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Affective Risk Appraisal and Vaccine Hesitancy: A Structural Equation Model of Fear, Perceived Risk, and Vaccination Experience

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Research Article

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Abstract

Vaccine hesitancy remains a major challenge for immunisation programmes, especially in digital health communication environments where emotionally salient vaccine narratives spread rapidly. Drawing on protection motivation theory, the affect heuristic, and risk perception theory, this study examines whether perceived vaccine risk mediates the association between health-related fear and vaccine hesitancy, and whether this pathway differs by prior vaccination experience. A cross-sectional survey was conducted with 2,204 adults recruited through a demographically quota-balanced online panel between February and June 2024. Confirmatory factor analysis and structural equation modelling were used to assess latent construct validity and estimate direct and indirect associations, with bias-corrected bootstrapping based on 5,000 resamples. The three-factor measurement model showed satisfactory fit, $\chi^2(87) = 124.3$, CFI = .963, TLI = .954, RMSEA = .058, and SRMR = .054. Health-related fear was positively associated with perceived vaccine risk, $\beta = .463$, and vaccine hesitancy, $\beta = .214$. Perceived vaccine risk was also positively associated with hesitancy, $\beta = .371$. The indirect association through perceived risk was significant, $\beta = .174$, accounting for approximately 45% of the total fear–hesitancy association. Stronger indirect associations were observed among participants without prior vaccination experience. Findings suggest that public health communication should address both factual risk information and emotional uncertainty.

Contributions to the Literature

• Vaccine hesitancy research often separates emotions from judgments about vaccine safety; this study connects them within one population-health framework.

• It explains why factual correction alone may be insufficient when fear shapes how people interpret vaccine risks.

• It identifies prior vaccination experience as an important source of variation in the link between fear, risk appraisal, and hesitancy.

• It supports communication strategies that combine clear risk information with emotional reassurance, procedural transparency, and tailored support for vaccine-naive adults.

1. Introduction

1.1 Vaccine Hesitancy in a Digital Health Communication Environment

Vaccination is among the most effective public health technologies for reducing preventable disease burden. The World Health Organization estimates that immunisation prevents approximately 3.5 to 5 million deaths each year from vaccine-preventable diseases [1]. Yet vaccine availability does not ensure vaccine uptake. Many immunisation programmes still face delayed acceptance, selective refusal,

and uncertainty among eligible populations. Vaccine hesitancy, defined as delay in acceptance or refusal of vaccination despite the availability of vaccination services, remains a major challenge for public health systems [2].

This challenge is increasingly shaped by digital health communication. Vaccine information is no longer received only through clinicians, public health agencies, or traditional media. It also circulates through platform algorithms, peer sharing, comment threads, search visibility, and emotionally charged narratives. Users encounter vaccine-related content as ranked, repeated, and socially endorsed signals rather than neutral evidence. Psychological research has identified confidence, complacency, constraints, calculation, and collective responsibility as important antecedents of vaccination behaviour [3]. The 5C framework further specifies how confidence, risk calculation, and collective responsibility shape vaccine attitudes [4]. Global evidence also shows that vaccine confidence and perceived barriers vary substantially across populations [5]. Cross-national COVID-19 evidence confirms that acceptance is shaped by trust, perceived safety, and institutional context [6]. However, information-based explanations remain incomplete. The COVID-19 social media infodemic illustrates how health information and misinformation circulate differently across online platforms [7]. Experimental evidence shows that exposure to online vaccine misinformation can reduce vaccination intention [8]. Review evidence further links social media environments to vaccine hesitancy across contexts [9]. Vaccine hesitancy therefore needs to be examined as an outcome of information exposure, affective response, and subjective risk appraisal.

1.2 Fear as an Affective Risk Signal

Fear is a salient affective component of vaccine decision-making. Risk-as-feelings theory suggests that affective states can shape health judgments under uncertainty [10]. The affect heuristic likewise indicates that negative affect can make a health intervention appear riskier and less beneficial [11]. Protection Motivation Theory suggests that fear may support protective behaviour when threat appraisal is accompanied by strong coping appraisal [12]. Its revised formulation further emphasizes self-efficacy and response efficacy as conditions for adaptive action [13]. The Extended Parallel Process Model explains why fear may instead be associated with avoidance when perceived threat is high and perceived efficacy is weak [14].

In vaccination contexts, fear is often directed not only toward disease but also toward the vaccine itself. Injection-related fear has been empirically linked to COVID-19 vaccine hesitancy [15]. Broader psychological profiles of vaccine hesitancy also include distrust, threat sensitivity, and resistance-related beliefs [16]. In digital settings, such fears can become highly visible through adverse-event stories, personal testimony, visual content, and repeated negative messages. These signals may make rare or uncertain outcomes feel more immediate and personally relevant. Fear should therefore not be treated only as a background emotion. It may operate as an affective risk signal that shapes how vaccine information is weighted and interpreted.

1.3 Risk Perception as an Affective–Cognitive Pathway

Risk perception provides a theoretical link between fear and vaccine hesitancy. The social amplification of risk framework explains how risk signals are intensified or attenuated through institutions, media systems, and interpersonal networks [17]. Risk perception theory also shows that people evaluate hazards through familiarity, dread, controllability, trust, and personal experience rather than objective probability alone [18]. The affect heuristic further suggests that emotional states can act as rapid evaluative cues: when people feel fear toward a health intervention, that intervention may be judged as more dangerous, less controllable, and less beneficial [11].

In vaccine decision-making, perceived vaccine risk is therefore more than knowledge of side-effect probability. It is a subjective appraisal formed through emotion, communication exposure, prior experience, and institutional trust. Existing vaccine hesitancy studies often examine fear, risk perception, trust, and misinformation exposure as separate predictors. This identifies correlates but does not fully explain how affect becomes linked to hesitancy. A more precise mechanism model should test whether fear is associated with vaccine hesitancy partly through perceived vaccine risk. This pathway is also relevant to digital health communication, where risk cues may be intensified by repeated exposure, algorithmic visibility, and emotionally salient narratives.

Prior vaccination experience may further shape this pathway. Individuals with previous vaccination experience may have direct evidence of vaccine tolerability, which can reduce reliance on imagined risk or second-hand narratives. Vaccine-naive individuals may depend more heavily on indirect information from social media, news stories, peer testimony, or adverse-event narratives. Prior vaccination experience may therefore indicate heterogeneity in the fear–risk perception–hesitancy pathway. Given the cross-sectional design of the present study, this heterogeneity is interpreted as subgroup variation rather than causal moderation.

1.4 Research Gaps, Objectives, and Contributions

Three gaps remain in the current literature. First, affective variables are often treated as peripheral correlates in vaccine hesitancy research rather than components of a theoretically specified appraisal structure. Second, fear and risk perception are frequently examined as parallel predictors, although affect heuristic theory suggests that emotional states may shape subjective risk appraisal. Third, digital health communication studies have documented misinformation exposure and online diffusion patterns, but fewer studies connect these communication environments to individual-level affective–cognitive processes using validated latent constructs and structural modelling.

The present study develops and tests a theoretically specified affective–cognitive appraisal model of vaccine hesitancy. Specifically, the study examines whether health-related fear is positively associated with vaccine hesitancy, whether perceived vaccine risk forms an indirect association between fear and hesitancy, and whether this indirect association differs across prior vaccination-experience groups. A cross-sectional survey of 2,204 adults was analysed using confirmatory factor analysis and structural equation modelling. Bias-corrected bootstrapping was applied to estimate indirect associations. Robustness checks included alternative estimators, common-method-bias diagnostics, and alternative

outcome specifications. Because the data are cross-sectional, the findings are interpreted as evidence consistent with a theoretically specified correlational pathway rather than causal mediation.

This study contributes to the literature in three ways. First, it integrates protection motivation theory, affect heuristic theory, and risk perception theory into a unified affective–cognitive appraisal framework. Second, it models perceived vaccine risk as a latent indirect pathway linking health-related fear to vaccine hesitancy rather than treating fear and risk perception as unrelated predictors. Third, it incorporates prior vaccination experience as a source of subgroup heterogeneity within the appraisal structure. The study therefore extends vaccine hesitancy research beyond information-deficit explanations toward a communication-sensitive model of emotional risk appraisal and subjective vaccine judgement.

2. Theoretical Background and Hypotheses

2.1 Fear in Health Decision-Making

Fear is a discrete negative emotion activated by perceived threat, uncertainty, or possible harm. Risk-as-feelings theory treats fear as an affective response that can enter judgement before deliberate probability calculation [10]. The affect heuristic similarly explains why a feared object may be judged as more risky even when statistical evidence is available [11]. Compared with general concern, fear is more immediate. It narrows attention, increases sensitivity to threat cues, and may encourage avoidance when individuals feel unable to control the risk source.

