 (7.24%)	1354 (27.89%)	1311 (27.17%)	1021 (16.11%)	2388 (34.63%)	1140 (17.44%)	1445 (24.23%)	532 (9.03%)	1296 (17.61%)	1642 (23.35%)	261 (4.37%)	25255 (17.75%)
Moderate risk	1354 (21.86%)	1027 (21.15%)	1240 (25.71%)	1438 (22.70%)	3051 (44.24%)	2181 (33.36%)	1290 (21.63%)	1647 (27.97%)	2461 (33.43%)	2016 (28.69%)	359 (6.01%)	39216 (27.57%)
High Risk	4390 (70.89%)	2473 (50.95%)	2272 (47.12%)	3877 (61.20%)	1457 (21.13%)	3217 (49.20%)	3226 (54.13%)	3708 (63.00%)	3604 (48.96%)	3370 (47.96%)	5349 (89.62%)	77794 (54.68%)
Risk: Likelihood of contagion												
Low likelihood	691 (11.16%)	2623 (54.05%)	2408 (49.93%)	3162 (49.92%)	1950 (28.28%)	1354 (20.72%)	4094 (68.69%)	1516 (25.75%)	1868 (25.37%)	1538 (21.88%)	1617 (27.08%)	42174 (29.64%)
Moderate likelihood	1039 (16.77%)	865 (17.81%)	1120 (23.22%)	1817 (28.68%)	3206 (46.49%)	2069 (31.64%)	1258 (21.11%)	2068 (35.12%)	2732 (37.12%)	2285 (32.52%)	1237 (20.71%)	44072 (30.98%)
High likelihood	4464 (72.08%)	1366 (28.14%)	1295 (26.85%)	1356 (21.40%)	1740 (25.23%)	3114 (47.64%)	609 (10.21%)	2304 (39.13%)	2762 (37.52%)	3205 (45.60%)	3116 (52.21%)	56019 (39.38%)
Risk: Perceived severity												
Not at all serious	543 (8.76%)	1216 (25.06%)	484 (10.03%)	749 (11.82%)	1049 (15.22%)	1006 (15.38%)	461 (7.73%)	253 (4.29%)	883 (12.00%)	1085 (15.43%)	245 (4.10%)	18153 (12.76%)
Somewhat serious	2977 (48.07%)	1464 (30.15%)	2172 (45.02%)	1758 (27.74%)	3078 (44.64%)	2961 (45.30%)	2498 (41.91%)	1549 (26.31%)	3547 (48.19%)	2784 (39.61%)	1647 (27.58%)	60847 (42.77%)
Very serious	2674 (43.17%)	2174 (44.79%)	2168 (44.95%)	3829 (60.44%)	2768 (40.14%)	2570 (39.32%)	3002 (50.36%)	4086 (69.40%)	2931 (39.81%)	3160 (44.96%)	4078 (68.32%)	63265 (44.47%)
Confidence: Healthcare workers												
Do not trust	371 (5.99%)	434 (8.93%)	624 (12.94%)	239 (3.77%)	1042 (15.11%)	912 (13.95%)	193 (3.24%)	676 (11.48%)	316 (4.28%)	485 (6.89%)	123 (2.05%)	10488 (7.37%)
Somewhat Trust	2399 (38.74%)	1868 (38.48%)	2170 (44.98%)	2370 (37.40%)	4224 (61.26%)	2607 (39.88%)	2290 (38.42%)	2499 (42.44%)	2662 (36.16%)	2409 (34.28%)	1804 (30.22%)	58142 (40.87%)
Trust	3423 (55.27%)	2553 (52.60%)	2030 (42.08%)	3727 (58.83%)	1629 (23.62%)	3018 (46.17%)	3477 (58.34%)	2713 (46.08%)	4384 (59.55%)	4134 (58.83%)	4043 (67.73%)	73636 (51.76%)
Confidence: Scientists												
Do not trust	173 (2.79%)	217 (4.46%)	322 (6.68%)	126 (1.98%)	554 (8.02%)	680 (10.40%)	202 (3.37%)	464 (7.88%)	292 (3.96%)	465 (6.61%)	79 (1.31%)	6814 (4.79%)
Somewhat Trust	1546 (24.96%)	1163 (23.95%)	1193 (24.74%)	1359 (21.44%)	3018 (43.77%)	1930 (29.53%)	2062 (34.59%)	1644 (27.92%)	2029 (27.56%)	1822 (25.92%)	1204 (20.16%)	42193 (29.66%)
Trust	4474 (72.25%)	3474 (71.58%)	3308 (68.59%)	4851 (76.57%)	3324 (48.21%)	3927 (60.07%)	3697 (62.04%)	3779 (64.20%)	5040 (68.47%)	4742 (67.48%)	4687 (78.53%)	93259 (65.55%)
Confidence: WHO												
Do not trust	422 (6.81%)	303 (6.23%)	417 (8.64%)	353 (5.57%)	1496 (21.69%)	1369 (20.93%)	321 (5.37%)	1020 (17.33%)	678 (9.21%)	1471 (20.92%)	297 (4.98%)	17198 (12.09%)
Somewhat Trust	1918 (30.96%)	993 (20.46%)	1177 (24.39%)	1808 (28.54%)	3380 (49.02%)	2431 (37.19%)	2153 (36.13%)	2466 (41.88%)	2407 (32.69%)	2091 (29.75%)	1375 (23.03%)	47077 (33.09%)
Trust	3853 (62.22%)	3559 (73.32%)	3230 (66.97%)	4174 (65.89%)	2020 (29.29%)	2738 (41.88%)	3486 (58.50%)	2402 (40.79%)	4277 (58.10%)	3467 (49.33%)	4297 (72.00%)	77990 (54.82%)
Confidence: Government and health authorities												
Do not trust	1269 (20.49%)	766 (15.77%)	657 (13.62%)	597 (9.41%)	2969 (43.06%)	1738 (26.58%)	394 (6.60%)	965 (16.38%)	1077 (14.63%)	1604 (22.82%)	135 (2.25%)	24454 (17.19%)
Somewhat Trust	3045 (49.16%)	1792 (36.92%)	1914 (39.67%)	2776 (43.82%)	3222 (46.73%)	2752 (42.09%)	2583 (43.33%)	2519 (42.79%)	3760 (51.08%)	3357 (47.76%)	1272 (21.31%)	62477 (43.92%)
Trust	1880 (30.35%)	2296 (47.31%)	2253 (46.71%)	2963 (46.77%)	704 (10.21%)	2048 (31.33%)	2984 (50.07%)	2404 (40.83%)	2524 (34.29%)	2068 (29.42%)	4563 (76.44%)	55335 (38.90%)
Gender												
Male	3015 (48.68%)	2601 (53.58%)	2655 (55.04%)	3054 (48.22%)	3426 (49.69%)	3231 (49.42%)	2884 (48.38%)	2848 (48.38%)	3577 (48.59%)	3366 (47.89%)	3177 (53.22%)	71514 (50.27%)
Female	3178 (51.32%)	2253 (46.42%)	2168 (44.96%)	3281 (51.78%)	3469 (50.31%)	3306 (50.58%)	3076 (51.62%)	3039 (51.62%)	3784 (51.41%)	3662 (52.11%)	2792 (46.78%)	70751 (49.73%)
Age												
18-30	2264 (36.55%)	2042 (42.06%)	2445 (50.69%)	2582 (40.75%)	1439 (20.87%)	1230 (18.81%)	1117 (18.73%)	1905 (32.35%)	1479 (20.09%)	1415 (20.13%)	2328 (38.99%)	42171 (29.64%)
31-40	1295 (20.91%)	1196 (24.63%)	1063 (22.04%)	1387 (21.88%)	1533 (22.23%)	1316 (20.13%)	991 (16.62%)	1277 (21.68%)	1246 (16.92%)	1272 (18.09%)	1338 (22.41%)	28260 (19.86%)
41-50	1072 (17.30%)	801 (16.50%)	549 (11.37%)	986 (15.56%)	1418 (20.55%)	1369 (20.94%)	1384 (23.22%)	1233 (20.95%)	1303 (17.69%)	1237 (17.59%)	980 (16.41%)	25837 (18.16%)
51-60	894 (14.43%)	612 (12.60%)	466 (9.65%)	795 (12.54%)	918 (13.32%)	1224 (18.72%)	1328 (22.28%)	792 (13.45%)	1337 (18.16%)	1222 (17.39%)	856 (14.33%)	22289 (15.67%)
61-Over 60	670 (10.81%)	204 (4.20%)	302 (6.24%)	587 (9.26%)	1588 (23.02%)	1400 (21.41%)	1142 (19.15%)	681 (11.57%)	1998 (27.14%)	1884 (26.80%)	470 (7.86%)	23709 (16.67%)
Educational Level												
Low	194 (3.13%)	13 (0.26%)	49 (1.01%)	61 (0.96%)	282 (4.09%)	234 (3.58%)	411 (6.89%)	967 (16.42%)	40 (0.53%)	462 (6.57%)	101 (1.69%)	6623 (4.66%)
Mid	1985 (32.04%)	736 (15.16%)	277 (5.74%)	1358 (21.43%)	3271 (47.44%)	2261 (34.59%)	1798 (30.16%)	1999 (33.95%)	1975 (26.83%)	1375 (19.56%)	1923 (32.21%)	45388 (31.90%)
High	4015 (64.83%)	4105 (84.58%)	4497 (93.25%)	4916 (77.61%)	3342 (48.47%)	4042 (61.84%)	3752 (62.95%)	2922 (49.63%)	5347 (72.64%)	5191 (73.86%)	3945 (66.10%)	90254 (63.44%)
Urban/Rural area												

