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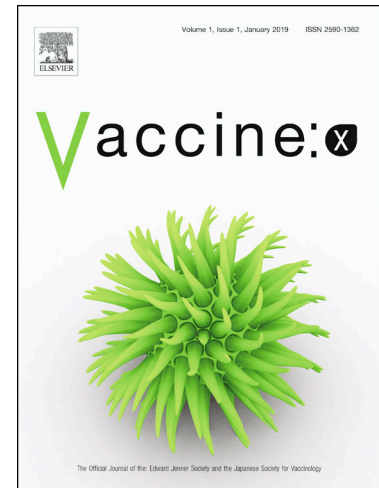
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Vaccine Hesitancy and Cognitive Biases: Evidence for tailored communication with parents

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Abstract

Background: Vaccine hesitancy (VH) remains worldwide a reason of concern. Most of the vaccination education strategies followed a "fact-based" approach, based on the assumption that decision making is a rational process, without considering the influence of cognitive biases and heuristics. Our study aimed at identifying factors involved in the parents' vaccination choice to inform and shape communication interventions.

Methods: We conducted an online national survey among parents between November 2020 and April 2021. The questionnaire consisted of 42 items organised in 4 parts: 1) personal information, 2) cognitive biases and risk propension, 3) Analytic Thinking (Cognitive Reflection Test), 4) conspiracy mentality, health literacy, and VH. Exploratory factor analysis was conducted to identify latent variables underlying the 19 items related to the 6 cognitive biases. Factors were categorised in quintiles and the corresponding pseudo-continuous variables used as predictors of the VH. Logistic regression model was applied to assess the association of the VH with factors, conspiracy mentality and risk propension. We adjusted for age, gender, economic status, and education levels.

Results: The study included 939 parents, 764 women (81.4%), 69.8% had a degree or higher level of education. Considering cognitive biases, four factors explaining 54% of the total variance were identified and characterised as: fear of the side effects of vaccines (scepticism factor); carelessness of the risk and consequences of infections (denial factor); optimistic attitude (optimistic bias factor); preference for natural products (naturalness bias factor). All factors were positively associated to VH ($p < 0.001$) as were conspiracy mentality ($p = 0.007$) and risk propension ($p = 0.002$).

Conclusions: This study confirmed the need to amplify the model used to analyse the VH considering cognitive biases as important factor affecting the parents' decision making. These results may be useful to design personalised communication interventions regarding vaccines and vaccination.

Keywords:

Decision making, vaccine hesitancy, cognitive bias, communication

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1. Background

Notwithstanding vaccination is one of the most successful and cost-effective public health interventions, reduced vaccine acceptance can jeopardize immunization programmes. Vaccine hesitancy (VH), defined as the “delay in acceptance or refusal of vaccination despite availability of vaccination services”¹, has been worldwide increasing over the time, and was included among the ten threats to global health by the World Health Organization (WHO) in 2019. This phenomenon affected seriously Italy, where vaccination coverage (VC) constantly decreased from 2012 to 2017 for all vaccines at all age-groups. Such decline triggered the introduction of mandatory vaccination for ten paediatric diseases in 2017, thus reverting the trend of VC that raised beyond 90% in 2019 at national level². However, national trends may conceal pockets of sub-optimal coverage persisting in certain geographical areas or among vulnerable population groups.

The impact of COVID-19 on paediatric routine immunization has not yet been completely assessed, but globally it was estimated a reduction of 7.7% for third-dose diphtheria-tetanus-pertussis vaccine and 7.9% for first-dose measles-containing vaccine compared to the expected doses delivered³; hence, the design of a catch-up strategy may be necessary. Vaccination services in Italy had to undergo a major reduction or interruption, especially during the first phase of the pandemic. According to a survey carried out by the Italian Ministry of Health in May 2020⁴, a reduction in the number of vaccines administered was observed on the national territory, especially among children above 1 year of age, adolescents, and adults. The main reasons reported were parents' concern about overloading the health care system and exposing themselves and their children to the risk of SARS-Cov-2 infection⁵. Similarly, in the UK, a 20% drop in measles, mumps, and rubella (MPR) vaccination was observed during the first weeks of the lockdown. According to the Centers for Disease Control and Prevention (CDC), a substantial decrease in administered vaccine doses was reported from March to May 2020 and was followed by an increase in the period June – September 2020, yet not sufficient to achieve catch-up coverage, compared with historical data⁶. Moreover, the pandemic and the COVID-19 vaccination campaigns may have impaired VH and consequently VC of childhood routine vaccinations⁷. In addition, VH may severely affect people's compliance to COVID-19 vaccination program, particularly in children.