Protection Motivation Theory provides the first theoretical basis for this relationship. PMT distinguishes between threat appraisal, which concerns perceived severity and susceptibility, and coping appraisal, which concerns perceived response efficacy [12]. The revised PMT framework further highlights self-efficacy as a central condition for adaptive response [13]. Fear does not necessarily reduce protective behaviour. When efficacy beliefs are strong, fear may support action. When perceived control is weak, fear may be associated with defensive avoidance. The Extended Parallel Process Model makes a similar distinction between danger control and fear control, explaining why fear appeals may promote adaptive responses under high efficacy but message rejection under low efficacy [14].

In vaccination contexts, fear is often directed toward the vaccine itself. Individuals may fear injection, adverse reactions, unknown long-term effects, rapid development, vaccine ingredients, or insufficient transparency about safety monitoring. These concerns are especially visible in digital health communication, where personal testimony, adverse-event stories, images, and repeated negative posts can increase the salience of rare or uncertain outcomes. Empirical evidence supports this concern. Injection-related fears have been associated with COVID-19 vaccine hesitancy [15]. Broader psychological characteristics such as distrust and threat sensitivity have also been linked to vaccine hesitancy and resistance [16]. Fear is therefore treated here as an affective risk signal rather than a general emotional background variable. It may shape how vaccine information is selected, weighted, and

remembered. Statistical safety evidence may be discounted, while vivid negative cues may receive greater attention. From a health communication perspective, this process matters because vaccine attitudes are formed through both message content and emotional processing.

H1: Health-related fear is positively associated with vaccine hesitancy.

2.2 Perceived Vaccine Risk as a Cognitive Appraisal Process

Risk perception refers to subjective judgement about the likelihood, severity, controllability, and acceptability of a hazard [18]. In vaccine decisions, perceived risk is not the same as actuarial risk. Individuals rarely evaluate vaccine safety only through statistical probability. They also rely on affect, prior experience, perceived transparency, institutional trust, peer narratives, and media exposure.

The social amplification of risk framework explains why technical risk estimates and public risk responses may diverge. Risk signals are transmitted through media systems, institutions, interpersonal networks, and cultural contexts. During this process, some risks are amplified, while others are attenuated [17]. This framework is highly relevant to vaccine communication. A single adverse-event narrative may become influential when repeatedly shared, visually framed, or interpreted as evidence of institutional failure. Digital platforms can intensify this process through algorithmic visibility, engagement-based ranking, and networked repetition [7].

The affect heuristic offers a complementary explanation. Affect can act as a rapid evaluative cue in judgement and decision-making. When an object evokes negative emotion, people often judge it as riskier and less beneficial [11]. In vaccine contexts, fear may increase the subjective weight assigned to side effects, uncertainty, and distrust. This does not require complete rejection of scientific evidence. Fear may simply shift how risk-benefit information is experienced.

Pandemic and vaccine communication research supports this affective–cognitive link. Dryhurst et al. [19] found that COVID-19 risk perception varied with psychological, social, and experiential factors across ten countries. Featherstone and Zhang [20] showed that vaccine misinformation and refutational messages were associated with negative emotions and vaccination attitudes. Loomba et al. [8] found that exposure to online vaccine misinformation reduced vaccination intent in the UK and USA. These findings suggest that perceived vaccine risk should be understood as a cognitive appraisal shaped by emotion and communication exposure.

H2: Health-related fear is positively associated with perceived vaccine risk.

2.3 The Mediating Role of Risk Perception

If fear is associated with perceived vaccine risk, and perceived vaccine risk is associated with hesitancy, risk perception may form an affective–cognitive pathway between fear and vaccine hesitancy. In this pathway, fear increases sensitivity to threat cues. Perceived risk translates this sensitivity into a more

explicit judgement about vaccine danger, uncertainty, or acceptability. Hesitancy reflects reluctance, delay, or refusal under this subjective risk appraisal.

This pathway helps address a limitation of information-deficit explanations. Vaccine hesitancy is often treated as a lack of knowledge or exposure to inaccurate information. Psychological intervention research shows that vaccination behaviour depends on confidence, perceived risk, and practical barriers rather than knowledge alone [3]. The 5C framework similarly indicates that hesitation reflects multiple psychological antecedents, not only factual misunderstanding [4]. Evidence on online vaccine misinformation further shows that affectively salient false claims can reduce vaccination intention even when corrective information is available [8]. A person may understand that severe adverse events are statistically rare, while still perceiving vaccination as personally unsafe. Risk perception offers a theoretical bridge between emotional response and vaccine attitude.

A mediation framework is appropriate for this study because fear, perceived vaccine risk, and vaccine hesitancy are latent psychological constructs measured through multiple items. Structural equation modelling can estimate direct and indirect associations while accounting for measurement error. This allows the model to separate the direct association between fear and hesitancy from the indirect association operating through perceived risk. It also aligns with the technical requirement of high-quality health communication research: the mechanism should be tested through validated constructs rather than isolated single indicators.

The model does not assume full mediation. Health-related fear may also be associated with vaccine hesitancy through processes not fully captured by perceived vaccine risk, including affective avoidance, distrust of medical authorities, identity-linked resistance, prior negative healthcare experience, or discomfort with vaccination procedures. Partial mediation is therefore theoretically plausible, with perceived vaccine risk expected to explain a meaningful, but not exhaustive, portion of the fear–hesitancy association.

H3: Perceived vaccine risk is expected to form a significant indirect association between health-related fear and vaccine hesitancy.

This association is interpreted as correlationally consistent with a mediating role rather than evidence of causal mediation in cross-sectional data.

2.4 Prior Vaccination Experience and Pathway Heterogeneity

Prior vaccination experience may affect how individuals process fear and vaccine risk. Individuals who have previously received vaccines without severe adverse outcomes may have direct evidence of vaccine tolerability. This experience can reduce dependence on imagined risks, online narratives, or second-hand accounts. It may also strengthen perceived response efficacy and control, which are central to PMT.

Individuals without prior vaccination experience may rely more heavily on mediated information. Their risk appraisal may be more sensitive to adverse-event narratives, peer testimony, misinformation exposure, and uncertainty about safety. For this group, fear may carry greater weight in perceived vaccine risk. This possibility has practical relevance. Vaccine-naive individuals may require communication strategies that combine factual risk correction with procedural explanation, clinician-led reassurance, uncertainty reduction, and experience-based confidence building.

Given the cross-sectional design, this study treats prior vaccination experience as a source of subgroup heterogeneity rather than definitive causal moderation. The analysis examines whether the indirect pathway from fear to hesitancy through perceived risk differs across vaccination-experience groups.

RQ1: Does the indirect pathway from health-related fear to vaccine hesitancy through perceived vaccine risk differ by prior vaccination experience?

Figure 1 summarises the theoretical mechanism tested in this study, linking health-related fear, perceived vaccine risk, vaccine hesitancy, and subgroup heterogeneity by prior vaccination experience.

Note

The model proposes that health-related fear is positively associated with vaccine hesitancy and perceived vaccine risk. Perceived vaccine risk is expected to mediate the association between fear and hesitancy. Prior vaccination experience is examined as a source of subgroup heterogeneity in the indirect pathway. Solid arrows indicate hypothesised direct and mediated associations. The dashed grouping path indicates comparison of indirect association across prior vaccination-experience groups. Empirical coefficients are reported in the Results section.

3. Methodology

3.1 Participants and Procedure

This study used a cross-sectional online survey design to examine the associations among health-related fear, perceived vaccine risk, and vaccine hesitancy. Data were collected through Qualtrics XM between February and June 2024. Participants were recruited from a demographically quota-balanced online sample via Prolific Academic, with quota targets set for age, gender, education, and geographic region. This sampling strategy improved demographic heterogeneity but did not produce a probability-based nationally representative sample.

A total of 2,341 adults aged 18 years or older completed the questionnaire before quality screening. The target analytic sample was approximately 2,200. An a priori power analysis was conducted using GPower 3.1, with $\alpha = .05$, statistical power = .95, and a small-to-moderate expected effect size. The result indicated that the planned sample was sufficient for structural equation modelling, mediation analysis,

and subgroup comparison. Power analysis was conducted using G*Power 3.1 [21], which is commonly used in behavioural and health research.