City	5018 (81.04%)	2898 (59.71%)	3597 (74.58%)	4293 (67.77%)	3124 (45.31%)	3577 (54.72%)	2482 (41.65%)	4025 (68.37%)	1914 (26.00%)	3623 (51.55%)	3989 (66.83%)	82848 (58.23%)
Town	916 (14.79%)	1591 (32.78%)	498 (10.33%)	1231 (19.43%)	2343 (33.98%)	1556 (23.79%)	1437 (24.11%)	1423 (24.17%)	3420 (46.46%)	2180 (31.02%)	567 (9.50%)	34372 (24.16%)
Village or rural area	259 (4.17%)	365 (7.50%)	728 (15.09%)	811 (12.80%)	1428 (20.71%)	1405 (21.49%)	2041 (34.24%)	440 (7.47%)	2027 (27.54%)	1226 (17.44%)	1413 (23.67%)	25046 (17.60%)
Perceived Health Status												
Poor	1210 (19.54%)	232 (4.76%)	482 (9.98%)	530 (8.36%)	1297 (18.81%)	1277 (19.53%)	1426 (23.93%)	989 (16.79%)	1437 (19.52%)	1180 (16.79%)	1313 (21.99%)	25098 (17.64%)
Fair	2437 (39.36%)	1291 (26.59%)	1543 (32.00%)	1841 (29.07%)	3100 (44.97%)	2556 (39.10%)	2557 (42.90%)	2555 (43.41%)	2547 (34.59%)	2504 (35.63%)	2885 (48.33%)	55216 (38.81%)
Good	2546 (41.10%)	3332 (68.65%)	2799 (58.03%)	3964 (62.57%)	2498 (36.23%)	2705 (41.37%)	1977 (33.17%)	2343 (39.80%)	3378 (45.89%)	3344 (47.58%)	1772 (29.68%)	61952 (43.55%)
Information Exposure												
Low Exposure	2053 (33.15%)	2622 (54.01%)	3576 (74.15%)	2513 (39.67%)	2757 (39.98%)	3326 (50.88%)	3557 (59.68%)	2289 (38.87%)	2904 (39.45%)	3020 (42.97%)	3166 (53.04%)	65223 (45.85%)
High Exposure	4140 (66.85%)	2232 (45.99%)	1247 (25.85%)	3822 (60.33%)	4138 (60.02%)	3211 (49.12%)	2403 (40.32%)	3598 (61.13%)	4457 (60.55%)	4008 (57.03%)	2803 (46.96%)	77042 (54.15%)
N	6192	4853	4822	6334	6894	6536	5959	5886	7360	7027	5968	142264

Note: Willingness to vaccinate, perceived risk index and confidence index means differ form country means used in descriptive graphs and main model of the paper (see the following table). In this table, highlighting the individual-level distributions, country averages are computed form individual-level data, being therefore sensitive to wave sample-sizes. In the paper, as addressed in the methodological section, each country average is computed as the average of country-waves means. Means are therefore insensitive to country-waves sample sizes, and each wave has the same relative weight on the country-means.

Table 4 – Willingness to vaccinate, perceived risk and Confidence indexes at country-wave and country levels Standard deviations in parentheses. Weighted.