To understand and respond to the challenges of VH, several models were proposed. A well-established one is the expanded 5C model⁸, in which the multiple factors known to affect VH were summarized in five main determinants: complacency (not perceiving diseases as high risk), convenience (how a vaccine is accessible and affordable), confidence (trust in the effectiveness and safety of vaccines and in the system that delivers them), constraints (structural and psychological barriers), and calculation (engagement in extensive information searching); aspects pertaining to collective responsibility (willingness to protect others) were also included.

Beyond this model, additional studies have investigated how parents decide whether to vaccinate their children and which cognitive processes are involved. Some theories used to explain the vaccine decision, such as the “Health Belief Model and Sick Role Behavior”⁹, “Protection Motivation Theory”¹⁰, and the “Theory of Planned Behavior” and the “Theory of Reasoned Action”¹¹, assume that decision making is a composite, but unique process based on individual rational capability. On the same assumption, it is based the vision of the decision-maker in the classic economics theory that recently undergo a substantial revision that influence largely behavioural disciplines¹² and medical sciences¹³. A current and more realistic evidence suggested the presence of different systems of thoughts, with different features, which are involved in the human decisions and also in vaccination choice¹⁴: the first one is intuitive, automatic, and requiring less time and mental capacity; the second one is slow, deliberative, and is implicated in complex decisions¹⁵. The first system produces

strategies adapted to the environment, mental shortcuts, called heuristics, and is affected by internal and contextual factors, such as emotions, habits, and social influences. The heuristics are often useful to take fast decisions based on limited information but can lead to systematic errors, called bias. Cognitive biases and heuristics explain how human decision-making is not completely rational. The behavioural economics overcomes the vision of classic economics considering the individual as an actor characterised by this bounded rationality¹⁶, with limited information, time, and capacity, and influenced by cognitive, affective, and social factors.

The bounded rationality approach may be useful to also understand vaccine decision-making and to give some insights to influence parents' behaviour and to shape effective interventions to promote vaccination¹⁷. Previous studies have underlined the relation between some cognitive biases and heuristics and VH; as an example, Ritov and Baron¹⁸ observed that the parents preferred the omission of the act (not to vaccinate) than the commission (to vaccinate) in a situation of risk (the probability that the child should have an adverse effect), even when the risk correlated to the inaction (the probability of a severe illness for the child) is higher. In another study, the focus was on the relationship between vaccine intention, confirmation bias, and risk perception. Nonetheless, only a few studies have tried to investigate the cognitive biases and heuristics not singularly but in associations, in the attempt to understand the cognitive style of the individual¹⁹.

Besides to the cognitive processes, other factors are correlated with the VH, such as Health Literacy (HL), defined as "the degree to which individuals can obtain, process, and understand basic health information and services needed to make appropriate health decisions"²⁰. Some studies have shown an association of limited HL with reduced adoption of protective behaviours such as immunization²¹. Nevertheless, the relationship between HL and VH remains unclear, and it seems to be influenced by some key factors, such as country, age, and type of vaccine²².

Another factor correlated with VH is the belief in conspiracy theories. Conspiracy beliefs in fact can impact health decisions, such as HIV treatment adherence, condom use, and embracing alternative medicines²³. In many studies, vaccine-related conspiracy theories were associated with a decreased intention to get vaccinated or to vaccinate their children²⁴.

This study aimed to assess the constellation of cognitive biases in relation to VH and provide a reframing of these factors in order to support the design and tailoring of communication interventions during vaccination counselling and doctor-patient's interactions. We then assessed the relationship between the VH and other factors known as relevant in literature, such as the conspiracy belief.

2. Methods

2.1 Study design and sample

A national cross-sectional online survey was conducted between November 2020 and April 2021 among Italian parents. The inclusion criteria to participate in the study were: to be older than 18 years; to have one or more children; to be fluent in Italian. The questionnaire was disseminated through online platforms, like Instagram and Facebook groups dedicated to parenting, schooling, paediatric health or related to children vaccination. Associations of parents of different orientations (i.e. catholic/religious, parents of LGBTQIA+ young people) and associations that promote vaccination and active citizenship, such as *IoVaccino*, the platform *VaccinarSi* of the *Italian Society of Hygiene and Preventive Medicine*, and *CittadinanzAttiva*, were also involved in the dissemination. Italian scientific

societies of paediatricians have been contacted in order to boost the dissemination through their journals and networks.