Data quality screening included attention checks, response-time inspection, and straight-lining detection. Participants who failed two or more of three attention checks were excluded (n = 84). Responses completed in under four minutes were removed (n = 31). Cases showing invariant response patterns across matrix items were also excluded (n = 22). The final analytic sample consisted of 2,204 participants. Ethical approval was obtained from the University of Oxford Central University Research Ethics Committee (CUREC) before data collection. All procedures involving human participants were conducted in accordance with the Declaration of Helsinki and applicable institutional ethical standards. All participants provided informed consent before accessing the online survey. Participation was voluntary and anonymous. No personally identifiable information was retained in the analytic dataset.

3.2 Measures

The English-language questionnaire was assembled for the present study and has not previously been published as a complete instrument. The focal measures combined items developed specifically for this study with theory-adapted items, as detailed below. The complete questionnaire, including item wording, response options, and coding information, is provided in Supplementary File 1.

All focal constructs were measured using multi-item Likert-type scales. Responses ranged from 1 = strongly disagree to 5 = strongly agree. Higher scores indicated higher levels of the corresponding construct. Composite scores were calculated after reliability and latent construct validity were assessed.

Health-related fear

Health-related fear toward vaccines was measured using a five-item scale developed for this study. Item generation was guided by Protection Motivation Theory, which links fear appeals to threat and coping appraisal [12]. The revised PMT formulation further informed items related to self-efficacy, uncertainty appraisal, and response efficacy [13]. The items assessed fear of serious side effects, anxiety about vaccination, concern about long-term safety, emotional response to adverse-event information, and discomfort with rapid vaccine development. The scale was reviewed for content clarity and pilot-tested with a separate sample of 312 adults. Pilot feedback was used to refine wording. In the main sample, the scale showed strong internal consistency, with Cronbach's $\alpha = .882$ and McDonald's $\omega = .889$. Item development followed a theory-guided procedure. Initial items were derived from protection motivation theory and vaccine communication literature addressing adverse-event salience, uncertainty appraisal, and emotional responses to vaccination. Three researchers with expertise in health communication, vaccination psychology, and survey methodology reviewed the item pool for conceptual clarity and content relevance. Pilot testing with 312 adults supported a coherent single-factor structure and acceptable item discrimination before CFA validation in the main sample.

Perceived vaccine risk

Perceived vaccine risk was measured using five items adapted from general risk perception theory [18]. The item wording was also informed by COVID-19 risk appraisal research showing that perceived risk varies with psychological, social, and experiential factors [19]. Items captured perceived vaccine danger, perceived probability of harm, risk–benefit imbalance, uncertainty about vaccine ingredients, and concern about unknown long-term consequences. The construct was treated as subjective risk appraisal, not objective medical risk estimation. The scale showed good reliability, with Cronbach's α = .876 and McDonald's ω = .883.

Vaccine hesitancy

Vaccine hesitancy was measured using a five-item composite scale adapted from the WHO SAGE definition of vaccine hesitancy [2]. The scale also drew on the 5C psychological antecedents framework, particularly confidence, calculation, and complacency [4]. Items assessed delay, doubt, postponement, low confidence in vaccine safety, and preference for avoiding vaccination when possible. The scale captured attitudinal hesitancy rather than a single behavioural endpoint. Internal consistency was high, with Cronbach's α = .891 and McDonald's ω = .897.

Control variables

Seven control variables were included: age, gender, education level, household income, prior COVID-19 vaccination experience, chronic health condition, and exposure to anti-vaccine content in the previous 30 days. Age was entered as continuous. Gender was dummy-coded. Education was treated as ordinal. Household income was treated as continuous. Prior vaccination experience was coded into three categories: no prior dose, one dose, and two or more doses. Chronic health condition and recent anti-vaccine content exposure were binary indicators. These variables were included because demographic position, health vulnerability, behavioural experience, and information exposure may influence vaccine attitudes and subjective risk appraisal.

3.3 Measurement Validation

Confirmatory factor analysis was conducted before structural testing. The measurement model included three correlated latent constructs: health-related fear, perceived vaccine risk, and vaccine hesitancy. Each construct was specified with five observed indicators. The CFA assessed factor loadings, internal consistency, convergent validity, discriminant validity, and global model fit.

Reliability was evaluated using Cronbach's α, McDonald's ω, and composite reliability. Convergent validity was assessed through standardised factor loadings and average variance extracted. Discriminant validity was assessed by comparing the square root of AVE with inter-construct correlations. Model fit was evaluated using CFI, TLI, RMSEA, and SRMR. The following benchmarks were applied: CFI ≥ .950, TLI ≥ .950, RMSEA ≤ .060, and SRMR ≤ .060, following Hu and Bentler [22]. χ^2 was reported but not treated as the sole criterion because of its sensitivity to large samples.

3.4 Analytical Strategy

All analyses were conducted in R 4.3.2. Structural equation modelling was performed using the lavaan package, an open-source R package for latent variable modelling and SEM [23]. The analysis followed four steps: descriptive statistics, CFA, structural path estimation, and mediation testing. The structural model estimated the association between health-related fear and vaccine hesitancy, the association between fear and perceived vaccine risk, and the association between perceived risk and hesitancy. Bias-corrected bootstrapping with 5,000 resamples was used to estimate confidence intervals for indirect association.

Given the cross-sectional design, mediation was interpreted as a theoretically specified indirect association rather than causal mediation. The terms "direct association" and "indirect effect" refer to SEM-estimated pathways, not definitive causal effects. Prior vaccination experience was examined through subgroup analysis to assess pathway heterogeneity across vaccination-experience groups. This analysis was not interpreted as proof of causal moderation.

Robustness checks included weighted least squares estimation, bootstrapped OLS models, ordinal logistic regression, and an alternative outcome specification using vaccination intention. Common method bias was examined using Harman's single-factor test and a marker-variable approach, following Podsakoff et al. [24]. Fully standardised path coefficients, standard errors, z-values, p-values, and 95% confidence intervals were reported. For indirect association, inference was based primarily on bootstrapped confidence intervals because indirect association often deviate from normality.

Because cross-sectional mediation models may yield biased estimates of longitudinal mediation parameters, indirect associations were interpreted cautiously and were not treated as evidence of temporal or causal ordering [25]. The analysis therefore evaluates whether the observed covariance structure is statistically consistent with the proposed affective–cognitive appraisal framework.

4. Results

4.1 Sample Characteristics

Table 1 reports the demographic profile, health-related background, information exposure, and descriptive statistics for the final analytic sample. The sample included 2,204 adults. Participants had a mean age of 38.7 years (SD = 13.4), with a broad age range from 18 to 75 years. Women accounted for 56.6% of the sample, men for 41.5%, and non-binary or other gender identities for 2.0%. Education levels were distributed across high school or below, vocational or some college education, bachelor's degree, and postgraduate education.

The key psychological variables showed adequate dispersion for latent-variable modelling. Mean scores were moderate for health-related fear (M = 2.91, SD = 0.94), perceived vaccine risk (M = 3.04, SD = 0.98), and vaccine hesitancy (M = 2.84, SD = 1.07). The full 1–5 response range was observed for all three constructs, suggesting sufficient variation for CFA and SEM analyses. In the health background variables, 36.4% of participants reported no prior COVID-19 vaccination, while 46.3% reported two or more prior

doses. More than half of the sample reported exposure to anti-vaccine content in the previous 30 days (51.9%), supporting the relevance of information exposure as a contextual control variable.

Table 1
Sample Characteristics and Descriptive Statistics (N = 2,204)

Variable	n / M	% / SD	Range / Notes
Demographics			
Age (years)	38.7	± 13.4	18–75
Female	1,247	56.6%	
Male	914	41.5%	
Non-binary / other	43	2.0%	
Education: ≤High school	498	22.6%	
Education: Some college / vocational	634	28.8%	
Education: Bachelor's degree	712	32.3%	
Education: Graduate or professional	360	16.3%	
Household income (USD, annual)	54,280	± 27,460	15k–180k
Married / partnered	1,189	54.0%	
Health-Related Background			
Chronic health condition (yes)	604	27.4%	
Prior COVID-19 vaccination (1 dose)	382	17.3%	
Prior COVID-19 vaccination (2 + doses)	1,021	46.3%	
No prior COVID-19 vaccination	801	36.4%	
Previously experienced vaccine side effects	387	17.6%	
Key Study Variables (1–5 Likert)			
Fear Scale (composite, α = .882)	2.91	± 0.94	1.00–5.00
Risk Perception (composite, α = .876)	3.04	± 0.98	1.00–5.00
Vaccine Hesitancy (composite, α = .891)	2.84	± 1.07	1.00–5.00
Information Exposure			
Primary news source: Social media	803	36.5%	
Primary news source: Traditional media	748	34.0%	
Primary news source: Online news / other	653	29.6%	

Note. Chronic health condition includes asthma, diabetes, cardiovascular disease, immunodeficiency, or other ongoing medical conditions requiring regular treatment. Fear, Risk Perception, and Vaccine Hesitancy are composite Likert scale scores (1–5; higher = greater on the construct).