Country	Var	Wave 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Avg
ARG	Vaccine acceptance	68.8%	75.0%	74.9%	70.4%	69.9%	66.2%	72.0%	67.6%	60.3%	49.6%	52.3%	51.9%	69.2%	47.0%	60.5%	64.8%	69.8%	73.9%	76.2%	67.6%
	Risk index	0.01 (1.00)	0.03 (0.92)	0.10 (1.03)	0.13 (0.96)	0.21 (0.95)	0.31 (0.91)	-0.11 (1.01)	0.11 (0.95)	0.30 (0.85)	0.02 (0.91)	-0.11 (1.00)	0.05 (0.95)	0.29 (0.88)	0.27 (0.90)	0.15 (0.88)	0.31 (0.78)	0.18 (0.89)	0.06 (1.00)	0.25 (0.98)	0.12 (0.95)
	Confidence Index	-0.04 (1.04)	0.02 (0.95)	-0.08 (1.05)	-0.05 (1.00)	-0.12 (1.04)	-0.19 (1.13)	-0.10 (1.11)	-0.25 (1.21)	-0.04 (0.93)	-0.11 (1.15)	-0.20 (1.07)	-0.40 (1.26)	-0.09 (0.87)	-0.32 (1.24)	-0.20 (1.16)	-0.06 (1.02)	0.00 (0.91)	-0.24 (1.05)	-0.03 (0.96)	-0.11 (1.06)
BGD	Vaccine acceptance	93.0%	85.7%	85.7%	85.2%	83.8%	88.8%	84.3%	84.9%	79.5%	89.3%	78.5%	81.2%	83.6%	87.0%	70.1%	75.9%	71.7%	90.8%	83.2%	84.3%
	Risk index	0.04 (1.05)	0.12 (0.99)	0.00 (0.97)	-0.12 (1.04)	-0.26 (1.00)	0.30 (0.89)	-0.07 (1.01)	-0.06 (1.00)	-0.20 (1.01)	-0.13 (0.82)	-0.38 (0.88)	0.27 (0.95)	-0.08 (1.19)	-0.22 (0.87)	-0.25 (0.98)	-0.72 (1.05)	-0.32 (1.11)	-0.15 (1.07)	-0.01 (1.04)	-0.09 (1.02)
	Confidence Index	-0.03 (0.82)	-0.13 (0.97)	-0.12 (0.94)	-0.21 (1.28)	-0.06 (0.97)	0.08 (0.81)	-0.05 (0.91)	-0.13 (1.09)	-0.20 (1.16)	0.05 (0.89)	0.05 (0.87)	-0.03 (0.84)	-0.06 (1.07)	0.15 (0.64)	0.10 (0.71)	0.08 (0.68)	0.02 (0.91)	0.07 (0.94)	0.03 (0.79)	-0.06 (0.96)
BRA	Vaccine acceptance	86.4%	84.3%	85.2%	82.8%	82.6%	77.8%	80.4%	73.6%	70.6%	56.9%	69.7%	78.6%	69.9%	68.4%	73.9%	79.6%	84.3%	87.2%	88.0%	79.9%
	Risk index	0.29 (1.00)	0.24 (0.91)	0.33 (0.91)	0.34 (0.95)	0.25 (0.91)	0.15 (1.10)	0.30 (0.96)	0.12 (1.09)	0.22 (0.96)	0.36 (0.98)	0.24 (1.09)	0.50 (0.88)	0.51 (0.82)	0.37 (0.91)	0.42 (0.91)	0.34 (1.02)	0.47 (0.96)	0.65 (0.83)	0.65 (0.79)	0.33 (0.95)
	Confidence Index	0.06 (0.76)	-0.00 (0.88)	0.07 (0.74)	0.06 (0.97)	0.06 (0.84)	-0.03 (0.90)	-0.06 (0.96)	-0.06 (1.05)	-0.01 (0.97)	-0.09 (1.03)	0.10 (0.81)	0.03 (0.88)	-0.00 (0.96)	-0.00 (0.87)	0.01 (0.88)	-0.11 (0.98)	-0.02 (1.01)	0.09 (0.82)	0.09 (0.71)	0.02 (0.89)
COL	Vaccine acceptance	73.0%	79.3%	76.7%	70.9%	67.1%	67.5%	64.0%	69.5%	65.8%	67.5%	63.6%	59.6%	63.8%	65.5%	70.5%	68.1%	68.2%	65.0%	73.9%	70.0%
	Risk index	0.51 (0.89)	0.46 (0.94)	0.44 (0.88)	0.41 (0.86)	0.45 (0.98)	0.43 (0.92)	0.29 (0.89)	0.46 (0.85)	0.41 (0.93)	0.57 (0.78)	0.57 (0.79)	0.41 (0.93)	0.65 (0.87)	0.52 (1.00)	0.49 (0.95)	0.49 (0.86)	0.28 (0.84)	0.34 (1.04)	0.45 (0.94)	0.45 (0.91)
	Confidence Index	-0.05 (1.01)	-0.19 (1.19)	-0.07 (1.11)	-0.10 (1.10)	-0.20 (1.27)	0.04 (0.88)	-0.05 (1.09)	-0.09 (1.05)	-0.12 (1.13)	0.04 (1.02)	-0.03 (0.97)	0.04 (0.92)	-0.04 (1.12)	0.21 (0.66)	-0.01 (1.22)	-0.01 (0.86)	-0.06 (1.09)	-0.12 (1.20)	0.04 (0.97)	-0.07 (1.08)
EGY	Vaccine acceptance	69.1%	68.7%	72.3%	64.2%	66.5%	67.1%	59.7%	56.4%	56.3%	59.1%	65.2%	52.4%	38.3%	41.7%	39.1%	43.8%	37.7%	41.2%	39.5%	58.4%
	Risk index	0.44 (0.89)	0.18 (0.96)	0.30 (0.86)	0.26 (0.90)	0.23 (0.97)	0.25 (0.81)	0.32 (0.93)	0.33 (0.95)	0.27 (0.93)	0.47 (0.93)	0.53 (0.88)	0.40 (0.89)	0.63 (0.89)	0.72 (0.90)	0.40 (0.82)	0.17 (0.86)	0.40 (0.85)	0.44 (0.89)	0.31 (0.93)	0.34 (0.92)
	Confidence Index	-0.12 (1.02)	-0.22 (1.14)	-0.22 (1.17)	-0.30 (1.19)	-0.32 (1.23)	-0.10 (1.23)	-0.15 (1.07)	-0.15 (1.15)	-0.31 (1.08)	-0.23 (1.21)	-0.14 (0.90)	-0.11 (0.86)	-0.13 (1.06)	-0.05 (0.85)	-0.32 (1.18)	-0.04 (0.84)	-0.24 (1.14)	-0.20 (1.05)	-0.21 (1.02)	-0.20 (1.10)