The responses were collected using a survey on Microsoft Forms[®]. The survey included a detailed explanation regarding the purpose and the non-compulsory nature of the study and clarified that respondents' anonymity would be guaranteed.

2.2 Survey instrument

The development of the questionnaire was informed by a narrative synthesis of existing literature on vaccine hesitancy and cognitive biases. Three studies, in particular, served to establish the reference background of the instrument and the categorisation of biases: the study by Dubov & Phung (2015)²⁵, which described how cognitive biases are particularly relevant in the context of decisions about the flu vaccination and how nudges instead of mandates can be used to overcome these biases; the editorial by Poland & Poland (2011)²⁶, which highlighted the importance of evaluating current vaccine promotion and messaging efforts in order to tailor them to each cognitive style to increase individual awareness, knowledge, and behaviour in terms of vaccine acceptance; and the study by Ceschi et al (2019)²⁷, which provides a descriptive classification of a variety of heuristics and biases and clusters them on the basis of their underlying relationships.

The questionnaire consisted of four parts:

I) *personal information*: after acquiring informed consent, the first part of the questionnaire was focused on gathering parents' personal information (age, gender, educational and socio-economic level).

II) *factors involved in the decision-making linked to vaccine acceptance*: the second part explored the main cognitive biases involved in the decision-making related to childhood vaccination. The participants were asked to answer 25 questions, formulated in a 5-point Likert scale (2 levels of agreement, 1 neutral choice, 2 levels of disagreement), regarding the decision to vaccinate their children. The selection of the cognitive biases was based on the existing literature. In Dubov & Phung²⁵, the following biases were identified: the *omission bias* (the tendency to prefer potentially harmful inaction to a potentially less harmful act); the *ambiguity aversion* (the tendency to prefer a known risk to an unknown risk); the *availability bias* (the tendency to judge the occurrence of side effects as likely or frequent if it is easy to imagine or recall), the *optimism bias* (the tendency to be more optimistic about a particular health risk, believing it is greater for other people than for themselves) and the *naturalness bias* (the tendency to prefer natural products or substances even when they are identical or worse than synthetic alternatives). Another bias found to be involved in the decision of whether to accept the vaccination is the *confirmation bias*. Besides, the *bandwagon effect* and the *risk propension* were included in the questionnaire as complementary elements. For each factor, a further literature search was performed to elaborate the corresponding Likert-scale items as detailed in table 1. The items were adapted to the vaccination in paediatric age, except those related to the risk propension, that was evaluated through a validated scale²⁸.

III) *analytical thinking*: in the third part, the ability of analytical thinking was assessed through three open questions, where only one answer was correct. The questions were derived from the Italian adaptation of the *cognitive reflection test*²⁹ (CRT). The answers have been classified as correct, *heuristic* (mental shortcuts based on intuitive thinking used in the decision-making), or atypical (none of the above). A single score has been calculated as the sum of the correct answers.

IV) *conspiracy mentality, health literacy, and vaccine hesitancy*: The *conspiracy mentality* and the level of *health literacy* were evaluated through two validated questionnaires: the *Conspiracy Mentality Questionnaire*³⁰, composed of ten items on a 10-point Likert scale, and the Italian version of the three-item *Brief Health Literacy Screener*³¹, on a 5-point Likert scale. The VH was measured through a questionnaire composed of six items on a 10-point Likert scale, created by Arzilli et al. (2018)³². Three questions were phrased positively (L1, L2, L3) and three negatively (L4, L5, L6). To create the score the answers to the three positive questions were inverted, and then all the answers were summed; higher scores corresponded to higher vaccine hesitancy and lower acceptance.

Prior to the analysis, the score of the following items was inverted: *omission bias 3-4, optimistic bias 1-4, confirmation bias 3-4, bandwagon 1, health literacy 3, VH 1, 2, and 5*. The following variables were obtained as sums of the original variables: VH (sum of six items), conspiracy mentality (sum of four items), risk propensity (sum of four items), health literacy (sum of three items), CRT (number of correct answers to the three questions). VH was then dichotomised into "low" and "high" according to the median. The full questionnaire is available in Annex 1.

