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Do cognitive styles affect vaccine hesitancy? A dual-process cognitive framework for vaccine hesitancy and the role of risk perceptions

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A R T I C L E I N F O

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A B S T R A C T

Rationale: In this study, we consider cognitive differences in vaccine hesitancy and how perceived risks intervene in this relationship. Recent research agrees on the existence of two cognitive processes, intuitive and analytic cognition. Different individuals lean toward one of these processes with varying degrees of strength, influencing day-to-day behavior, perceptions, and decisions. Thinking dispositions might influence, at the same time, vaccine acceptance and perceived risks of vaccine-preventable disease, but the implications of individuals' cognitive differences for vaccination uptake have seldom been addressed from a sociological standpoint.

Objective: We bridge this gap by adopting a dual-process framework of cognition and investigate how thinking styles have a direct association with vaccine hesitancy and an indirect one through perceptions of risk.

Methods: We use data from original surveys carried out between September and November 2019 on a sample of the Italian population, participating in an online panel run by a major Italian survey company. We 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: Net of individual socio-demographic characteristics, intuitive thinking is positively associated with the likelihood of being vaccine hesitant, and this direct association is as important as the indirect one through risk perceptions. Affective risk perceptions account for over half of the indirect association, underlining the centrality of affective versus probabilistic approaches to risk perception.

Conclusion: This study contributes to the existing literature by highlighting the importance of including cognitive characteristics in vaccine hesitancy research, and empirically showing individuals' qualitatively complex perceptions of risks. Taking into account individuals' preferred cognitive style and affective concerns might be important in developing better tailored communication strategies to contain vaccine hesitancy.

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" (World Health Organization, 2013 in Brewer et al., 2017:151). Despite strong public support for vaccination, vaccine hesitancy (the delay or refusal of vaccine prophylaxis) is re-emerging as an issue, especially in those contexts where vaccination's most beneficial effects have been seen (Larson et al., 2014). Additionally, vaccine acceptance will be fundamental to resolving the COVID-19 pandemic, but early results suggest that "distrust is likely to become an issue" (Peretti-Watel et al., 2020:769). A large-scale research involving 67 nations has identified Italy as one of the countries most affected by vaccine hesitancy, reporting the second highest level of vaccine-related skepticism between Russia, first, and Azerbaijan, third (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., 2015:99–100). This study 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., 2017:158), several behavioral theories have been used to explain vaccination intentions, such as the "Health Belief Model and Sick Role Behavior" (Becker,

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1974), "Protection Motivation Theory" (Rogers, 1975), and the "Theory of Planned Behavior" and the "Theory of Reasoned Action" (Fishbein and Ajzen, 2011). The main limitation of key models of health behavior is in considering individuals as 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, limited cognitive capacity and ability, displaying a bounded rationality (Simon, 1955). In this framework, cognitive science, together with sociology and social psychology, has elaborated complex models to take into account 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), is based on 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, 1974:1124). As an example, availability heuristic (Tversky and Kahneman, 1974; Nisbett and Ross, 1980) expects individuals to give greater probability to evidence they can easily bring to mind. 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, which limits to rationality might be generated by the way our cognition works.

Individuals' cognitive differences in vaccination uptake have seldom been addressed, but as Frederick 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" (Lubinski and Humphreys, 1997 in Frederick, 2005:25). 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 a number of risk perceptions can indirectly intervene in this association.

We use data from original surveys carried out between September and November 2019 in Italy, assessing individuals' ability to overcome intuitive thinking and collecting fine-grained measures of risk perceptions. We rely on Karlson et al. (2012) decomposition (KHB decomposition) to measure the total, direct, and indirect association of cognitive styles with vaccine hesitancy, and disentangle the contribution of each perceived element of risk.

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

2. Theoretical framework

2.1. Two systems of cognition

The distinction between two kind 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), and 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 existing research agrees on cognition being 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 structures and processes: Fast/Slow (Kahneman, 2011), Practical/Discursive (Vaisey, 2009), Intuitive/Deliberate (Evans and Stanovich, 2013). In this article, we will 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, 2019:4). Automatic cognition is an "effortless, immediate, universalized and subconscious thought" (Brekhus, 2015:29) 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 efforts. Analytic cognition "involves slow, deliberate, conscious, verbalized thought processes" (Brekhus, 2015:29), implying a different neural experience. When engaged in analytic thinking, individuals may reject or override their previous, automatic, cognitive assumptions, and actively put effort into cognitive activities (Cerulo, 2002). It could be said that analytic cognition is our deep-level cognitive method, but several studies on dual processes of cognition show 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 is in charge of 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). For this reason, the two systems would 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 article, 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), varying as a function of the individual's characteristics and the situation. Crucially, evidence suggests, in fact, that different people employ and rely on each of these systems with varying degrees of strength: Epstein (2014) elaborates 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 towards a more "intuitive style", characterized by a prevalent use of automatic cognition, others towards a more "analytic style", where analytic cognition is more often in charge. This orientation is 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 has to be considered as an important corrective to rational action theories that dominate 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 the issue of 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, 2012; Sloman, 2014).