FRA	**Vaccine acceptance**	52.6%	46.2%	46.7%	40.0%	41.0%	40.3%	41.2%	45.8%	43.1%	32.7%	35.7%	34.6%	43.2%	58.5%	51.1%	57.6%	56.9%	66.2%	74.0%	46.6%
	Risk index	-0.09	-0.03	-0.18	-0.17	-0.38	-0.16	-0.18	-0.12	0.00	-0.13	-0.10	0.02	-0.16	-0.29	-0.09	-0.15	-0.27	-0.13	-0.08	-0.14
		(0.90)	(0.95)	(0.94)	(0.96)	(0.97)	(0.90)	(1.01)	(0.87)	(0.95)	(0.93)	(0.93)	(0.88)	(0.92)	(0.97)	(0.95)	(0.98)	(0.92)	(0.96)	(0.86)	(0.94)
	Confidence Index	0.04	-0.02	-0.03	0.01	-0.08	0.02	-0.02	-0.00	-0.06	-0.06	-0.07	0.10	0.01	-0.08	-0.17	0.03	-0.11	-0.08	0.05	-0.02
		(1.00)	(1.09)	(1.11)	(1.04)	(1.12)	(0.98)	(1.05)	(1.09)	(1.09)	(1.23)	(1.14)	(0.92)	(1.08)	(1.06)	(1.27)	(1.03)	(1.22)	(1.15)	(0.91)	(1.08)
GER	**Vaccine acceptance**	61.5%	64.1%	59.7%	59.9%	55.3%	48.5%	55.1%	57.7%	54.3%	52.6%	53.3%	57.1%	69.3%	76.4%	73.7%	64.9%	77.0%	77.8%	74.3%	61.7%
	Risk index	-0.55	-0.40	-0.37	-0.37	-0.60	-0.49	-0.47	-0.39	-0.24	-0.42	-0.25	-0.09	-0.14	-0.02	-0.03	-0.46	-0.28	-0.15	-0.30	-0.35
		(0.99)	(0.97)	(0.97)	(0.99)	(0.98)	(1.07)	(0.95)	(0.94)	(0.94)	(1.02)	(1.02)	(0.99)	(0.94)	(0.93)	(0.95)	(1.12)	(0.96)	(0.95)	(1.04)	(0.99)
	Confidence Index	0.05	0.08	0.01	0.06	0.01	-0.00	-0.06	0.03	0.10	0.07	-0.01	0.11	0.07	0.16	0.08	-0.18	0.00	0.01	-0.04	0.03
		(1.04)	(0.95)	(1.06)	(1.01)	(1.10)	(1.08)	(1.20)	(0.96)	(0.90)	(0.89)	(1.13)	(0.96)	(0.94)	(0.95)	(0.99)	(1.38)	(1.11)	(1.13)	(1.14)	(1.05)
IND	**Vaccine acceptance**	81.1%	77.3%	75.0%	70.6%	70.3%	75.7%	78.9%	79.5%	74.7%	68.1%	68.2%	76.2%	57.9%	71.9%	71.0%	84.1%	80.3%	85.9%	77.9%	75.4%
	Risk index	0.06	-0.20	-0.25	-0.34	-0.20	-0.30	-0.14	-0.13	-0.52	-0.13	0.08	-0.09	-0.18	-0.24	-0.30	-0.30	-0.03	-0.14	-0.17	-0.19
		(1.10)	(1.06)	(1.07)	(1.07)	(1.07)	(1.08)	(1.18)	(0.92)	(1.18)	(1.10)	(0.96)	(1.17)	(1.01)	(1.10)	(1.10)	(1.15)	(1.03)	(1.02)	(1.00)	(1.08)
	Confidence Index	0.24	0.10	0.03	0.17	0.17	0.18	0.01	0.02	-0.00	0.22	0.01	0.12	-0.02	0.29	-0.05	0.10	0.14	0.23	0.12	0.11
		(0.56)	(0.83)	(0.95)	(0.73)	(0.68)	(0.65)	(0.97)	(0.96)	(1.04)	(0.68)	(1.18)	(0.78)	(0.98)	(0.50)	(1.03)	(0.99)	(0.93)	(0.79)	(1.09)	(0.86)
IDN	**Vaccine acceptance**	60.1%	52.9%	60.7%	53.8%	56.7%	65.3%	52.8%	56.2%	48.2%	53.6%	42.3%	55.0%	40.6%	62.1%	64.8%	60.3%	64.5%	70.2%	76.1%	57.1%
	Risk index	0.28	0.20	0.13	0.10	0.30	0.46	0.16	0.02	-0.02	-0.12	0.11	0.10	0.09	0.19	0.20	0.21	0.09	0.14	0.27	0.17
		(0.86)	(0.95)	(0.97)	(1.07)	(0.96)	(0.86)	(0.98)	(0.99)	(1.10)	(1.07)	(1.00)	(1.10)	(1.05)	(1.03)	(0.99)	(1.01)	(0.97)	(1.03)	(0.94)	(0.99)
	Confidence Index	0.23	0.20	-0.00	0.02	0.23	0.21	0.03	0.05	-0.03	0.10	0.12	0.12	-0.03	0.27	0.11	0.20	0.19	0.02	0.19	0.12
		(0.81)	(0.92)	(1.31)	(1.26)	(0.77)	(0.86)	(1.20)	(1.07)	(1.25)	(1.02)	(1.04)	(1.03)	(1.14)	(0.74)	(1.05)	(0.87)	(0.76)	(1.18)	(0.93)	(1.04)
ITA	**Vaccine acceptance**	64.1%	65.5%	70.4%	64.3%	62.7%	62.5%	62.3%	59.5%	65.1%	64.0%	65.7%	67.2%	75.8%	78.4%	82.8%	74.4%	79.4%	87.7%	76.9%	68.0%
	Risk index	-0.48	-0.40	-0.40	-0.42	-0.35	-0.28	-0.18	-0.15	-0.11	0.17	-0.18	0.02	-0.08	-0.07	-0.01	-0.12	-0.08	-0.01	-0.12	-0.24
		(0.81)	(0.86)	(0.81)	(0.79)	(0.86)	(0.75)	(0.78)	(0.83)	(0.90)	(0.85)	(0.86)	(0.80)	(0.89)	(0.87)	(0.80)	(0.82)	(0.86)	(0.92)	(0.88)	(0.85)
	Confidence Index	0.04	0.01	0.07	0.09	0.03	0.06	0.15	0.06	0.02	0.11	0.05	0.16	0.07	0.22	0.13	0.11	-0.13	0.18	-0.02	0.07
		(0.93)	(1.10)	(0.91)	(0.91)	(0.93)	(1.05)	(0.87)	(0.90)	(1.06)	(0.96)	(0.86)	(0.68)	(0.87)	(0.72)	(0.71)	(0.83)	(1.18)	(0.69)	(1.04)	(0.94)
JPN	**Vaccine acceptance**	69.4%	72.0%	60.0%	63.0%	47.7%	41.5%	54.7%	59.7%	50.2%	60.5%	47.9%	42.3%	43.6%	51.2%	48.5%	61.2%	66.3%	71.6%	73.9%	59.4%
	Risk index	-0.33	-0.17	-0.23	-0.19	-0.38	-0.44	-0.40	-0.47	-0.44	-0.21	-0.26	-0.09	-0.05	0.02	0.09	-0.25	-0.23	-0.25	-0.18	-0.25
		(0.85)	(0.78)	(0.77)	(0.81)	(0.80)	(0.74)	(0.82)	(0.76)	(0.80)	(0.80)	(0.79)	(0.86)	(0.79)	(0.79)	(0.73)	(0.76)	(0.73)	(0.84)	(0.73)	(0.80)
	Confidence Index	-0.29	-0.21	-0.26	-0.15	-0.06	-0.18	-0.18	-0.10	-0.19	-0.07	-0.13	-0.08	-0.14	-0.12	-0.01	-0.16	-0.12	-0.02	-0.02	-0.15
		(1.00)	(1.00)	(1.09)	(1.05)	(0.98)	(1.34)	(1.04)	(0.95)	(1.19)	(0.83)	(1.08)	(0.98)	(1.03)	(0.95)	(0.90)	(0.98)	(0.96)	(0.92)	(0.84)	(1.01)