Variable	n / M	% / SD	Range / Notes
Exposed to anti-vaccine content (past 30 days)	1,143	51.9%	

Note. Chronic health condition includes asthma, diabetes, cardiovascular disease, immunodeficiency, or other ongoing medical conditions requiring regular treatment. Fear, Risk Perception, and Vaccine Hesitancy are composite Likert scale scores (1–5; higher = greater on the construct).

The descriptive results indicate that the sample contains meaningful heterogeneity in vaccination experience, information exposure, and psychological responses to vaccination. This distribution is suitable for testing the proposed affective–cognitive pathway and for examining whether the pathway differs by prior vaccination experience.

4.2 Measurement Model

Before estimating the structural paths, the three-factor measurement model was evaluated using confirmatory factor analysis. The model specified health-related fear, perceived vaccine risk, and vaccine hesitancy as correlated latent constructs, each measured by five observed indicators. This step was used to verify whether the three constructs were empirically distinguishable before testing the hypothesised indirect pathway.

Table 2 presents the standardised factor loadings, reliability indices, and validity statistics. All factor loadings were statistically significant and above .70, ranging from .749 to .823. Internal consistency was strong across the three scales. Cronbach's α ranged from .876 to .891, McDonald's ω ranged from .883 to .897, and composite reliability exceeded .87 for all constructs. Average variance extracted exceeded the .50 threshold for health-related fear (AVE = .612), perceived vaccine risk (AVE = .594), and vaccine hesitancy (AVE = .631). These results indicate acceptable convergent validity. Discriminant validity was also supported. The square root of AVE for each construct was higher than its correlations with the other constructs. Inter-construct correlations were moderate: fear–risk perception, r = .527; fear–hesitancy, r = .471; risk perception–hesitancy, r = .499. This pattern shows that the constructs were related but not redundant. Global model fit was satisfactory: $\chi^2(87) = 124.3$, $p = .005$; CFI = .963; TLI = .954; RMSEA = .058, 90% CI [.042, .074]; SRMR = .054.

Table 2
Confirmatory Factor Analysis: Factor Loadings, Reliability, and Validity Indices

Item / Scale	Factor loading	SE	z-value	AVE / CR
Health-related fear scale				AVE = .612; CR = .887
FS1: Serious side-effect fear	0.784	0.021	37.3***	
FS2: Vaccination anxiety	0.801	0.019	42.2***	
FS3: Long-term safety worry	0.812	0.018	45.1***	
FS4: Adverse-event fear	0.768	0.023	33.4***	
FS5: Development-speed unease	0.754	0.025	30.2***	
Perceived vaccine risk scale				AVE = .594; CR = .879
RP1: Significant health risk	0.791	0.02	39.6***	
RP2: Perceived harm probability	0.772	0.022	35.1***	
RP3: Risk-benefit imbalance	0.763	0.023	33.2***	
RP4: Ingredient safety uncertainty	0.749	0.025	30.0***	
RP5: Unknown long-term consequences	0.782	0.021	37.2***	
Vaccine hesitancy scale				AVE = .631; CR = .895
VH1: Wait-and-see preference	0.823	0.017	48.4***	
VH2: Necessity doubt	0.798	0.02	39.9***	
VH3: Vaccination postponement	0.812	0.018	45.1***	
VH4: Low safety confidence	0.784	0.021	37.3***	
VH5: Avoidance preference	0.771	0.022	35.0***	
CFA model fit indices				
χ^2(df = 87)	124.3	p = .005		
CFI	0.963			Good fit

*Note. All factor loadings are standardised. ***p < .001. AVE = average variance extracted; CR = composite reliability; CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root mean square error of approximation; SRMR = standardised root mean square residual.*

Item / Scale	Factor loading	SE	z-value	AVE / CR
TLI	0.954			Good fit
RMSEA, 90% CI	0.058	[.042, .074]		Acceptable fit
SRMR	0.054			Good fit

*Note. All factor loadings are standardised. ***p < .001. AVE = average variance extracted; CR = composite reliability; CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root mean square error of approximation; SRMR = standardised root mean square residual.*

These measurement results justify the use of latent variables in the structural model. The three-factor measurement model demonstrated satisfactory discriminant validity, as the square root of AVE for each construct exceeded its inter-construct correlations. These findings support the empirical separability of health-related fear, perceived vaccine risk, and vaccine hesitancy before structural associations were estimated.

4.3 Structural Model and Indirect Pathway

The structural model tested the hypothesised associations among health-related fear, perceived vaccine risk, and vaccine hesitancy. Table 3 reports fully standardised path coefficients, bootstrapped confidence intervals, and control-variable estimates. The results were consistent with H1. Health-related fear was positively associated with vaccine hesitancy, β = .214, SE = .019, 95% CI [.178, .250], p < .001. The total association between fear and hesitancy was β = .388, 95% CI [.352, .424].

The results were also consistent with H2. Health-related fear was positively associated with perceived vaccine risk, β = .463, SE = .021, 95% CI [.421, .505], p < .001. Perceived vaccine risk was positively associated with vaccine hesitancy, β = .371, SE = .020, 95% CI [.332, .410], p < .001. The bootstrapped indirect association from fear to hesitancy through perceived vaccine risk was statistically different from zero, β = .174, SE = .013, 95% CI [.148, .200], p < .001. This indirect association accounted for approximately 45% of the total fear–hesitancy association. The model explained 41.2% of the variance in vaccine hesitancy. This value suggests substantial explanatory capacity for a psychological and health communication model based on cross-sectional survey data. The residual direct association between fear and hesitancy remained significant after perceived risk was included, indicating partial mediation. This pattern is consistent with an affective–cognitive pathway: perceived risk explains a meaningful part of the fear–hesitancy association, while other affective or social mechanisms may remain.

Table 3
Structural Equation Model Results: Path Coefficients and Indirect Pathway Analysis (N = 2,204)

Path	β	SE	z	95% BootCI	p
Main structural paths					
Fear -> VH (total)	0.388	0.018	21.6	[.352, .424]	< .001
Fear -> VH (direct)	0.214	0.019	11.3	[.178, .250]	< .001
Fear -> RP	0.463	0.021	22	[.421, .505]	< .001
RP -> VH	0.371	0.02	18.6	[.332, .410]	< .001
Indirect pathway					
Fear -> RP -> VH	0.174	0.013	13.4	[.148, .200]	< .001
Indirect proportion	45%	—	—	—	—
Control variables predicting vaccine hesitancy					
Age	−.031	0.008	−3.9	[− .047, − .015]	< .001
Gender, female = 1	−.067	0.024	−2.8	[− .114, − .020]	0.005
Education, higher = lower hesitancy	−.098	0.018	−5.4	[− .133, − .063]	< .001
Household income	−.041	0.015	−2.7	[− .070, − .012]	0.007
Prior vaccination: 2 + doses vs. none	−.187	0.022	−8.5	[− .230, − .144]	< .001
Chronic health condition	0.072	0.026	2.8	[.021, .123]	0.005
Anti-vaccine content exposure	0.114	0.024	4.8	[.067, .161]	< .001
Model fit and explained variance					
χ^2(df = 174)	231.8	p = .002			
CFI / TLI	.963 / .954				
RMSEA, 90% CI	0.058	[.044, .072]			
SRMR	0.054				
R^2, vaccine hesitancy	0.412				

Note. All path coefficients are fully standardised. Standard errors and confidence intervals were derived from 5,000 bias-corrected bootstrap resamples. VH = vaccine hesitancy; RP = perceived vaccine risk. Prior vaccination reference category = no prior COVID-19 vaccination.

Path	β	SE	z	95% BootCI	p
Total observations	2,204				

Note. All path coefficients are fully standardised. Standard errors and confidence intervals were derived from 5,000 bias-corrected bootstrap resamples. VH = vaccine hesitancy; RP = perceived vaccine risk. Prior vaccination reference category = no prior COVID-19 vaccination.

The control-variable results are substantively consistent with the health communication interpretation of the model. Higher education, higher income, older age, and prior vaccination experience were associated with lower hesitancy. Recent exposure to anti-vaccine content was associated with higher hesitancy. This pattern suggests that both individual background and information exposure remain relevant after the affective–cognitive pathway is modelled. Figure 2 then provides a visual summary of these structural associations and fit statistics.