The analytic style has been positively associated with a higher level of acceptance of scientifically verifiable beliefs, and intuitive style to a number of different 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). As an example, while cognitive styles are almost certainly not the sole cause of religious belief or disbelief, research has found that individuals leaning towards 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) for a 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, 2012:320).

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), while analytic thinking "is assumed to be a generative mechanism that, through education, decreases paranormal beliefs" (Aarnio and Lindeman, 2005:1228). Along the same lines, Genovese (2005) shows that the lowest levels of paranormal belief are found among analytical thinkers and that thinking style contributes, alongside other individual characteristics, in shaping an individual's beliefs.

Although little literature investigates this specific association in cases of vaccine hesitancy, with remarkable exceptions (*see* Anderson, 2016; Schindler et al., 2020; Tomljenovic et al., 2019, 2020), research shows that, under incomplete information, individuals might stumble across heuristic cognitive flaws that support vaccine misconceptions (Jacobson, 2007). Poland et al.'s (2014) review found that heuristics use is associated with automatic processing and greater vaccine skepticism. Since intuitive thinking is characterized by the use of heuristics, and individuals who lean towards an intuitive thinking style have been found to share various misconceptions about vaccination (Poland et al., 2014), intuitive thinking might therefore hide a certain level of vaccine hesitancy. Recent research (Schindler et al., 2020) underlines how the perception of low prevalence of vaccine-preventable diseases (VPDs), combined with the availability of prominent accounts of vaccine side effects, might have generated an intuitive response disparaging the safety and usefulness of vaccines. Tomljenovic et al. (2020) show that parents relying more heavily on intuitive reasoning were more likely to endorse invalid statements, and to advocate vaccine avoidance or even support conspiracy theories about vaccinations (Tomljenovic et al., 2019).

2.3. Vaccine hesitancy, cognitive styles, and risk perception

Existing studies allow 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 risks: dangers might be real, but risks are socially constructed (Slovic, 2005). Beck (1992) describes modernity as a "risk society": at a time where rapid technological development has reduced the perception of dangers as inevitable, it has encouraged individuals to minimize risks, to make their future secure (Giddens, 1990). As a consequence, perceived hazards belong more and more to the category of "manufactured uncertainties" (Beck, 1992), direct but unintended consequences of scientific progress. This is particularly true of health, which has become a "super value" (Price et al., 2016). In a very specialized environment, where individuals have to delegate knowledge in many fields, fear of unintended consequences may result in 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., 2016:59). 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 (Floyd et al., 2000; Brewer et al., 2017). This appears to apply also to the recent COVID-19 pandemic, where several studies underlined the importance of perceived risks of the disease in driving the decision to immunize (Attema et al., 2021; Dryhurst et al., 2020; Caserotti et al., 2021 in the Italian context). Most of the existing research categorizes risks in the way classic models of health behavior do, assuming that people pay close attention to likelihood and odds. But a systematization of dimensions involving risk perception (Slovich et al., 2005) has found that people have a broad conception of risks, qualitative and complex, that calls into play individuals' cognitive systems. Recent literature shows, 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) suggests that individuals' assessment of the risk vaccination presents is 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, 2016:4). 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, a strategy that can be referred to as "affect heuristic" (Finucane et al., 2000).

Although many 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" (2005:32) but the author shows how these two elements are strongly tied together. Individuals may differ in the extent to which intuitive or analytic style influences their perceptions of risks. "For example, whereas a medical professional's understanding of risk as statistical probability may be more heavily influenced by the deliberative system, lay understanding may rely on more experiential ways of knowing" (Reventlow et al., 2001 in Slovic et al., 2005:37). As an 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 study, we aim to further investigate 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 study:

Q1: *Are thinking styles directly associated with vaccine hesitancy?*

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

Q2: *Are thinking styles associated with risk perceptions?*

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

Q3: *Do risk 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 research knowledge on determinants of vaccine hesitancy, and is a first step towards including these elements more frequently in analyses of vaccine hesitancy. Additionally, as previous research has advocated, determining which cognitive styles individuals lean towards could help provide more tailored information (Poland et al., 2014). Understanding whether individuals characterized by different thinking styles and perceptions of risk, tend to (or not to) accept vaccination could invite further research into the usefulness of including these characteristics in developing effective strategies to decrease vaccine hesitancy.