MYS	**Vaccine acceptance**	73.3%	77.5%	78.8%	77.4%	74.2%	74.1%	72.3%	69.0%	76.9%	68.5%	69.5%	59.6%	61.3%	60.2%	58.9%	70.9%	68.6%	85.2%	85.1%	72.9%
	Risk index	0.04 (1.04)	0.16 (1.01)	0.10 (0.96)	0.03 (0.95)	-0.06 (1.00)	0.22 (0.90)	0.26 (0.87)	0.12 (0.93)	0.27 (0.89)	0.21 (0.92)	0.03 (0.96)	0.11 (0.96)	0.21 (0.92)	0.23 (0.86)	0.29 (0.86)	0.27 (0.83)	0.02 (0.89)	-0.03 (0.86)	-0.00 (1.01)	0.12 (0.95)
	Confidence Index	0.33 (0.44)	0.32 (0.51)	0.37 (0.40)	0.34 (0.39)	0.30 (0.63)	0.40 (0.25)	0.33 (0.43)	0.33 (0.52)	0.29 (0.64)	0.30 (0.65)	0.34 (0.59)	0.18 (0.88)	0.36 (0.39)	0.32 (0.45)	0.34 (0.42)	0.26 (0.72)	0.20 (0.92)	0.33 (0.46)	0.32 (0.53)	0.32 (0.54)
MEX	**Vaccine acceptance**	74.5%	76.6%	73.0%	71.6%	62.7%	71.8%	69.6%	72.0%	72.2%	68.8%	67.3%	71.7%	73.6%	73.8%	80.0%	81.4%	75.8%	86.0%	78.2%	73.1%
	Risk index	0.46 (0.87)	0.37 (0.92)	0.35 (0.92)	0.38 (0.89)	0.31 (0.87)	0.24 (0.98)	0.34 (0.85)	0.40 (0.98)	0.51 (0.89)	0.46 (0.86)	0.34 (0.79)	0.49 (1.03)	0.57 (0.92)	0.56 (0.89)	0.66 (0.70)	0.72 (0.72)	0.53 (0.90)	0.55 (0.88)	0.59 (0.80)	0.44 (0.89)
	Confidence Index	0.08 (0.90)	0.10 (0.82)	-0.02 (0.99)	0.08 (0.86)	0.06 (0.86)	-0.09 (1.09)	0.04 (0.81)	-0.04 (0.96)	0.19 (0.72)	0.11 (0.87)	0.07 (0.90)	0.01 (0.96)	-0.01 (1.04)	0.27 (0.59)	0.02 (0.91)	0.11 (0.84)	0.16 (0.75)	-0.00 (0.90)	0.08 (0.69)	0.06 (0.88)
NGA	**Vaccine acceptance**	62.8%	59.0%	54.1%	59.0%	64.8%	47.9%	61.3%	65.2%	60.9%	75.1%	71.3%	64.9%	54.9%	46.0%	54.5%	56.1%	60.7%	67.3%	52.0%	60.2%
	Risk index	-0.27 (1.10)	-0.24 (1.08)	-0.49 (1.04)	-0.50 (1.13)	-0.53 (1.06)	-0.52 (1.18)	-0.25 (1.04)	-0.56 (1.18)	-0.49 (1.06)	-0.45 (1.07)	-0.55 (1.12)	-0.21 (1.06)	-0.24 (1.07)	-0.35 (1.07)	-0.34 (1.00)	-0.45 (1.08)	-0.26 (1.22)	-0.41 (0.98)	-0.28 (1.11)	-0.40 (1.09)
	Confidence Index	0.06 (0.97)	-0.08 (1.23)	-0.02 (1.01)	-0.03 (1.17)	0.07 (0.91)	0.06 (1.07)	0.02 (0.96)	0.04 (1.02)	-0.04 (1.19)	0.20 (0.60)	0.11 (0.91)	0.13 (0.74)	0.03 (0.91)	0.12 (0.67)	0.10 (0.89)	0.21 (0.64)	0.19 (0.73)	-0.11 (1.17)	0.17 (0.76)	0.04 (1.00)
PAK	**Vaccine acceptance**	67.4%	69.1%	64.9%	72.9%	62.0%	59.4%	67.3%	72.0%	74.3%	65.7%	73.6%	58.4%	54.6%	53.2%	52.2%	66.8%	81.4%	55.5%	71.3%	66.7%
	Risk index	-0.26 (1.04)	-0.32 (1.04)	-0.35 (1.08)	-0.36 (1.01)	-0.68 (1.14)	-0.18 (1.06)	-0.35 (1.11)	-0.37 (1.10)	-0.21 (1.13)	-0.01 (0.84)	-0.04 (0.90)	-0.21 (1.02)	-0.19 (0.97)	-0.13 (1.00)	-0.24 (0.98)	-0.11 (0.84)	-0.32 (1.07)	-0.21 (1.04)	-0.14 (0.91)	-0.28 (1.04)
	Confidence Index	-0.06 (0.97)	-0.04 (1.11)	-0.04 (1.05)	-0.12 (1.19)	-0.23 (1.39)	-0.05 (1.22)	-0.26 (1.38)	-0.22 (1.37)	-0.16 (1.26)	0.18 (0.70)	0.06 (0.97)	0.21 (0.80)	-0.02 (1.09)	0.08 (0.85)	-0.18 (1.40)	0.05 (0.86)	-0.13 (1.36)	-0.06 (1.04)	0.17 (0.77)	-0.07 (1.13)
PHL	**Vaccine acceptance**	63.5%	61.9%	61.3%	54.6%	51.7%	50.1%	58.5%	43.3%	50.8%	58.3%	52.6%	48.0%	49.7%	41.7%	36.6%	49.5%	45.9%	57.8%	48.9%	53.8%
	Risk index	0.07 (0.96)	0.08 (0.96)	0.08 (0.97)	-0.03 (0.94)	-0.13 (1.03)	0.10 (0.86)	-0.06 (0.95)	-0.16 (1.06)	-0.11 (1.03)	0.08 (0.82)	-0.06 (1.01)	-0.24 (1.02)	-0.12 (1.05)	-0.06 (1.04)	-0.18 (0.95)	-0.27 (1.01)	-0.08 (1.08)	-0.38 (0.99)	-0.09 (1.03)	-0.06 (0.99)
	Confidence Index	0.21 (0.70)	0.26 (0.58)	0.24 (0.69)	0.28 (0.53)	0.08 (0.96)	0.22 (0.62)	0.23 (0.72)	0.18 (0.79)	0.15 (0.81)	0.24 (0.62)	0.18 (0.94)	0.18 (0.82)	0.24 (0.57)	0.15 (0.75)	0.20 (0.71)	0.20 (0.81)	0.28 (0.60)	0.27 (0.51)	0.33 (0.36)	0.22 (0.71)
POL	**Vaccine acceptance**	45.2%	46.9%	46.9%	40.5%	36.4%	30.8%	36.6%	44.4%	39.3%	42.8%	40.3%	40.5%	59.2%	61.1%	61.9%	58.4%	72.1%	63.8%	69.2%	47.5%
	Risk index	-0.71 (0.95)	-0.61 (0.94)	-0.59 (0.97)	-0.68 (1.00)	-0.72 (1.00)	-0.77 (1.04)	-0.44 (1.04)	-0.21 (1.06)	-0.14 (0.98)	-0.22 (0.93)	-0.33 (0.97)	-0.28 (0.98)	-0.29 (0.87)	-0.32 (0.92)	-0.40 (0.98)	-0.49 (1.10)	-0.25 (0.90)	-0.41 (0.93)	-0.15 (0.94)	-0.46 (1.00)