To aid interpretation of the SEM results reported in Table 3, Fig. 2 visually summarises the main structural associations, fear-quartile patterns, bivariate association, and model-fit indices.

Note

Panel A displays fully standardised SEM associations with 95% bootstrapped confidence intervals. Panel B presents mean perceived vaccine risk and vaccine hesitancy across fear quartiles. Panel C shows the bivariate association between health-related fear and vaccine hesitancy with a fitted regression line and 95% confidence band. Panel D compares observed SEM fit indices with commonly recommended threshold values.

Figure 2 provides a graphical check on the numerical results. The strongest pathway appears between fear and perceived vaccine risk, followed by the pathway from perceived risk to hesitancy. The quartile pattern suggests that individuals in higher fear groups also report higher subjective risk and hesitancy. These visual patterns are descriptive and should be interpreted as supportive illustrations, not additional causal evidence.

4.4 Robustness Checks and Subgroup Analyses

Table 4 reports robustness checks and subgroup estimates. The main pathway remained stable across alternative model specifications. The fear–hesitancy direct association ranged from β = .198 to β = .231. The fear–risk perception association ranged from β = .434 to β = .493. The perceived risk–hesitancy association ranged from β = .343 to β = .402. The indirect pathway ranged from β = .149 to β = .198. These estimates show that the main pattern was not dependent on a single estimator or outcome specification.

Common method bias was examined through Harman's single-factor test and a marker-variable procedure. The largest single factor accounted for 24.1% of the variance, below the conventional 50% diagnostic threshold. The marker-variable model yielded only minor changes in the main path estimates.

These findings do not eliminate the possibility of common method bias, but they reduce the likelihood that the main results are driven entirely by a single common response factor. This wording is more appropriate than claiming that common method bias was "ruled out." Subgroup analyses showed pathway heterogeneity. The indirect pathway was larger among participants with no prior vaccination experience, $\beta = .198$, than among participants with two or more prior doses, $\beta = .149$. The indirect pathway was also somewhat larger among women than men and among younger adults than older adults. These subgroup differences should be interpreted cautiously. Although the indirect association appeared numerically larger among vaccine-naive participants, the subgroup analyses do not establish causal moderation or temporal attenuation. The findings are better interpreted as exploratory pathway heterogeneity within the observed cross-sectional structure.

The pattern is still theoretically meaningful. It suggests that vaccine-naive individuals may rely more heavily on fear-linked risk appraisal when forming hesitancy attitudes.

Table 4
Robustness Checks and Subgroup Indirect Pathway Estimates

Model / Subgroup	Fear → VH direct β	Fear → RP β	RP → VH β	Indirect β
Primary model				
Base SEM, all controls	.214***	.463***	.371***	.174***
Alternative specifications				
Ordinal logistic specification	.231***	.451***	.384***	.173***
Bootstrapped OLS with controls	.218***	.459***	.368***	.169***
Weighted least squares estimation	.209***	.471***	.365***	.172***
Common method bias diagnostics				
Harman's single-factor test	24.10%	—	—	Largest factor below 50%
Marker-variable adjusted model	.211***	.461***	.369***	.170***
Subgroup analyses				
Female participants, n = 1,247	.227***	.479***	.381***	.183***
Male participants, n = 914	.198***	.445***	.359***	.160***
Age 18–35, n = 681	.241***	.488***	.392***	.191***
Age 36–55, n = 843	.214***	.462***	.373***	.172***
Age 56+, n = 680	.184**	.439***	.351***	.154**
No prior vaccination, n = 801	.248***	.493***	.402***	.198***
Two or more prior vaccinations, n = 1,021	.176***	.434***	.343***	.149***
Alternative outcome				
Fear → vaccination intention, reversed scale	−.198***	—	—	—
Fear → RP → vaccination intention	—	—	—	−.159***

*Note. All values are fully standardised estimates unless otherwise stated. ***p < .001; **p < .01. VH = vaccine hesitancy; RP = perceived vaccine risk. Harman's single-factor result reports the variance explained by the largest unrotated factor. The alternative outcome uses vaccination intention scored so that higher values indicate stronger intention.*

The robustness results support the stability of the proposed pathway. The indirect estimate remained significant and similar in magnitude under alternative estimators and model specifications. The common method diagnostics also suggest that the findings are not simply an artefact of a single response tendency. The subgroup results add a communication-relevant observation: fear-linked risk appraisal appears stronger among those without prior vaccination experience. Figure 3 displays the bootstrap distribution and subgroup estimates that correspond to these robustness and heterogeneity results.

Figure 3 visualises the bootstrapped indirect association and subgroup variation reported in Table 4, showing how the fear-risk-hesitancy pathway differs across vaccination-experience and demographic groups.

Note

Panel A shows the bootstrap distribution of the indirect association from health-related fear to vaccine hesitancy through perceived vaccine risk. Panel B presents subgroup-specific indirect estimates with 95% confidence intervals. Panel C displays subgroup variation in the fear–hesitancy association across prior vaccination-experience groups. These patterns are interpreted as exploratory subgroup heterogeneity rather than causal moderation.

Figure 3 complements Table 4 by showing that the indirect pathway is positive across all major subgroups. The strongest indirect pathway appears among participants without prior vaccination experience. This pattern is consistent with the idea that direct vaccination experience may weaken reliance on fear-based risk appraisal. It should be treated as exploratory pathway heterogeneity rather than causal evidence of attenuation.

5. Discussion

5.1 Summary of Main Findings

This study tested an affective–cognitive mechanism model of vaccine hesitancy using latent-variable modelling. The results were consistent with the proposed pathway. Health-related fear was positively associated with vaccine hesitancy and perceived vaccine risk. Perceived vaccine risk was also positively associated with vaccine hesitancy. The indirect pathway from fear to hesitancy through perceived risk was significant and accounted for approximately 45% of the total fear–hesitancy association. The model explained 41.2% of the variance in vaccine hesitancy, indicating meaningful explanatory capacity for a psychological and health communication model.

The findings suggest that fear is not merely a general negative emotion in vaccine decision-making. A substantial part of its association with hesitancy appears to operate through subjective risk appraisal. Participants reporting higher fear also tended to perceive vaccines as riskier, and higher perceived risk was associated with stronger hesitancy. The remaining direct association between fear and hesitancy

indicates partial mediation. Other pathways may also be involved, including affective avoidance, distrust, prior negative experience, social identity, or reduced confidence in institutional safety monitoring.

Subgroup results showed a stronger indirect pathway among participants without prior vaccination experience than among those with two or more prior doses. This pattern should be interpreted as pathway heterogeneity, not causal moderation. Vaccine-naive individuals may rely more heavily on mediated risk signals, adverse-event narratives, imagined harm, or peer testimony. Prior vaccination experience may provide experiential evidence of vaccine tolerability and weaken fear-linked risk appraisal.

Among the control variables, prior vaccination experience showed one of the strongest associations with vaccine hesitancy, $\beta = -.187$, $p < .001$. This finding suggests that experiential knowledge may contribute to vaccine attitudes partly independently of the affective–cognitive appraisal structure. Individuals with prior vaccination experience may possess more concrete perceptions of vaccine tolerability, procedural familiarity, and response efficacy. Future longitudinal research should examine whether repeated vaccination alters emotional risk appraisal over time or whether individuals with lower baseline hesitancy are simply more likely to become vaccinated.

5.2 Theoretical Implications

The study contributes to vaccine hesitancy theory by moving beyond a narrow information-deficit account. Knowledge, trust, and misinformation exposure remain important, but the results show that emotional risk processing also deserves central attention. Fear may function as an affective risk signal that shapes subjective appraisal of vaccine safety. This interpretation is consistent with risk-as-feelings theory, where emotion enters judgement before or alongside deliberative reasoning [10]. It is also consistent with the affect heuristic, which explains why negative affect can increase perceived risk and decrease perceived benefit [11].

The findings also clarify the role of risk perception. Vaccine hesitancy studies often treat fear and risk perception as parallel predictors. The present model positions perceived vaccine risk as a latent appraisal pathway linking fear to hesitancy. This gives more precise empirical form to the threat-appraisal component of Protection Motivation Theory and the Extended Parallel Process Model. Fear may increase sensitivity to vaccine-related threat cues; perceived risk translates this sensitivity into a more explicit judgement about danger, uncertainty, and acceptability.

The study adds a communication-system perspective. In digital health environments, adverse-event stories, personal testimony, negative visual content, and emotionally intense claims may gain visibility through repeated sharing and platform ranking. Under such conditions, fear may alter the weight attached to vaccine-related information. Vaccine hesitancy should therefore be understood as a product of individual emotion, subjective risk construction, and communication ecology.