3. Methods

3.1. Data

We use a dataset obtained from two primary data collections. This study was approved by the Institutional Review Board of the author's institution. A first survey was administered in September and October 2019, and 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 participating 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, is proportional to the 2018 Italian population as surveyed by ISTAT, the Italian National Institute of Statistics. Educational level (low, medium, high) is distributed equally among the sample population. To account for this sampling characteristic, frequency weights are applied. Quota sampling, although being far from an ideal probabilistic sampling method, was chosen following careful consideration of the research funds available, research goals, and the need to obtain accurate data in the Italian context. For this reason, point estimates in the following analysis will have to be carefully considered, always taking the limitations of this method into account. In contrast, the opportunity to collect primary data on this theme allowed us access to a qualitatively complex dataset, combining measures that, to the best knowledge of the authors, have never been surveyed together before.

3.2. Variables

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 the appendix. Our outcome variable is whether the respondent would hesitate to administer to a hypothetical child the mandatory and recommended vaccinations, in Italy, on a scale from 0 to 10 indicating degree of hesitancy. Given the skewed distribution (mean: 3.05; SD: 3.5; median: 1) we re-expressed the variable as a dichotomy: 0 indicates no hesitancy and 1 indicates hesitancy.

Our main predictor variable is the individual's thinking style. To assess this, we rely on an extended version of the Cognitive Reflection Test (CRT) (Frederick, 2005) proposed by Primi et al. (2016), 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 as the first question of the follow-up questionnaire. We combined the six items, obtaining the full CRT-L test.

The six CRT-L questions were as follows:

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? (correct answer: 5 cents; heuristic answer: 10 cents)
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? (correct answer: 5 minutes; heuristic answer: 100 minutes)
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? (correct answer: 47 days; heuristic answer: 24 days)
4) If three elves can wrap three toys in an hour, how many elves are needed to wrap six toys in 2 hours? (correct answer: three elves; heuristic answer: six elves)
5) Giovanni received both the 15th-highest and the 15th-lowest mark in the class. How many students are in the class? (correct answer: 29 students; heuristic answer: 30 students)
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? (correct answer: 15 medals; heuristic answer: 20 medals)

The CRT-L test is a relatively simple one, 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, engaging in analytic thinking. Frederick (2005) shows how, among all the incorrect answers, the heuristic one dominates, suggesting that it is indeed possible to distinguish individuals who engage in analytical thinking from those who answer intuitively.

To be able to clearly distinguish individuals leaning towards a more intuitive thinking style from those in whom an analytic style dominates, we recoded our main predictor variable into four categories. Individuals who gave the correct answer to four or more questions were assigned to the "Analytic style" category, 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" category, as were individuals giving three intuitive answers, one correct answer and two incorrect answers (or two correct and one incorrect). The two residual categories are constituted by individuals giving a majority of incorrect answers, constructed with the same rationale of the two previous categories, classified as "Incorrect", and those giving 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), categorized as "Unassigned".

For the sake of clarity and given the scope of this study, throughout this article, we only compare 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 additionally 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 suggesting respondents imagine they have to take care of a child, today, in Italy. We measure four distinct risk perception concepts: severity of a disease, likelihood of contagion, susceptibility to illness, and feeling at risk. The severity of a disease is represented by the perceived magnitude of an adverse event (Becker, 1974), such as a VPD. Likelihood of contagion is defined as "one's [perceived] probability of being harmed by a hazard under certain behavior conditions" (Brewer et al., 2007:137), therefore a probability assessment. Perceived susceptibility is articulated both as a general property of the hypothetical child – a "constitutional" vulnerability to diseases – and as a perceived risk specifically from VPDs. The fourth dimension, "feeling at risk", follows the intuitions of Slovic et al. (2005) and Kahan (2014), suggesting that "one can define risk as an 'analysis' (e.g., a probability judgment) or risk as a 'feeling'" (Weinstein et al., 2007:147). In this interpretation, risk can be defined as an affective state, distinct from cognitive judgment (Weinstein et al., 2007:147).

To measure perceived likelihood of contagion and feeling at risk we presented two hypothetical scenarios, asking respondent to imagine 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 only use 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 investigate the perception of probability and severity of side effects. Following results from 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 given the opportunity to indicate that they "don't know" their position on a given 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 mean 0 and standard deviation 1. Control variables are respondent's educational level (lower: up to eight years of education; medium: up to thirteen years of education; higher: more than thirteen years of education), gender, age, whether respondents have children (categorized as 0 = no, 1 = one, 2 = more than one), and geographic area of residence (north-east, north-west, centre, south and islands).