Question n°	Domain	Reference
6	Availability bias	Khan HH, Naz I, Qureshi F, Ghafoor AJBIR. Heuristics and stock buying decision: Evidence from Malaysian and Pakistani stock markets. ³³
7 - 10	Omission bias	Wroe AL, Turner N, Salkovskis PMJHP. Understanding and predicting parental decisions about early childhood immunizations. ³⁴

11 - 14	Optimistic bias	Seale H, Heywood AE, McLaws M-L, et al. Why do I need it? I am not at risk! Public perceptions towards the pandemic (H1N1) 2009 vaccine. ³⁵
15 - 18	Confirmation bias	Jiménez ÁV, Mesoudi A, Tehrani JJJPo. No evidence that omission and confirmation biases affect the perception and recall of vaccine-related information. ³⁶
19 – 21	Ambiguity bias	Asch DA, Baron J, Hershey JC, et al. ³⁷ .
22 - 24	Naturalness bias	Dibonaventura MD, Chapman GBJMDM. Do decision biases predict bad decisions? Omission bias, naturalness bias, and influenza vaccination.
25, 26	Bandwagon effect	Jacqueline R. Meszaros, David A. Asch, Jonathan Baron, John C. Hershey, Howard Kunreuther, and Joanne Schwartz-Buzaglo, Cognitive Processes and the Decisions of Some Parents to Forego Pertussis Vaccination for Their Children. ³⁸

Table 1. Questions related to availability bias, omission bias, optimistic bias, confirmation bias, ambiguity bias, naturalness bias, and bandwagon effect.

A pilot test involving 20 parents was conducted; the questionnaire was revised according to their suggestions.

The study received the approval of the Bioethics Committee of the University of Pisa.

2.3 Statistical analysis

Numerical variables were described in terms of mean and standard deviation and categorical variables in terms of absolute frequency and percentage. For each variable, a univariable logistic regression model was fitted to assess its association with the VH.

We performed an exploratory factor analysis (EFA) on the cognitive bias items (availability, omission, optimistic, confirmation, ambiguity, and naturalness bias). The number of factors was chosen according to Kaiser's criterion. Logistic regression models were used to analyse the association of VH with the individual factors categorised into quintiles; for each factor, the linear trend was tested using the corresponding pseudo-continuous variable and adjusting for the possible confounders age, gender, income, and educational level.

Finally, the logistic regression model of VH including the selected factors, bandwagon effect items, risk propensity, and conspiracy mentality was fitted, adjusting for possible confounders; CRT and HL were not included in the model due to their associations with the educational level.

To test the robustness of the results in relation to age, a sensitivity analysis was carried out by including in the analysis only fathers under 44 years of age and mothers under 40 years of age. These cut-offs were decided on the basis of the median age at first childbirth in Italy for women and men. Data analyses were carried out using the software R, version 4.1.1. [R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: [https://www.R-project.org/.](https://www.R-project.org/)]

3 Results

A total of 938 parents answered the survey, mostly women (82.0%). The median age was 41 years (interquartile range (IQR) 37-47).

The level of VH in our study sample was low (high vaccine acceptance), with a median of 9 (IQR 6 – 16, range 6 - 60).

The characteristics of the sample, overall and by vaccine hesitancy, dichotomised according to the median, are presented in Table 2.

Table 2. Socio-demographic characteristics of the parents and items' scores, overall and by vaccine hesitancy.

*Wald test from the univariable logistic regression model of the vaccine hesitancy as a function of the variable in the table.

†Mean (standard deviation).

Higher VH was associated with lower levels of education, income, CRT, and HL, and with higher scores in biases items, bandwagon effect items, risk propensity, and conspiracy mentality.

The Pearson linear correlation coefficients between the variables of each bias, bandwagon effect items, risk propensity, conspiracy mentality, CRT, and HL are represented in figure 1.

Figure 1. Plot of the linear correlations between the predictors. The correlations are represented both by colour (from red for a correlation of -1 to blue for a correlation of 1, according to the scale on the right) and by the area of the disc (proportional to the absolute value of the correlation).

Performing the EFA (Table 3), four latent factors were selected from the items used to investigate the cognitive biases, explaining 53.2% of the total variance.

Table 3. Loadings of the first four factors from the exploratory factor analysis. Only values > 0.40 are reported.

Factor 1 (explaining 15.7% of the variance) was characterised by the fear of side effects of the drugs (*omission bias 1-2*), and by an overestimation of the information against vaccines (*confirmation bias 1-2*) and of their side effects (*ambiguity bias 2-3*). We refer to this factor as “*scepticism*”. Factor 2 (of “*denialism*”, 14.5% of variance explained) was characterised by a disregard for the risks of non-vaccination (*omission bias 3-4*) and body of the evidence on vaccines safety and effectiveness (*confirmation bias 3-4*), and the overestimation of the risk of vaccines’ side effects (*availability bias*). Factor 3 (of “*optimism*”, 13.4% of variance explained) was associated with disregard for the risk of infection and the consequences of the potential infections resulting from non-vaccination (*optimistic bias 1-4*). Factor 4 (of “*naturalness*”, 9.6% of variance explained) was characterised by a preference for vaccines with natural components (*naturalness bias 1 and 3*) and the overestimation of the information against vaccines obtained from peers (*confirmation bias 2*).