Prior vaccination experience further suggests experiential calibration. Individuals with direct vaccination experience may have concrete evidence that competes with mediated fear signals. Vaccine-naive

individuals may lack this calibration. This finding indicates that risk communication theories should attend not only to average effects, but also to pathway heterogeneity across experience groups.

5.3 Practical and Policy Implications

The findings have direct implications for vaccine communication design. Factual correction remains necessary, but it may be insufficient for individuals with high vaccine-related fear. People may understand that severe adverse events are rare and still perceive vaccination as personally unsafe. Communication should combine factual risk correction with emotional uncertainty management. Messages should acknowledge fear, explain safety-monitoring procedures, clarify adverse-event reporting systems, and present absolute risks in plain language. Public health messaging research emphasizes clarity, trust, and audience-specific risk explanation during and after the COVID-19 pandemic [26]. Infodemic-focused guidance further highlights the need to help communities navigate emotionally charged vaccine information [27].

A more technical task is risk-signal calibration. Public health messages should reduce the disproportionate salience of rare negative outcomes without dismissing uncertainty. Overly reassuring messages may appear evasive. More effective formats may include clinician-endorsed explanations, visual risk scales, updated safety evidence, and narrative materials addressing specific fear contents such as long-term effects, side effects, or vaccine novelty. Prior vaccination experience can guide segmentation. Vaccine-naive individuals may need procedural familiarity, first-dose confidence, clinician support, and experience-based reassurance. Previously vaccinated individuals may respond better to messages reinforcing prior tolerability and response efficacy. Behavioral-insights approaches to vaccination policy suggest that interventions should be matched to specific behavioural barriers rather than applied as generic persuasion [28]. Vaccine communication evidence similarly shows that interventions work better when they address concrete psychological barriers to uptake [3]. The 5C framework provides a structured way to distinguish confidence, complacency, constraints, calculation, and collective responsibility when designing such interventions [4].

The digital information environment also matters. More than half of the sample reported recent exposure to anti-vaccine content. This does not establish causal influence, but it indicates the communication context in which risk appraisal occurs. Public health agencies should monitor circulating risk narratives, respond quickly to emotionally salient claims, and work with clinicians, community organisations, and platform intermediaries. The goal is not to remove uncertainty, but to prevent uncertainty from being interpreted as hidden danger.

5.4 Limitations and Future Directions

The first limitation concerns causal inference. The cross-sectional design does not establish temporal precedence among fear, perceived vaccine risk, and vaccine hesitancy. Although SEM can estimate theoretically specified direct and indirect associations, it cannot determine whether fear preceded risk appraisal or whether perceived risk preceded hesitancy. Cross-sectional mediation models may also produce biased estimates of longitudinal mediation parameters [25]. The present findings should

therefore be interpreted as statistically consistent with the proposed affective–cognitive appraisal structure rather than proof of theoretical mediation.

Second, the sample came from a quota-balanced online panel. Quota balancing improved demographic heterogeneity, but the sample should not be treated as a probability-based national sample. Online panel participants may differ from the general population in digital literacy, survey familiarity, health information exposure, and willingness to participate in research. Future studies should replicate the model using probability-based samples, community samples, clinical populations, and groups with limited digital access.

Third, the focal constructs were measured through self-report scales. The CFA results supported reliability, convergent validity, and discriminant validity. Still, self-report data remain vulnerable to recall bias, social desirability, response style, and shared method variance. Common-method diagnostics reduced this concern but cannot eliminate it. Future research should combine survey measures with behavioural indicators, such as verified vaccination records, appointment delay, missed vaccination opportunities, search behaviour, or digital exposure logs. Implicit or physiological indicators of fear, such as reaction time, eye-tracking, skin conductance, or affective language markers, could improve measurement precision.

Fourth, the study measured general vaccine-related fear and hesitancy rather than attitudes toward one vaccine type. Vaccine decision-making may differ across influenza, HPV, COVID-19, childhood immunisation, travel vaccines, and newly introduced technologies. Concerns about novelty, side effects, institutional trust, and perceived necessity may vary by vaccine category. Future studies should test whether the fear–risk perception–hesitancy pathway remains stable across vaccine types and epidemiological contexts.

Fifth, prior vaccination experience was treated as subgroup heterogeneity. This is theoretically useful but not equivalent to causal moderation. Individuals with multiple prior doses may also differ in trust, healthcare access, political orientation, perceived norms, or baseline risk tolerance. Matched designs, longitudinal models, or quasi-experimental approaches could help separate experiential learning from selection effects.

Finally, the model focused on one affective–cognitive pathway. Vaccine hesitancy is multidimensional. Trust, collective responsibility, moral values, political identity, healthcare access, social norms, and misinformation belief may interact with fear-based appraisal. Future research should test sequential and moderated mechanisms, including trust as a boundary condition, misinformation belief as an upstream exposure variable, and perceived efficacy as a competing appraisal pathway. Cross-national replication is also needed because public health governance, media trust, and vaccination histories differ across contexts.Despite these limitations, the consistency of the pathway across alternative estimators, subgroup analyses, and robustness checks increases confidence that the observed associations reflect a stable affective–cognitive appraisal structure rather than a model-specific artefact.

6. Conclusion

This study advances a mechanism-oriented account of vaccine hesitancy. The findings show that health-related fear is associated with vaccine hesitancy partly through perceived vaccine risk. The indirect pathway explained nearly half of the total fear–hesitancy association, while the remaining direct association suggests that fear may also relate to hesitancy through affective avoidance, distrust, or identity-linked resistance.

The study contributes to vaccine communication theory by integrating affect heuristic theory, risk perception theory, and protection motivation logic within a latent-variable SEM framework. Vaccine hesitancy is not simply a lack of information. It reflects how risk signals are encountered, emotionally encoded, cognitively appraised, and filtered through prior experience. The stronger indirect pathway among vaccine-naive participants suggests that experiential confidence may shape fear-based risk appraisal, although this pattern requires longitudinal confirmation.

The practical implication is that vaccine communication should move beyond statistical reassurance alone. Effective messages should calibrate subjective risk, address emotional uncertainty, explain safety-monitoring systems, and build confidence through trusted clinical and community channels. Communication strategies should also account for vaccination experience, because vaccine-naive individuals may need more procedural reassurance and experience-oriented support.

Overall, fear appears to be one important entry point into a broader vaccine risk appraisal system. Public health interventions that recognise this affective–cognitive architecture may be better positioned to reduce hesitancy in digital information environments where emotionally salient risk signals can be repeatedly amplified. Future studies should test this pathway using longitudinal, experimental, behavioural, and cross-national designs.

Declarations

Ethics Approval and Consent to Participate

Ethical approval for this study was obtained from the University of Oxford Central University Research Ethics Committee (CUREC) before data collection. All procedures involving human participants were conducted in accordance with the Declaration of Helsinki and applicable institutional ethical standards. All human participants provided informed consent before accessing the online survey. Participation was voluntary and anonymous, and no personally identifiable information was retained in the analytic dataset.

Human Ethics and Consent to Participate Statement

Human ethics approval and informed consent to participate were obtained as described above. All participants confirmed consent before taking part in the survey.

Funding Statement

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Clinical Trial Number

Clinical trial number: Not applicable.

Clinical Trial Registration

Not applicable. This study was not a clinical trial and therefore did not require clinical trial registration.

Competing Interests

The author declares that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The anonymized data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

M.H. conceptualized the study, developed the theoretical framework, designed the methodology, conducted the analysis, interpreted the results, wrote and revised the manuscript, approved the final version for submission, and agrees to be accountable for all aspects of the work.

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References

1. World Health Organization. Vaccines and immunization, 2023. [Online]. Available: https://www.who.int/health-topics/vaccines-and-immunization. Accessed: May 7, 2026.
2. MacDonald NE, and the SAGE Working Group on Vaccine Hesitancy., Vaccine hesitancy: Definition, scopedeterminants, Vaccine, vol. 33, no. 34, pp. 4161–4164, 2015.
3. Brewer NT, Chapman GB, Rothman AJ, Leask J, Kempe A. Increasing vaccination: Putting psychological science into action. Psychol Sci Public Interest. 2017;18(3):149–207.
4. Betsch C, Schmid P, Heinemeier D, Korn L, Holtmann C, Bohm R. Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. PLoS ONE, 13, 12, Art. no. e0208601, 2018.