3.3. Analytical strategy

The empirical analysis is 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.

1) In the first step, we measure the association between cognitive styles and vaccine hesitancy, first bivariate (m1) then controlling for individual characteristics (m2). This step assesses the existence of a relationship between thinking styles and vaccine hesitancy, estimates the strength of the total association, and measures 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) on the basis of 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 lets us disentangle the change in coefficients attributable to confounding and the change resulting from rescaling, which is of no substantive interest (Triventi, 2013; Kohler et al., 2011). In other words, KHB allows us to interpret the coefficients of direct and indirect associations of nonlinear models in the way commonly done for linear regression models, estimating coefficients of additional variables while taking into account the problem of rescaling (Connelly et al., 2016; Kohler et al., 2011).

The full model is:

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

where *TStyle* represents individual's thinking style, *RP* represents eight measures of risk perception, and *C* summarizes a number of individual characteristics.

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

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

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

KHB extracts the information not contained in X by calculating the residuals of a linear regression of *βRP* on *βTStyle*, 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 are estimated coefficients of the linear regression. *R* is then used in the reduced models (m1) and (m2):

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

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

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, ensuring the existence of a common standard deviation σ_F between models, allowing their magnitude to be compared (Kohler et al., 2011).

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

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

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

3) The third step investigates the association between RP measures and vaccine hesitancy, through multivariate logistic regression, controlling for individual characteristics. The model is:

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

This analysis is important to verify which specific risk perception measures are correlated with the outcome.

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

The equation for the full model is:

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

4. Results

4.1. Association of thinking styles with vaccine hesitancy

The first step examines the relationship between thinking styles and the probability of being vaccine-hesitant. Fig. 1 reports average marginal effects for a bivariate logistic regression (dark grey bar) predicting the probability of vaccine hesitancy, comparing intuitive thinking style with analytic thinking style, and the same model controlling for individuals' sociodemographic characteristics and individuals' general susceptibility to disease (light grey bar).

In model 1, individuals showing an intuitive style are, 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 decreases to 19.6 pp. Contrary to previous studies in the Italian context (Anello et al., 2017), we find a positive relationship between educational level and the probability of accepting vaccination, in line with recent multi-country analysis (Makarovs and Achterberg, 2017). Additionally, respondents with more than one child are generally less likely to be vaccine-hesitant. To interpret this result we argue that where one child has been immunized and did not suffer severe side-effects, this promotes vaccine acceptance. Finally, we find a significant divide between the Southern Italian region and the rest of the country: individuals living in the south are more likely to be vaccine hesitant (see Table 3 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 show how this correlation exists even where individual characteristics are held constant.

4.2. Association of cognitive styles with risk perception measures

In the second part of the analysis, we examine whether cognitive styles are associated with measures of RP, and if so, how. Fig. 2 reports coefficients of eight multivariate linear regressions where the outcome variable is a risk perception measure and the main predictor variable is thinking style, controlling for individual characteristics.

Overall, a clear pattern emerges: compared to analytic style, intuitive style is associated to a decrease in RP (questions not conditioned on vaccination) and, conversely, to an increase of RP (questions conditioned on vaccination).

More specifically, compared to the analytic style, the intuitive style is 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 is 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 risks. It is important to note that thinking styles are strongly associated with affective perceptions over assessments of probability.

4.3. Association of risk perception measures with vaccine hesitancy

Fig. 3 reports the average marginal effects for a logistic regression where measures of risk perception are regressed on vaccine hesitancy, controlling for individual characteristics.

Surveying a wide range of theoretically driven measurements of perceived risk, the results point towards a complex scenario. The likelihood of contagion, whether or not conditioned on vaccination, is 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 suggests, on the contrary, that an assessment of probability is not associated with the outcome, whereas we find a strong association between vaccine hesitancy and perceived feelings of vulnerability. Conditioned on no vaccination, a SD increase in the feeling of vulnerability to VPDs is associated with a 13.4 pp decrease in the likelihood of being vaccine hesitant. At the opposite end of the spectrum, conditioned on vaccination, a SD increase in feelings of vulnerability to VPDs is associated with a 4.6 pp increase in the likelihood of being vaccine hesitant. In other words, without vaccinations, individuals who *feel* vulnerable to VPDs are less likely to be vaccine hesitant, whereas after vaccinations, individuals who *feel* more vulnerable to VPDs are 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 existing studies, an increase in the perceived