In the multiple logistic regression analysis, VH was positively associated with the four latent factors, (all p 's < 0.001) risk propensity ($p < 0.001$), and conspiracy mentality ($p = 0.01$), while it was not significantly with either of the bandwagon effect items. The multiple logistic regression model restricted to fathers under 44 years of age and mothers under 40 years of age did not show any substantial variation from what was observed in all subjects (data not shown).

4. Discussion

Our study confirmed the importance of the role of cognitive biases and heuristics in understanding the VH. Differently from previous studies in which only a single or few biases were analysed, we investigated an array of cognitive biases and heuristics reported in the literature to be involved in vaccine’s decision making.

After this phase, for each bias/heuristic we developed a number of corresponding items adapted to paediatric vaccination. The resulting model proposed a categorization and reframing of cognitive biases and heuristics affecting decision making about paediatric vaccination in a population of Italian parents.

All biases selected through the literature review were confirmed to be associated with the VH in our sample. Through the EFA, from the items we used to investigate the cognitive biases, four latent factors emerged, depicting four different individual profiles. The factors combined underpinning

elements that influence decision processes in a similar way. The factors correlated with the vaccine intention, underlining their role in the decision making.

The resulting profiles allowed a reframing of initial bias categories and were consistent with findings reported in literature. Factor 1 "*scepticism*" explained the tendency, which has been growing in recent years, to fear more the adverse effects of the vaccine rather than the effects of vaccine-preventable diseases, as well described in the study of Poland as a "*fear-based profile*"²⁶. On the opposite side, the underestimation of the risk to acquire the disease or to develop a severe form was described in factor 3 defined "*optimism*". This attitude was also observed in a study about H1N1 vaccine during the pandemic in 2009³⁵, while in a recent study related to COVID-19 vaccine, no correlation was found between optimistic bias and vaccination intent³⁹. Consistently with our finding, other studies demonstrated the positive correlation between higher perception of risk related to the disease and the intention to vaccinate⁴⁰. The general distrust in vaccine data, neglecting the information about their safety and effectiveness, along with the under-estimation of disease-related risk and the overestimation of risks due to side effects of the vaccine, was identified by factor 2, which we called "*denial*", in line with the profile described by Poland et al²⁶. The last factor, "*naturalness*", largely related to the preference for vaccines containing natural components. The relationship between the use of alternative medications such as homeopathy or naturopathy and the VH, is well known in the literature⁴¹.

Most of the previous studies explored the impact of bias on vaccine decision making for vaccines offered to adults' individuals, and often to single vaccines, e.g. flu vaccine²⁵. Our study, contributed to expand the body of evidence on the relevance of cognitive biases for paediatric vaccines, without focusing on any specific disease.

An unexpected finding was the absence of correlation between cognitive biases and a higher score of CRT, as described in previous studies⁴². This may partially be explained considering the adaptation of the items to explicitly investigate biases for the paediatric vaccination. It is likely that specific distortion of decision processes for paediatric vaccines are not linked with the habitual reflection attitude of the parents.

In line with the literature, we also found a correlation of VH with the conspiracy belief and the risk propensity. In a study conducted in London⁴³ it emerged that parents distrusted the Government and believed that it could be leveraged by pharmaceutical companies or other economic interests. In another study in Croatia investigating the cognitive processes underlying vaccine-hesitant parents' decision-making, the vaccine conspiracy belief was found to be associated with VH⁴⁴.

The role of the risk perception and risk acceptance in influencing vaccine attitudes have been often investigated in research. According to available evidence, the essence of the individual vaccination choice is the result of balancing the risk perception of the disease and the adverse effects of the vaccine itself⁴⁵. In a study conducted in Germany on the flu vaccine, the authors found that in men a higher risk aversion was correlated with a higher intention to vaccinate⁴⁶. However, less is known on the effect of risk propensity on vaccination choices.

Only limited evidence was available on the role of the bandwagon effect. However, differently from what was described²⁶, in our study the two items assessing the band-wagon effect did not correlate with the VH in the multiple regression logistic analysis. Further studies may be needed to understand the relation between this specific bias and the VH.