	Confidence Index	-0.45 (1.35)	-0.50 (1.30)	-0.48 (1.31)	-0.57 (1.49)	-0.78 (1.45)	-0.83 (1.69)	-0.64 (1.47)	-0.49 (1.30)	-0.46 (1.31)	-0.40 (1.12)	-0.56 (1.40)	-0.45 (1.27)	-0.48 (1.27)	-0.32 (1.32)	-0.49 (1.27)	-0.76 (1.65)	-0.29 (1.26)	-0.52 (1.44)	-0.25 (0.95)	-0.51 (1.35)
ROU	**Vaccine acceptance**	49.6%	48.4%	51.2%	45.7%	37.2%	42.4%	43.1%	47.4%	45.5%	38.2%	48.2%	55.4%	63.6%	60.8%	68.1%	62.5%	62.4%	53.5%	72.5%	50.6%
	Risk index	-0.04 (1.06)	0.08 (1.13)	-0.04 (1.11)	-0.15 (1.13)	-0.25 (1.14)	-0.15 (1.02)	-0.05 (1.11)	0.03 (1.09)	0.05 (1.11)	-0.13 (1.14)	0.01 (1.04)	0.21 (1.09)	0.08 (1.02)	0.04 (1.20)	0.03 (0.99)	-0.21 (1.13)	-0.12 (1.04)	-0.36 (1.41)	0.11 (0.98)	-0.04 (1.11)
	Confidence Index	-0.41 (1.53)	-0.36 (1.51)	-0.42 (1.56)	-0.44 (1.48)	-0.48 (1.59)	-0.39 (1.47)	-0.29 (1.48)	-0.25 (1.38)	-0.47 (1.67)	-0.57 (1.65)	-0.43 (1.50)	-0.21 (1.37)	-0.23 (1.31)	-0.49 (1.66)	-0.14 (1.34)	-0.15 (1.09)	-0.35 (1.42)	-0.86 (1.93)	-0.37 (1.53)	-0.38 (1.52)
THA	**Vaccine acceptance**	79.2%	75.3%	74.4%	68.1%	78.0%	76.6%	76.6%	77.0%	81.7%	73.7%	75.2%	77.8%	79.6%	78.6%	68.7%	73.0%	72.3%	64.9%	60.9%	74.8%
	Risk index	-0.32 (0.95)	-0.41 (0.96)	-0.53 (1.05)	-0.52 (0.94)	-0.52 (1.10)	-0.34 (1.03)	-0.35 (0.97)	-0.42 (0.94)	-0.43 (0.98)	-0.40 (0.93)	-0.29 (0.90)	-0.11 (0.87)	-0.03 (0.85)	0.00 (0.96)	-0.27 (0.92)	-0.15 (0.97)	-0.26 (0.93)	-0.31 (0.93)	-0.30 (0.85)	-0.36 (0.97)
	Confidence Index	0.21 (0.76)	0.26 (0.68)	0.19 (0.84)	0.20 (0.83)	0.22 (0.72)	0.25 (0.73)	0.16 (0.90)	0.27 (0.72)	0.14 (1.02)	0.30 (0.51)	0.23 (0.76)	0.27 (0.58)	0.25 (0.76)	0.15 (1.04)	0.25 (0.71)	0.23 (0.67)	0.32 (0.47)	0.25 (0.61)	0.26 (0.74)	0.23 (0.77)
TUR	**Vaccine acceptance**	50.4%	53.1%	56.3%	53.2%	47.9%	45.0%	52.3%	47.1%	43.6%	48.4%	42.4%	47.5%	43.7%	52.8%	61.6%	57.8%	64.8%	58.4%	70.1%	52.2%
	Risk index	0.17 (0.99)	0.16 (0.93)	0.30 (0.90)	0.40 (0.93)	0.36 (1.00)	0.55 (0.86)	0.38 (0.94)	0.46 (0.93)	0.41 (0.97)	0.66 (0.96)	0.63 (0.84)	0.64 (0.88)	0.53 (0.95)	0.48 (0.95)	0.30 (0.87)	0.41 (1.01)	0.24 (0.92)	0.33 (1.05)	0.25 (0.99)	0.36 (0.96)
	Confidence Index	-0.16 (1.18)	-0.14 (1.16)	-0.20 (1.11)	-0.12 (1.13)	-0.35 (1.28)	-0.09 (1.19)	-0.26 (1.25)	-0.15 (1.10)	-0.22 (1.28)	-0.22 (1.24)	-0.04 (1.03)	-0.18 (1.19)	-0.29 (1.45)	-0.09 (1.09)	-0.16 (1.11)	-0.13 (1.08)	-0.16 (1.23)	-0.18 (1.30)	-0.13 (1.06)	-0.18 (1.18)
GBR	**Vaccine acceptance**	75.6%	77.5%	77.3%	68.5%	71.1%	70.4%	70.1%	71.8%	65.4%	73.9%	72.2%	77.5%	77.0%	81.4%	90.0%	87.9%	89.5%	91.9%	93.7%	76.4%
	Risk index	-0.10 (1.01)	-0.18 (1.00)	-0.07 (1.00)	-0.21 (0.98)	-0.34 (1.06)	-0.18 (1.05)	-0.03 (1.02)	-0.00 (1.03)	0.04 (1.02)	0.04 (1.03)	-0.00 (1.04)	-0.04 (1.08)	0.15 (1.05)	0.39 (1.07)	0.40 (0.97)	0.25 (1.03)	0.08 (1.05)	0.14 (1.04)	-0.03 (1.02)	-0.03 (1.04)
	Confidence Index	0.12 (0.86)	0.09 (0.91)	0.06 (0.95)	0.08 (0.95)	0.03 (1.04)	0.02 (1.09)	0.05 (1.02)	0.06 (0.99)	0.05 (1.01)	0.13 (0.90)	0.04 (1.02)	0.01 (1.11)	0.06 (1.08)	0.05 (1.18)	0.20 (0.79)	0.26 (0.73)	0.30 (0.59)	0.14 (0.84)	0.21 (0.68)	0.09 (0.95)
USA	**Vaccine acceptance**	63.0%	60.2%	53.5%	53.4%	46.6%	35.8%	47.0%	48.8%	44.1%	62.8%	60.1%	59.1%	56.5%	71.8%	68.8%	72.8%	71.7%	77.5%	76.0%	57.8%
	Risk index	0.01 (1.14)	0.05 (1.14)	-0.06 (1.17)	-0.11 (1.16)	-0.25 (1.26)	-0.15 (1.20)	-0.17 (1.17)	-0.07 (1.16)	-0.16 (1.21)	0.25 (1.06)	0.21 (1.18)	0.01 (1.19)	0.07 (1.23)	0.39 (1.09)	0.29 (0.95)	0.15 (1.00)	0.01 (1.06)	-0.09 (1.12)	0.06 (1.00)	-0.01 (1.15)
	Confidence Index	-0.18 (1.14)	-0.17 (1.26)	-0.27 (1.27)	-0.31 (1.34)	-0.31 (1.28)	-0.21 (1.11)	-0.18 (1.17)	-0.12 (1.16)	-0.22 (1.33)	-0.09 (1.10)	-0.14 (1.21)	-0.14 (1.26)	-0.34 (1.42)	0.06 (0.88)	-0.12 (1.15)	-0.04 (1.07)	-0.10 (1.20)	-0.23 (1.32)	-0.06 (1.18)	-0.18 (1.23)
VNM	**Vaccine acceptance**	85.8%	88.1%	85.9%	87.9%	82.7%	84.6%	83.1%	79.6%	75.2%	81.2%	79.7%	91.3%	83.5%	85.1%	78.3%	91.5%	71.7%	85.5%	73.4%	83.9%