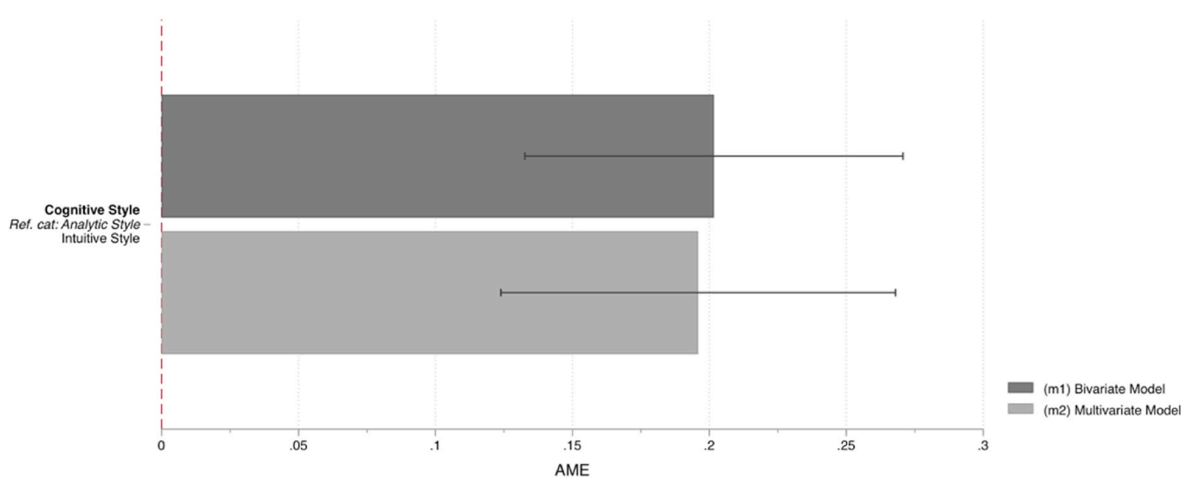

Fig. 1. Bivariate Logistic regression (m1) and multivariate logistic regression (m2) predicting vaccine hesitancy: average marginal effects (AME) of intuitive style versus analytic style. In (m2) AME controlled for individuals' sociodemographic characteristics (educational level, gender, age, number of children, geographical area of residence) and general susceptibility to disease. Weighted coefficients, 95% CIs.

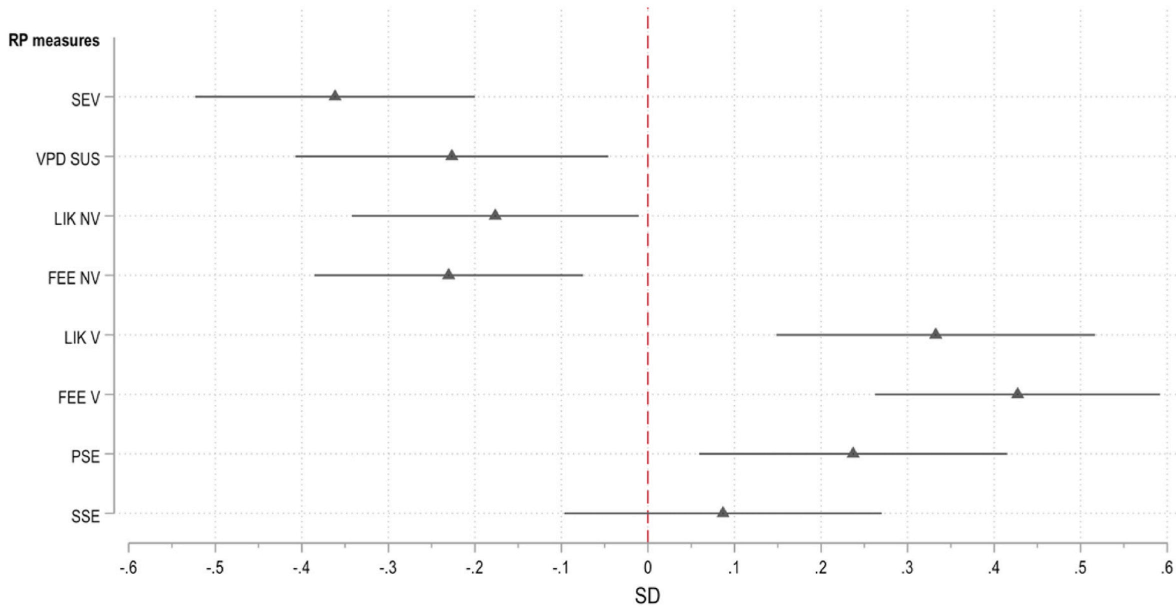

Fig. 2. Multivariate linear regression (m3–m10) estimating the association of intuitive thinking versus analytic thinking style on measures of risk perception. All indicators have been standardized. All models are controlled for individuals' sociodemographic characteristics (educational level, gender, age, number of children, geographical area of residence) and general susceptibility to disease. Weighted coefficients, 95% CIs.
(*Note.* 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.).