5. de Figueiredo A, Simas C, Karafillakis E, Paterson P, Larson HJ. Mapping global trends in vaccine confidence and investigating barriers to vaccine uptake: A large-scale retrospective temporal modelling study, The Lancet, 396, 10255, pp. 898–908, 2020.
6. Lazarus JV, Ratzan SC, Palayew A, Gostin LO, Larson HJ, Rabin K, Kimball S, El-Mohandes A. A global survey of potential acceptance of a COVID-19 vaccine. Nat Med. 2021;27(2):225–8.
7. Cinelli M, Quattrociocchi W, Galeazzi A, Valensise CM, Brugnoli E, Schmidt AL, Zola P, Zollo F, Scala A. The COVID-19 social media infodemic, Scientific Reports, 10, Art no 16598, 2020.
8. Loomba S, de Figueiredo A, Piatek SJ, de Graaf K, Larson HJ. Measuring the impact of COVID-19 vaccine misinformation on vaccination intent in the UK and USA. Nat Hum Behav. 2021;5(3):337–48.
9. Wilson SL, Wiysonge C. Social media and vaccine hesitancy. BMJ Global Health, 5, 10, Art. no. e004206, 2020.
10. Loewenstein GF, Weber EU, Hsee CK, Welch N. Risk as feelings Psychol Bull. 2001;127(2):267–86.
11. Slovic P, Finucane ML, Peters E, MacGregor DG. The affect heuristic. Eur J Oper Res. 2007;177(3):1333–52.
12. Rogers RW. A protection motivation theory of fear appeals and attitude change. J Psychol. 1975;91(1):93–114.
13. Maddux JE, Rogers RW. Protection motivation and self-efficacy: A revised theory of fear appeals and attitude change. J Exp Soc Psychol. 1983;19(5):469–79.
14. Witte K. Putting the fear back into fear appeals: The extended parallel process model, Communication Monographs, vol. 59, no. 4, pp. 329–349, 1992.
15. Freeman D, Lambe S, Yu L-M, Freeman J, Chadwick A, Vaccari C, Waite F, Rosebrock L, Petit A, Vanderslott S, Lewandowsky S, Larkin M, Giubilini A, McShane H, Pollard AJ, Loe BS. Injection fears and COVID-19 vaccine hesitancy. Psychol Med. 2023;53(4):1185–95.
16. Murphy J et al. Psychological characteristics associated with COVID-19 vaccine hesitancy and resistance in Ireland and the United Kingdom, Nature Communications, vol. 12, Art. no. 29, 2021.
17. Kasperson RE et al. The social amplification of risk: A conceptual framework, Risk Analysis, vol. 8, no. 2, pp. 177–187, 1988.
18. Slovic P. The Perception of Risk. London, U.K.: Earthscan; 2000.
19. Dryhurst S, et al. Risk perceptions of COVID-19 around the world. J Risk Res. 2020;23:7–8.
20. Featherstone JD, Zhang J. Feeling angry: The effects of vaccine misinformation and refutational messages on negative emotions and vaccination attitude. J Health Communication. 2020;25(9):692–702.
21. Faul F, Erdfelder E, Buchner A, Lang A-G. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses, Behavior Research Methods, vol. 41, no. 4, pp. 1149–1160, 2009.

22. Hu L-T, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives, Structural Equation Modeling: A Multidisciplinary Journal, 6, 1, pp. 1–55, 1999.
23. Rosseel Y. lavaan: An R package for structural equation modeling. J Stat Softw. 2012;48(2):1–36.
24. Podsakoff PM, MacKenzie SB, Lee J-Y, Podsakoff NP. Common method biases in behavioral research: A critical review of the literature and recommended remedies. J Appl Psychol. 2003;88(5):879–903.
25. Maxwell SE, Cole DA. Bias in cross-sectional analyses of longitudinal mediation, Psychological Methods, vol. 12, no. 1, pp. 23–44, 2007.
26. Larson HJ. A call to arms: Helping family, friends and communities navigate the COVID-19 infodemic. Nat Rev Immunol. 2020;20(8):449–50.
27. Nan X, Iles IA, Yang B, Ma Z. Public health messaging during the COVID-19 pandemic and beyond: Lessons from communication science, Health Communication, vol. 37, no. 1, pp. 123–132, 2022.
28. Betsch C, Bohm R, Chapman GB. Using behavioral insights to increase vaccination policy effectiveness, Policy Insights from the Behavioral and Brain Sciences, 2, 1, pp. 61–73, 2015.

Figures

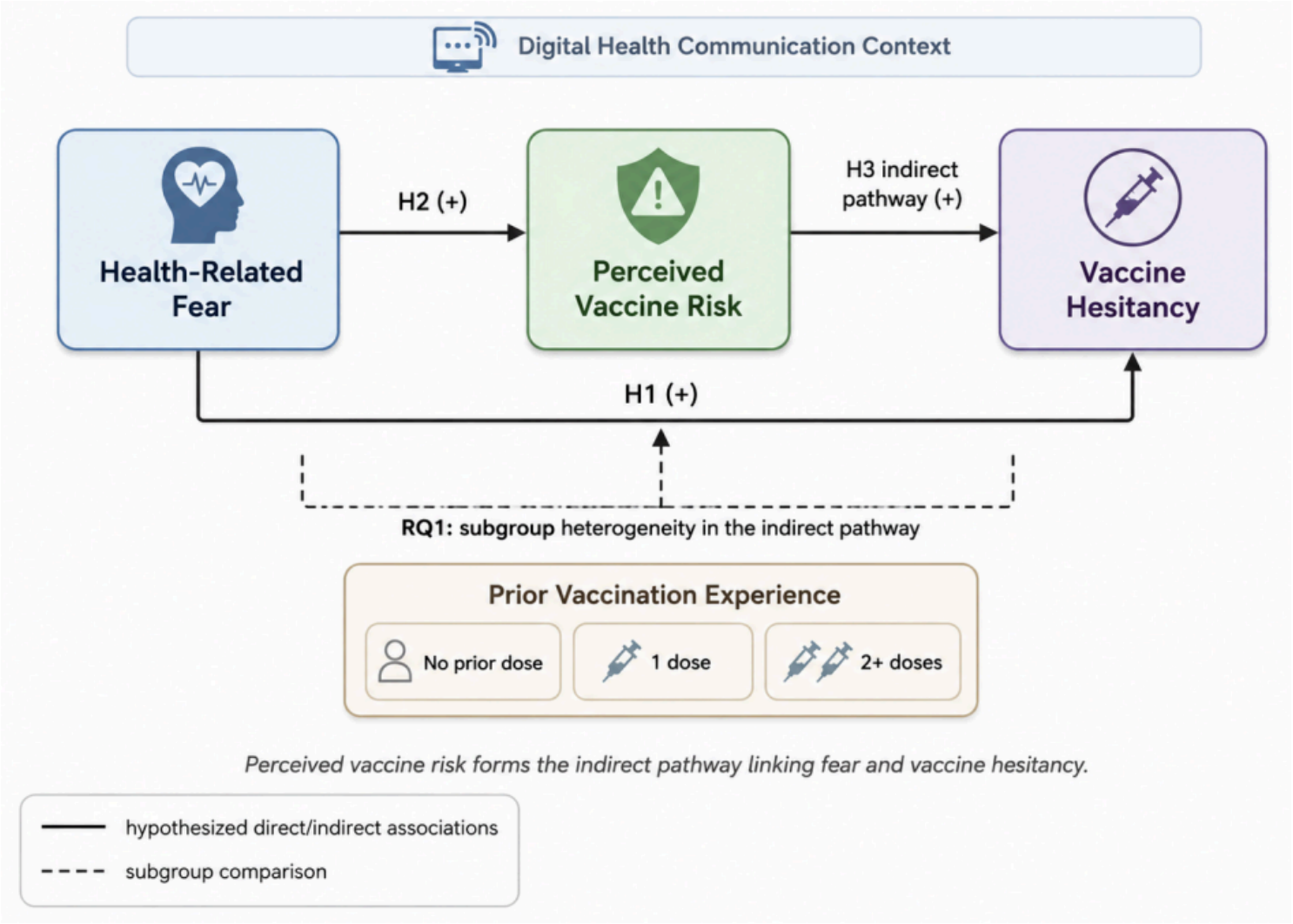


Figure 1

Theoretical Framework of the Affective-Cognitive Mechanism Model

Note. The model proposes that health-related fear is positively associated with vaccine hesitancy and perceived vaccine risk. Perceived vaccine risk is expected to mediate the association between fear and hesitancy. Prior vaccination experience is examined as a source of subgroup heterogeneity in the indirect pathway. Solid arrows indicate hypothesised direct and mediated associations. The dashed grouping path indicates comparison of indirect association across prior vaccination-experience groups. Empirical coefficients are reported in the Results section.