Our study may provide a useful tool to identify the parents' profile, based on our categorization, providing insight about their decision processes concerning vaccination. Further studies should be

needed also to investigate the transferability of this instrument and this approach in other contexts, other age groups (e.g. vaccination in the adolescents or the elderly), and for COVID-19 vaccination, including for the children. Besides, it may be interesting to use this instrument to investigate and segment other behaviours, such as to connect parental experience on vaccination and the interpretation of following events with a specific profile⁴⁷, or to better understand the parents' seeking strategies to explore vaccination topics⁴⁸.

However, the most prominent application of our profile segmentation is to develop a person-centred and tailored communication approach. As described by Shah and Hagell¹⁷, the knowledge of the cognitive bias and heuristics can help paediatricians in orienting and supporting the parents' decision by framing the consultation or building reminders messages based on the profile

Our study presents some limitations. First, our results may be affected by selection bias; even though we tried to include parents with different opinions and attitudes towards vaccines, contacting by email or Facebook associations and groups with different backgrounds, we reached mostly parents with positive attitudes and perceptions, thanks to the collaboration of pro-vax associations via Instagram and Facebook pages. However, the percentage of parents with high VH (around 1%) is in line with the most recent national estimates. On the other side, our sample cannot be considered fully representative of the Italian population since most of the respondents (68.8%) had a university degree or higher, whereas in the general population only 16% had this level of education⁴⁹. In addition, our sample was formed mostly by women (81%). This finding can be explained by the role of Italian mothers in childcare, being mostly in charge of vaccination decisions. Another factor to consider is the different response rates for gender and educational level: some studies demonstrated that women and people with higher education level are more likely to respond to surveys⁵⁰.

Another limitation was the methodological approach to dichotomize the VH to perform the analysis. This choice in the analysis may limit the transferability and reproducibility of the results of the study. In fact, several published studies assessed the VH as a spectrum ranging from hesitant parents to acceptant ones, including parents that accept the vaccination with doubts and those who delay the vaccinations.

In conclusion, our study confirmed the need to amplify the model used to analyse the VH considering cognitive biases as an important factor affecting the parents' decision making. Our results may be useful to create new and more efficient tools to assess parents' decisions processes, to understand the communication needs of the parents and to support the physicians in designing personalised communication interventions regarding vaccines and vaccination.

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All authors attest they meet the ICMJE criteria for authorship.

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Highlights:

- The model to analyse vaccine hesitancy should include the evaluation of cognitive biases
- Communication interventions should be tailored based on the drivers of parents' choice
- Conspiracy mentality and risk propension correlate with the vaccine hesitancy

Vaccine Hesitancy and Cognitive Biases: Evidence for tailored communication with parents

Abstract

Background: Vaccine hesitancy (VH) remains worldwide a reason of concern. Most of the vaccination education strategies followed a "fact-based" approach, based on the assumption that decision making is a rational process, without considering the influence of cognitive biases and heuristics. Our study

aimed at identifying factors involved in the parents' vaccination choice to inform and shape communication interventions.

Methods: We conducted an online national survey among parents between November 2020 and April 2021. The questionnaire consisted of 42 items organised in 4 parts: 1) personal information, 2) cognitive biases and risk propension, 3) Analytic Thinking (Cognitive Reflection Test), 4) conspiracy mentality, health literacy, and VH. Exploratory factor analysis was conducted to identify latent variables underlying the 19 items related to the 6 cognitive biases. Factors were categorised in quintiles and the corresponding pseudo-continuous variables used as predictors of the VH. Logistic regression model was applied to assess the association of the VH with factors, conspiracy mentality and risk propension. We adjusted for age, gender, economic status, and education levels.

Results: The study included 939 parents, 764 women (81.4%), 69.8% had a degree or higher level of education. Considering cognitive biases, four factors explaining 54% of the total variance were identified and characterised as: fear of the side effects of vaccines (scepticism factor); carelessness of the risk and consequences of infections (denial factor); optimistic attitude (optimistic bias factor); preference for natural products (naturalness bias factor). All factors were positively associated to VH ($p < 0.001$) as were conspiracy mentality ($p = 0.007$) and risk propension ($p = 0.002$).