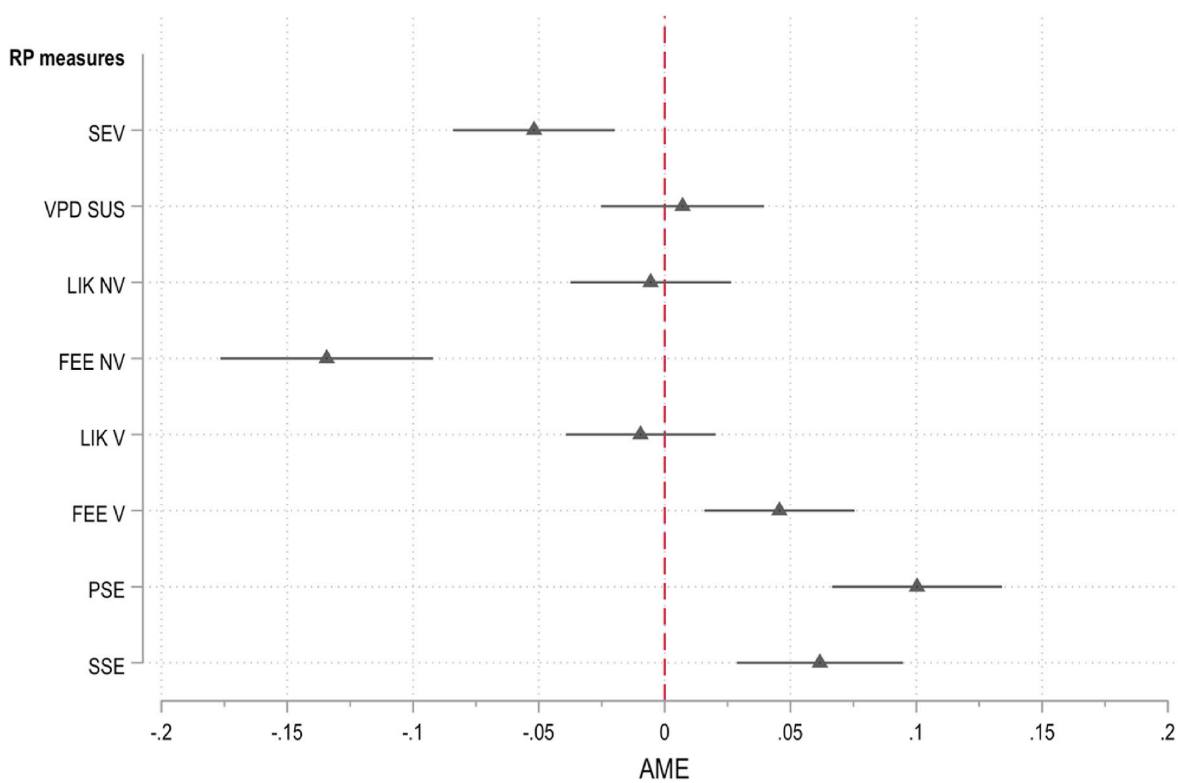

Fig. 3. Logistic regression (m11) predicting vaccine hesitancy by risk perception measures. AMEs controlled for individuals' sociodemographic characteristics (educational level, gender, age, number of children, geographical area of residence) and general susceptibility to disease. All indicators have been standardized. Weighted coefficients, 95% CIs.

severity of diseases is associated with a decrease in the probability of vaccine hesitancy, whereas perceived susceptibility to VPDs is not. Finally, as expected, increases in both the probability and the severity of side effects are associated respectively 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 are therefore more prone to be vaccine hesitant.

4.4. Total, direct, and indirect association of cognitive styles and the role of risk perceptions

In this final section, we rely 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 into this relationship, disentangling the contribution of each RP measure.

Table 1 reports average marginal effects of total, direct, and indirect association between intuitive versus analytic thinking style and vaccine hesitancy. We additionally report the confounding ratio between the reduced model (m2) and the full model (m12), the percentage reduction attributable to risk perception variables ("confounding percentage"), and the rescaling factor applied to (m1) and (m2), based on the most saturated model (m12).

Controlling for individual characteristics, individuals leaning towards an intuitive rather than an analytic thinking style show an increase, on average, of 19.6 pp in the likelihood of vaccine hesitancy, as showed in (m2). After controlling for risk perceptions, the direct association of intuitive style with vaccine hesitancy reduces to an average of 10.0 pp greater than analytic style, leaving an indirect positive association through risk perceptions of 9.5 pp. In other words, as reported in the second part of Table 1, the total association is 1.92 times the direct association, and 47.8% of the total association is attributable to all RP measures combined. Substantively, this suggests that there is indeed a direct relationship between thinking styles and vaccine hesitancy, and that this association is at least as strong as the indirect association through the risk perceptions we measured. Intuitive thinking style, as seen in Fig. 2, leads to lower risk perception without vaccinations and higher risk perception with vaccination, which in turn 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. Fig. 4 reports the percentage contribution of each RP variable to the difference between the full (m12) and the reduced model (m2).