	Risk index	0.50 (0.93)	0.81 (0.83)	0.86 (0.76)	0.83 (0.77)	0.56 (0.86)	0.65 (0.78)	0.57 (0.91)	0.58 (0.95)	0.61 (0.89)	0.46 (0.92)	0.46 (0.90)	0.78 (0.82)	0.60 (0.88)	0.76 (0.78)	0.79 (0.88)	0.90 (0.67)	0.68 (0.86)	0.76 (0.86)	0.73 (0.78)	0.69 (0.86)
	Confidence Index	0.30 (0.51)	0.34 (0.51)	0.32 (0.55)	0.37 (0.43)	0.34 (0.44)	0.32 (0.51)	0.33 (0.46)	0.28 (0.60)	0.07 (1.15)	0.39 (0.27)	0.29 (0.69)	0.40 (0.33)	0.32 (0.61)	0.35 (0.59)	0.30 (0.49)	0.37 (0.27)	0.41 (0.19)	0.38 (0.29)	0.39 (0.27)	0.32 (0.55)

Table 5 – Bivariate models at individual, country and country-wave levels. Weighted coefficients.

	Dependent variable: Willingness to vaccinate (0= No; 1= Yes)					
Risk Index	0.101***					
	(0.006)					
Confidence Index		0.094***				
		(0.006)				
Country Risk Index			0.099*			
			(0.074)			
Country Confidence Index				0.314**		
				(0.097)		
Country-Wave Risk Index					0.101***	
					(0.019)	
Country-wave Confidence Index						0.294***
						(0.026)
Wave. Ref = Wave 1						
Wave 2	-0.001	0.002				
	(0.008)	(0.008)				
Wave 3	-0.010	-0.007				
	(0.008)	(0.008)				
Wave 4	-0.041***	-0.044***				
	(0.009)	(0.009)				
Wave 5	-0.056***	-0.063***				
	(0.009)	(0.009)				
Wave 6	-0.067***	-0.067***				
	(0.012)	(0.012)				
Wave 7	-0.063***	-0.060***				
	(0.010)	(0.009)				
Wave 8	-0.058***	-0.056***				
	(0.009)	(0.009)				
Wave 9	-0.084***	-0.077***				
	(0.009)	(0.009)				
Wave 10	-0.083***	-0.075***				
	(0.011)	(0.011)				
Wave 11	-0.089***	-0.081***				
	(0.011)	(0.011)				
Wave 12	-0.093***	-0.080***				

	(0.011)	(0.011)
Wav 13	-0.081***	-0.063***
	(0.011)	(0.011)
Wave 14	-0.055***	-0.044***
	(0.011)	(0.011)
Wave 15	-0.046***	-0.031**
	(0.011)	(0.011)
Wave 16	-0.008	-0.004
	(0.011)	(0.011)
Wave 17	0.008	0.010
	(0.011)	(0.011)
Wave 18	0.038***	0.047***
	(0.011)	(0.010)
Wave 19	0.039***	0.043***
	(0.011)	(0.011)
Wave 2 * Risk Index	-0.003	
	(0.008)	
Wave 3 * Risk Index	0.015	
	(0.008)	
Wave 4 * Risk Index	0.013	
	(0.009)	
Wave 5 * Risk Index	0.003	
	(0.008)	
Wave 6 * Risk Index	0.004	
	(0.012)	
Wave 7 * Risk Index	0.001	
	(0.010)	
Wave 8 * Risk Index	0.003	
	(0.009)	
Wave 9 * Risk Index	-0.008	
	(0.009)	
Wave 10 * Risk Index	0.021*	
	(0.010)	
Wave 11 * Risk Index	-0.006	
	(0.011)	
Wave 12 * Risk Index	0.011	
	(0.011)	

Wave 13 * Risk Index	0.005	
	(0.011)	
Wave 14 * Risk Index	0.000	
	(0.011)	
Wave 15 * Risk Index	0.006	
	(0.011)	
Wave 16 * Risk Index	0.003	
	(0.011)	
Wave 17 * Risk Index	0.004	
	(0.011)	
Wave 18 * Risk Index	0.018	
	(0.011)	
Wave 19 * Risk Index	-0.003	
	(0.011)	
Wave 2 * Trust Index		-0.020*
		(0.008)
Wave 3 * Trust Index		-0.000
		(0.008)
Wave 4 * Trust Index		-0.005
		(0.009)
Wave 5 * Trust Index		0.002
		(0.008)
Wave 6 * Trust Index		0.003
		(0.011)
Wave 7 * Trust Index		0.000
		(0.009)
Wave 8 * Trust Index		-0.009
		(0.009)
Wave 9 * Trust Index		-0.012
		(0.009)
Wave 10 * Trust Index		0.014
		(0.011)
Wave 11 * Trust Index		0.027**
		(0.009)

Wave 12 * Trust Index		0.033***				
		(0.010)				
Wave 13 * Trust Index		0.017				
		(0.009)				
Wave 14 * Trust Index		0.033***				
		(0.010)				
Wave 15 * Trust Index		0.017				
		(0.011)				
Wave 16 * Trust Index		0.037***				
		(0.010)				
Wave 17 * Trust Index		0.027*				
		(0.012)				
Wave 18 * Trust Index		0.041***				
		(0.009)				
Wave 19 * Trust Index		0.025*				
		(0.010)				
Constant	0.683***	0.680***	0.646***	0.650***	0.646***	0.650***
	(0.006)	(0.006)	(0.023)	(0.019)	(0.006)	(0.006)
Observations	142,264	142,264	23	23	437	437
R-squared	0.057	0.054	0.077	0.335	0.062	0.223

Robust standard errors in parentheses; *** p<0.001,
** p<0.01, * p<0.05

Table 6 – Multilevel longitudinal models reporting the full set of wave FEs. All models are random intercept models, estimated using a Linear Probability model (LPM). SE clustered at country-level. Weighted coefficients.
[WE] = Within; [BE] = Between. N=142.264. Weighted coefficients.