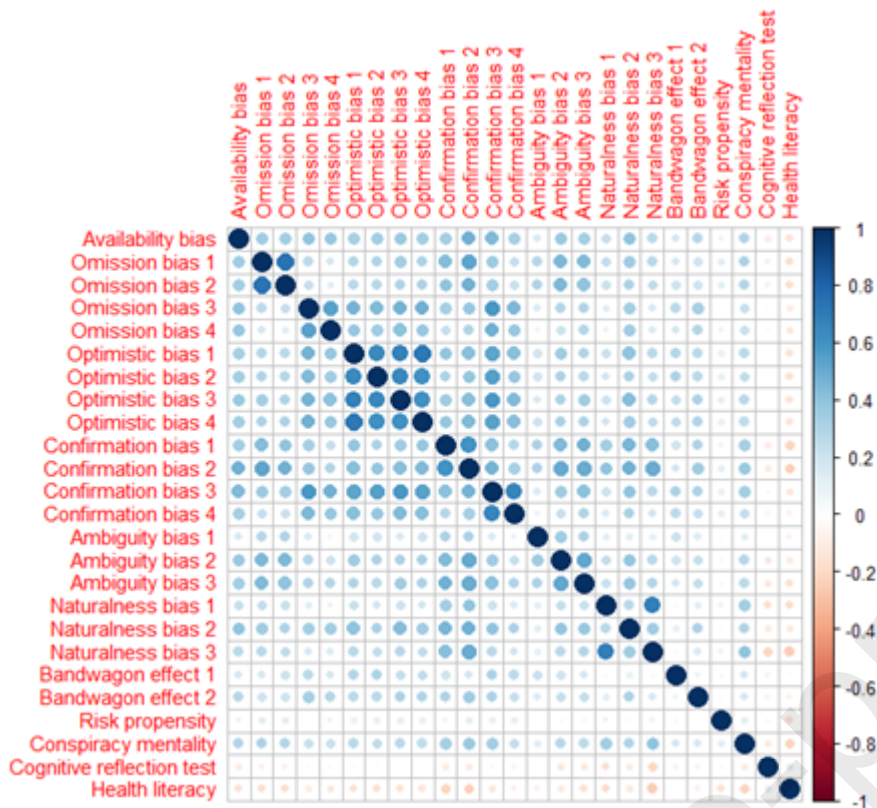
Conclusions: This study confirmed the need to amplify the model used to analyse the VH considering cognitive biases as important factor affecting the parents' decision making. These results may be useful to design personalised communication interventions regarding vaccines and vaccination.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Question n°	Domain	Reference
6	Availability bias	Khan HH, Naz I, Qureshi F, Ghafoor AJBIR. Heuristics and stock buying decision: Evidence from Malaysian and Pakistani stock markets. ³³
7 - 10	Omission bias	Wroe AL, Turner N, Salkovskis PMJHP. Understanding and predicting parental decisions about early childhood immunizations. ³⁴

11 - 14	Optimistic bias	Seale H, Heywood AE, McLaws M-L, et al. Why do I need it? I am not at risk! Public perceptions towards the pandemic (H1N1) 2009 vaccine. ³⁵
15 - 18	Confirmation bias	Jiménez ÁV, Mesoudi A, Tehrani JJJPo. No evidence that omission and confirmation biases affect the perception and recall of vaccine-related information. ³⁶
19 – 21	Ambiguity bias	Asch DA, Baron J, Hershey JC, et al. ³⁷ .
22 - 24	Naturalness bias	Dibonaventura MD, Chapman GBJMDM. Do decision biases predict bad decisions? Omission bias, naturalness bias, and influenza vaccination.