As Fig. 4 shows, five out of eight measures of risk perception are significantly associated with vaccine hesitancy. Feelings of vulnerability conditioned on no vaccination account for almost 35% of the indirect association, where a SD increase results in the probability of vaccine hesitancy decreasing by 13.6 pp. In descending order, the perceived probability of side effects follows, 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 point towards three considerations. First, controlling for individual characteristics and measures of risk perception, cognitive style has a direct, surveyable association with the probability of vaccine hesitancy. Individuals leaning towards an intuitive thinking style are more prone than those leaning towards an analytic style to be vaccine-hesitant. Second, part of this total relationship is spurious and operates indirectly through influencing individuals' risk perceptions. Third, the indirect association of cognitive styles with vaccine hesitancy through risk perceptions reveals a more complex picture than the one depicted by most literature on the theme. Feelings of vulnerability count for more than 54% of the indirect association of thinking styles with the probability of vaccine hesitancy, showing the centrality of this sometimes neglected concept.

Table 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.

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

Note. (Robust SE in parentheses.) 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.
***p < 0.001, **p < 0.01, *p < 0.05.

5. Discussion

Discussions of cognitive differences in vaccine hesitancy appear seldomly in academic literature, with remarkable exceptions (Anderson, 2016; Schindler et al., 2020; Tomljenovic et al., 2019, 2020). Nonetheless, an extensive set of contributions based on the dual-process of cognition framework has showed how cognitive characteristics play a significant role in shaping human perceptions, decisions, and behavior.

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

In the first part of the analysis, we show how intuitive style is associated with an increase in the probability of vaccine hesitancy, even after controlling for individual characteristics (see Fig. 1). In the second part, we show that intuitive style is associated with greater VPDs perceived risks conditioned on vaccination, suggesting vaccination to be perceived as a factor increasing vaccine hesitancy (see Fig. 2). In the third part of the analysis, we evaluate how perceptions of risk are associated with the probability of vaccine hesitancy, showing the importance of including affective perceptions in the analysis (see Fig. 3). In the last part of the analysis, we show 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 (see Table 1). Disentangling the contribution of each RP measure, we once again find that affective feelings account for over half of the indirect association of perceived risk, together with the important contribution of perceptions of probability and severity of side effects (see Fig. 4).

The importance of taking into account cognitive characteristics to explain the way individuals make decisions has a long-standing tradition in psychology and social psychology. On the other hand, sociologists interested in vaccine hesitancy discourse have often underlined the role of individual sociodemographic characteristics, contextual socioeconomic factors, and perceptions. With the seminal work of DiMaggio (1997) and the research 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 article, we aim at contributing to this cognitive sociology approach, by showing how embedded cognitive characteristics are indeed correlated to the way individuals' develop opinions and form