	Null b/(se)	M1 b/(se)	M2 b/(se)	M3 b/(se)	M4 b/(se)	M5 b/(se)
Individual level variables						
Gender *(Ref. = Male)*						
Female		- 0.085*** (0.011)	- 0.085*** (0.011)	- 0.085*** (0.011)	- 0.085*** (0.011)	- 0.085*** (0.011)
Age *(Ref. = 18-30)*						
31-40		- 0.032*** (0.008)	- 0.032*** (0.008)	- 0.032*** (0.008)	- 0.032*** (0.008)	- 0.032*** (0.008)
41-50		- 0.034*** (0.009)	- 0.034*** (0.009)	- 0.034*** (0.009)	- 0.034*** (0.009)	- 0.034*** (0.009)
51-60		-0.019* (0.009)	-0.019* (0.009)	-0.019* (0.009)	-0.019* (0.009)	-0.019* (0.009)
Over 60		0.023 (0.018)	0.023 (0.018)	0.023 (0.018)	0.023 (0.018)	0.023 (0.018)
Educational Level *(Ref. = Lower Educated)*						
Mid Educated		0.007 (0.011)	0.007 (0.011)	0.007 (0.011)	0.007 (0.011)	0.007 (0.011)
Higher Educated		0.041*** (0.012)	0.041*** (0.012)	0.041*** (0.012)	0.041*** (0.012)	0.041*** (0.012)
Area *(Ref. = City)*						
Town		-0.005 (0.006)	-0.005 (0.006)	-0.005 (0.006)	-0.006 (0.006)	-0.005 (0.006)
Village or rural area		-0.010 (0.007)	-0.010 (0.007)	-0.010 (0.007)	-0.010 (0.007)	-0.010 (0.007)
Self-reported health status *(Ref. = Poor)*						
Fair		0.007 (0.006)	0.007 (0.006)	0.007 (0.006)	0.006 (0.006)	0.006 (0.006)
Good		-0.002 (0.006)	-0.002 (0.006)	-0.002 (0.006)	-0.002 (0.006)	-0.002 (0.006)
Information exposure *(Ref. = Low)*						
High		0.039*** (0.004)	0.039*** (0.004)	0.039*** (0.004)	0.039*** (0.004)	0.039*** (0.004)
Perceived Risk Index		0.084*** (0.005)	0.085*** (0.005)	0.085*** (0.005)	0.085*** (0.005)	0.085*** (0.005)
Confidence Index		0.073*** (0.005)	0.073*** (0.005)	0.073*** (0.005)	0.073*** (0.005)	0.073*** (0.005)
Country and country-wave level variables						

Perceived Risk [WE]		0.015	-0.054	-0.054
		(0.033)	(0.033)	(0.033)
Perceived Risk [BE]		-0.016	-0.051	-0.053
		(0.047)	(0.053)	(0.054)
Confidence [WE]		0.053	0.056	0.059
		(0.050)	(0.043)	(0.043)
Confidence [BE]		0.222**	0.226*	0.228*
		(0.072)	(0.093)	(0.093)
New deaths per million [WE]			0.010***	0.010***
			(0.003)	(0.003)
New deaths per million [BE]			0.003	0.003
			(0.013)	(0.013)
Stringency Index [WE]			0.001	0.001
			(0.001)	(0.001)
Stringency Index [BE]			0.003	0.003
			(0.003)	(0.003)
New deaths per million [WE] * Perceived Risk [WE]				-0.010
Wave. Ref. = Wave 1				
Wave 2	-0.000	0.001	0.001	0.000
	(0.008)	(0.008)	(0.008)	(0.008)
Wave 3	-0.007	-0.004	-0.007	-0.008
	(0.010)	(0.011)	(0.012)	(0.011)
Wave 4	-0.033***	-0.030**	-0.035***	-0.035***
	(0.009)	(0.009)	(0.010)	(0.010)
Wave 5	-0.049***	-0.044**	-0.052***	-0.051***
	(0.012)	(0.014)	(0.015)	(0.014)
Wave 6	-0.073***	-0.072***	-0.070***	-0.070***
	(0.015)	(0.016)	(0.017)	(0.017)
Wave 7	-0.049***	-0.046***	-0.048***	-0.051***
	(0.011)	(0.011)	(0.012)	(0.012)
Wave 8	-0.049***	-0.047***	-0.049***	-0.051***
	(0.012)	(0.013)	(0.014)	(0.014)
Wave 9	-0.071***	-0.068***	-0.075***	-0.077***
	(0.014)	(0.015)	(0.016)	(0.017)
Wave 10	-0.077***	-0.079***	-0.093***	-0.096***
	(0.016)	(0.016)	(0.018)	(0.019)
Wave 11	-0.080***	-0.079***	-0.104***	-0.106***
	(0.015)	(0.015)	(0.018)	(0.018)
Wave 12	-0.083***	-0.086***	-0.104***	-0.105***
	(0.017)	(0.018)	(0.021)	(0.021)

Wave 13			-0.080***	-0.081***	-0.100***	-0.101***
			(0.023)	(0.023)	(0.022)	(0.022)
Wave 14			-0.060*	-0.065**	-0.088***	-0.088***
			(0.025)	(0.025)	(0.022)	(0.022)
Wave 15			-0.047	-0.048	-0.078**	-0.077**
			(0.028)	(0.028)	(0.028)	(0.028)
Wave 16			-0.007	-0.008	-0.040*	-0.042*
			(0.019)	(0.018)	(0.019)	(0.019)
Wave 17			0.008	0.006	-0.016	-0.019
			(0.026)	(0.026)	(0.025)	(0.024)
Wave 18			0.044	0.046	0.030	0.028
			(0.024)	(0.025)	(0.023)	(0.023)
Wave 19			0.033	0.029	0.019	0.018
			(0.028)	(0.028)	(0.026)	(0.025)
						(0.008)
Constant	0.649***	0.653***	0.689***	0.690***	0.490**	0.492**
	(0.023)	(0.022)	(0.023)	(0.023)	(0.173)	(0.173)
Variance Components						
Country	0.0112	0.00881	0.00891	0.00705	0.00615	0.00621
Country-Wave	0.00641	0.00609	0.00447	0.00445	0.00380	0.00379
Individual	0.211	0.193	0.193	0.193	0.193	0.193
Log Likelihood	-91724.599	-85526.665	-85472.253	-85468.422	-85441.050	-85440.526
AIC	183457	171089	171016	171017	170970	170971
BIC	183497	171267	171372	171412	171404	171415

Robust standard errors in parentheses, *** p<0.001,
** p<0.01, * p<0.05