25, 26	Bandwagon effect	Jacqueline R. Meszaros, David A. Asch, Jonathan Baron, John C. Hershey, Howard Kunreuther, and Joanne Schwartz-Buzaglo, Cognitive Processes and the Decisions of Some Parents to Forego Pertussis Vaccination for Their Children. ³⁸
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	Total (N=938) N (%)	Vaccine hesitancy		P-value*
		Low (N=487) N (%)	High (N=451) N (%)	
<i>Gender</i>				0.45
Female	764 (82.0)	394 (81.1)	370 (83.0)	
Male	168 (18.0)	92 (18.9)	76 (17.0)	
<i>Age (years)†</i>	42.7 (8.2)	42.8 (8.3)	42.5 (8.1)	0.64
<i>Educational level</i>				<0.001
Non-graduate	293 (31.2)	119 (24.4)	174 (38.6)	
Graduate	383 (40.8)	199 (40.9)	184 (40.8)	
Post-graduate	262 (27.9)	169 (34.7)	93 (20.6)	
<i>Income</i>				0.003
<36,152€	535 (58.3)	257 (54.0)	278 (63.0)	
36,152-70,000€	289 (31.5)	161 (33.8)	128 (29.0)	
>70,000€	93 (10.1)	58 (12.2)	35 (7.9)	
<i>Number of children</i>				0.49
1	402 (42.9)	210 (43.1)	192 (42.6)	
2	446 (47.5)	236 (48.5)	210 (46.6)	
≥3	90 (9.6)	41 (8.4)	49 (10.9)	
<i>Availability bias†</i>	1.5 (0.8)	1.2 (0.5)	1.8 (0.9)	<0.001
<i>Omission bias 1†</i>	2.7 (1.3)	2.2 (1.2)	3.2 (1.2)	<0.001
<i>Omission bias 2†</i>	2.8 (1.3)	2.4 (1.2)	3.3 (1.3)	<0.001
<i>Omission bias 3†</i>	1.2 (0.7)	1.0 (0.3)	1.4 (0.9)	<0.001
<i>Omission bias 4†</i>	1.4 (0.8)	1.1 (0.5)	1.6 (1.0)	<0.001
<i>Optimistic bias 1†</i>	1.8 (1.0)	1.4 (0.8)	2.2 (1.1)	<0.001
<i>Optimistic bias 2†</i>	1.6 (0.9)	1.3 (0.6)	1.9 (1.0)	<0.001
<i>Optimistic bias 3†</i>	1.6 (0.9)	1.3 (0.6)	2.0 (1.1)	<0.001
<i>Optimistic bias 4†</i>	1.7 (1.0)	1.4 (0.7)	2.1 (1.1)	<0.001
<i>Confirmation bias 1†</i>	2.2 (1.2)	1.6 (1.0)	2.7 (1.2)	<0.001
<i>Confirmation bias 2†</i>	1.8 (1.0)	1.3 (0.6)	2.4 (1.1)	<0.001
<i>Confirmation bias 3†</i>	1.5 (0.8)	1.2 (0.5)	1.8 (0.9)	<0.001
<i>Confirmation bias 4†</i>	1.6 (0.9)	1.3 (0.7)	1.9 (0.9)	<0.001
<i>Ambiguity bias 1†</i>	3.4 (1.0)	3.3 (1.0)	3.6 (1.0)	<0.001
<i>Ambiguity bias 2†</i>	2.3 (1.1)	1.9 (1.0)	2.6 (1.1)	<0.001
<i>Ambiguity bias 3†</i>	2.1 (1.1)	1.7 (1.0)	2.5 (1.1)	<0.001
<i>Naturalness bias 1†</i>	2.6 (1.4)	2.1 (1.3)	3.1 (1.4)	<0.001
<i>Naturalness bias 2†</i>	1.4 (0.9)	1.1 (0.6)	1.8 (1.0)	<0.001
<i>Naturalness bias 3†</i>	2.3 (1.4)	1.7 (1.1)	2.9 (1.3)	<0.001
<i>Bandwagon effect 1†</i>	2.9 (1.4)	2.7 (1.4)	3.1 (1.3)	<0.001
<i>Bandwagon effect 2†</i>	1.2 (0.6)	1.1 (0.4)	1.3 (0.7)	<0.001

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<i>Risk propensity†</i>	6.7 (2.3)	6.3 (2.0)	7.1 (2.6)	<0.001
<i>Conspiracy mentality†</i>	18.3 (8.8)	15.3 (7.6)	21.5 (9.0)	<0.001
<i>Cognitive reflection test†</i>	1.5 (1.1)	1.7 (1.1)	1.4 (1.1)	<0.001
<i>Health literacy†</i>	12.5 (2)	13.0 (1.9)	12.0 (2.1)	<0.001

	Factor 1 "Scepticism"	Factor 2 "Denialism"	Factor 3 "Optimism"	Factor 4 "Naturalness"
<i>Availability bias</i>		0.44		
<i>Omission bias 1</i>	0.81			
<i>Omission bias 2</i>	0.81			
<i>Omission bias 3</i>		0.62		
<i>Omission bias 4</i>		0.60		
<i>Optimistic bias 1</i>			0.78	
<i>Optimistic bias 2</i>			0.65	
<i>Optimistic bias 3</i>			0.65	
<i>Optimistic bias 4</i>			0.70	
<i>Confirmation bias 1</i>	0.45			
<i>Confirmation bias 2</i>	0.54			0.41
<i>Confirmation bias 3</i>		0.68		
<i>Confirmation bias 4</i>		0.60		
<i>Ambiguity bias 1</i>				
<i>Ambiguity bias 2</i>	0.53			
<i>Ambiguity bias 3</i>	0.48			
<i>Naturalness bias 1</i>				0.74
<i>Naturalness bias 2</i>				
<i>Naturalness bias 3</i>				0.85