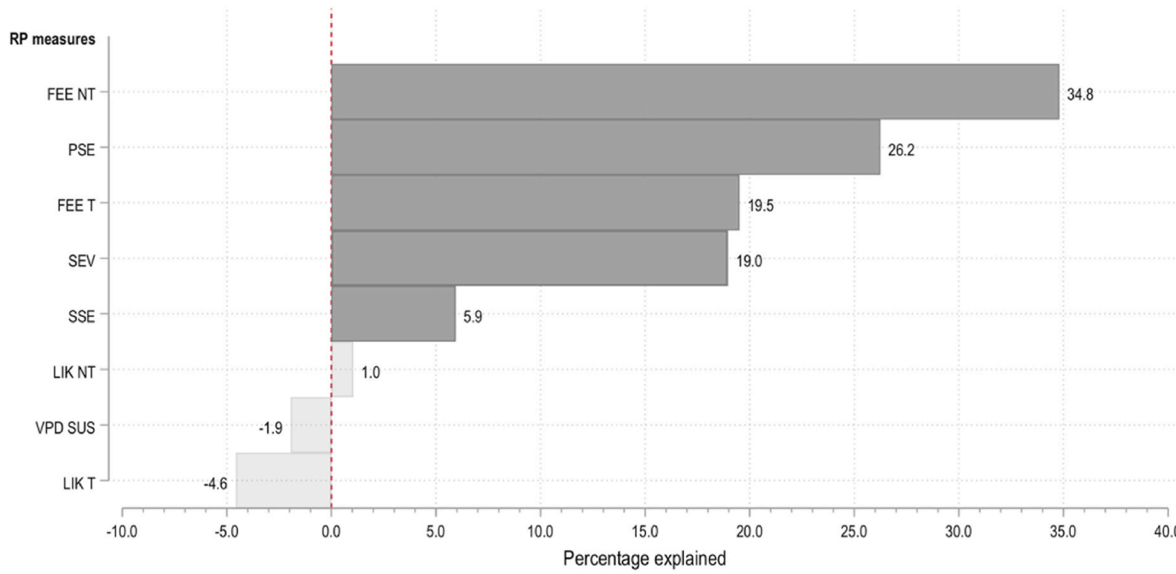

Fig. 4. Percentage contribution of each risk perception variable to the indirect association of intuitive style on the probability of vaccine hesitancy, compared with analytic style. Dark grey bars indicate statistically significant associations at $p < 0.05$.

preferences on the subject of vaccine hesitancy Additionally, while sociology often underlined the importance of perceived risks, applied to vaccine hesitancy discourse this often happened through the lenses of classic models of health behavior. In this study, we instead exploit several theoretically distinct concepts that reveal a complex pattern of associations in the empirical analysis, both directly between measures of risk perception and vaccine hesitancy (see Fig. 3), and indirectly in the association between cognitive styles and vaccine hesitancy (see Fig. 4). 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 (see Fig. 1), revealing the importance of taking this dimension into account. Second, although recent research has underlined the need for social and behavioral scientists to be cautious when making policy recommendations (IJzerman et al., 2020), we believe the current study could be a starting point in developing more specific knowledge about the importance of including individual cognitive characteristics in strategies to increase vaccine acceptance. As an example, recent research (Schindler et al., 2020) suggests that, in face-to-face settings, increasing participants' awareness of their intuitive feelings, and suggesting how to deliberately monitor them, could be valuable. Third, individuals' concerns about vaccine-preventable diseases and vaccination risks are legitimate anxieties that should be addressed attentively, by understanding the exact points they insist on. This study has shown how individuals' risk perceptions are less concerned with assessments of probability and more with affective states and emotional perceptions (see Fig. 4). Previous studies have underlined how, to favor vaccine acceptance, existing strategies often involve emphasizing 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.

5.1. Limitations

This work, although contributing to the current stream of research on vaccine hesitancy, 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 together before. Future researchers should certainly attempt to collect more accurate data, using a probabilistic sampling method to obtain more reliable estimates.

Second, in this study we test the possibility that perceived risks indirectly intervene 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., 2011). Several methodological contributions, in fact, warn about the infeasibility of distinguishing between different theoretical models through a statistical test in a correlational design (Fielder et al., 2011; Bullock 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), so 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 recent COVID-19 pandemic, further efforts should be made to obtain experimental data that could greatly benefit vaccine hesitancy research by exploring causality more cleanly. Unfortunately, at least in the Italian case, this is not yet practical, and this exploratory study is a first step towards the collection of more accurate data that would allow better designs and further-reaching results.

Lastly, in this article, we take a position in a current debate about the relationship between two cognitive processing mechanisms, by considering them a feature of individuals somehow stable through a specific period.

6. Conclusions

Addressing vaccine hesitancy is a primary concern, especially at present. Vaccine acceptance has been a significant issue throughout the last decade, but in the light of COVID-19 research further underlines how crucial it is to increase awareness of the importance of vaccination (Dubé and MacDonald, 2020). For this reason, understanding beliefs, motives, and reasons behind vaccine hesitancy is an important task from both an academic, and a very pragmatic public policy perspective. In this study, we show how individuals differ, among other ways, in their leaning toward a more analytic or intuitive thinking style. We show how this characteristic correlates with vaccine acceptance, where individuals favoring intuitive systems of processing show greater degrees of vaccine hesitancy, independently of sociodemographic characteristics. We additionally underline the importance of understanding different dimensions of perceived risk, especially those involving affective concerns, and show how risk perceptions intervene in the association between thinking styles and vaccine acceptance. Results are important from an academic perspective, underlining the relevance of including individuals' cognitive characteristics and a faceted assessment of risk perceptions in vaccine hesitancy analysis. To improve vaccine acceptance it might therefore be important to adapt communication strategies, developing tailored messages that take into account individual cognitive characteristics and affective concerns. Future research could be addressed at further developing these insights, to elaborate effective strategies to improve vaccine acceptance.

Credit author statement

Mauro Martinelli: Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. Giuseppe A. Veltri: Conceptualization, Methodology, Supervision, Resources, Funding acquisition.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2021.114403.

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