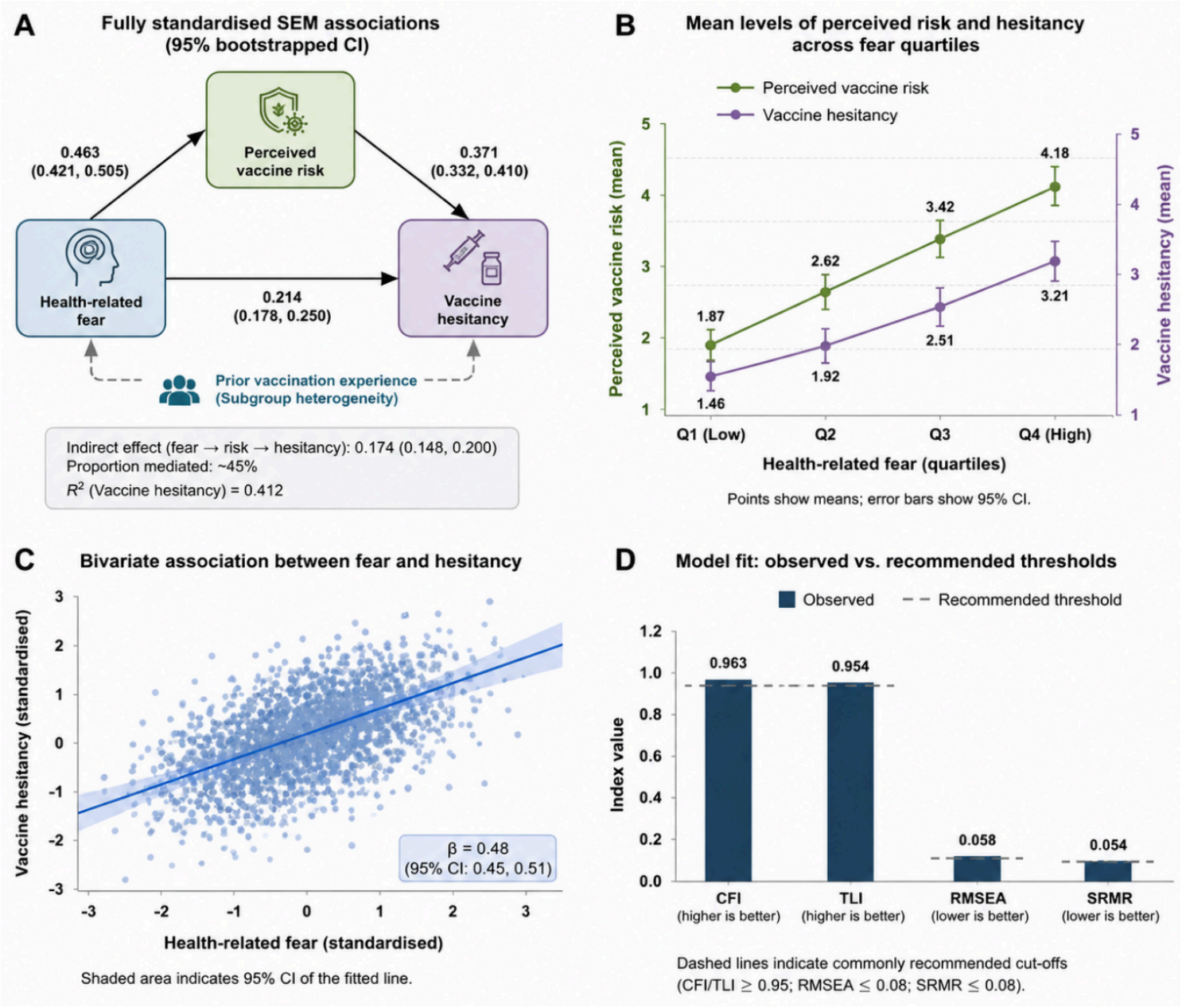


Figure 2

Visual Summary of Main Structural Associations

Note. Panel A displays fully standardised SEM associations with 95% bootstrapped confidence intervals. Panel B presents mean perceived vaccine risk and vaccine hesitancy across fear quartiles. Panel C shows the bivariate association between health-related fear and vaccine hesitancy with a fitted regression line and 95% confidence band. Panel D compares observed SEM fit indices with commonly recommended threshold values.

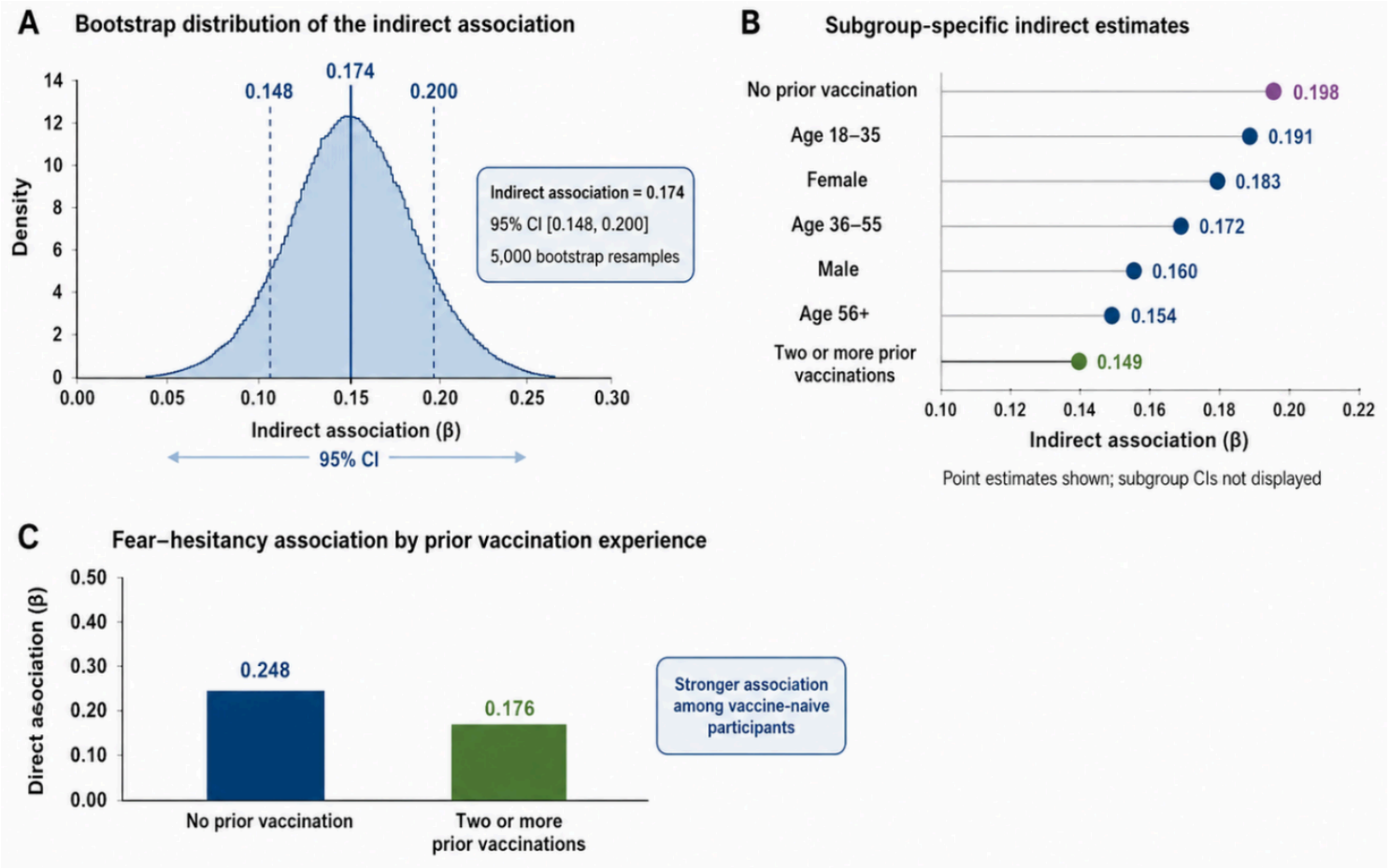


Figure 3

Bootstrap Indirect Association and Subgroup Variation

Note. Panel A shows the bootstrap distribution of the indirect association from health-related fear to vaccine hesitancy through perceived vaccine risk. Panel B presents subgroup-specific indirect estimates with 95% confidence intervals. Panel C displays subgroup variation in the fear–hesitancy association across prior vaccination-experience groups. These patterns are interpreted as exploratory subgroup heterogeneity rather than causal moderation.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryQuestionnaireAffectiveRisk.docx