Heliyon 10 (2024) e24826

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Testing an extended theory of planned behaviour in predicting Covid-19 vaccination intention over the course of the pandemic: A three-wave repeated cross-sectional study

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ARTICLE INFO

Keywords:
Theory of planned behaviour
Covid-19 vaccine
Vaccine hesitancy
Vaccination intention
Repeated cross-sectional survey

ABSTRACT

Background: Mass vaccination against Covid-19 has been recognised as the most effective strategy for overcoming the pandemic emergency and remains crucial in the ongoing efforts to mitigate the impact of the virus. The present study aimed to test the efficacy of an extended Theory of Planned Behaviour (TPB) model in predicting vaccination intention in three different phases of the pandemic. Understanding how psychological drivers of vaccine acceptance may have changed throughout the pandemic is essential for informing public health strategies and addressing vaccine hesitancy, even in the current post-pandemic context.
Methods: Using a repeated cross-sectional survey, we tested the hypothesised extended TPB model (intention, attitude, subjective norms, perceived behavioural control, anticipated affective reactions, risk perception, trust in science, trust in institutions and religiosity) across three independent samples: before (T1: November–December 2020; $N = 657$), during (T2: March–May 2021; $N = 818$), and after (T3: February–March 2022; $N = 605$) the start of the vaccination campaign in Italy.
Results: Results indicated significant differences between the time points in all investigated variables, pointing to a general trend of improvement in vaccine acceptability levels at T2 compared to T1, and a worsening at T3 compared to the other two time points. Interestingly, net of these differences, a multi-group Structural Equation Modeling analysis supported the invariance, across time, of the structural relationships examined within the extended TPB.
Conclusion: Findings demonstrated the efficacy of the TPB in predicting Covid-19 vaccination intention at different stages of the pandemic, suggesting that the model, in its extended version, represents a valuable framework for designing interventions aimed at promoting vaccine acceptance.

1. Introduction

Between December 2019 and January 2020, Chinese authorities identified a new coronavirus (officially classified as SARS-CoV-2) responsible for the coronavirus disease (Covid-19). Clinical manifestations associated with SARS-CoV-2 infection typically include symptoms common to other forms of flu (e.g., cough, sore throat, and fever). In the most severe cases, acute respiratory distress

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https://doi.org/10.1016/j.heliyon.2024.e24826
Received 26 October 2023; Received in revised form 6 January 2024; Accepted 15 January 2024
Available online 20 January 2024
2405-8440/

syndrome and pneumonia may occur, making the virus potentially life-threatening, especially in the presence of risk factors, such as older age and/or suffering from pre-existing medical conditions [1]. Despite the proven impact of adopting a number of preventive measures (e.g., wearing a mask indoors) on outbreak control [2], mass vaccination remains the most effective strategy for mitigating the impact of the virus, even in the current post-pandemic era.

In Italy, the adherence rate to the anti-Covid-19 vaccination campaign steadily increased, going from 30 % to 90 % of individuals fully vaccinated (i.e., with two doses) between May 2021 and December 2023 [3]. This surge may be attributed in part to the implementation of the "Green Pass", certified by the Italian Government in July 2021 [4]. Unfortunately, despite this relatively reassuring picture, Covid-19 cases continue to grow mainly due to the spread of SARS CoV-2 mutations that are more transmissible than the original virus and potentially resistant to vaccines [5]. This situation, together with evidence that the protective effect of Covid-19 vaccines tends to decrease over time [6], made it necessary for the Italian government to authorise the administration of "booster doses" among the population (or specific risky groups) to continue to guarantee high levels of protection against symptomatic disease and mortality [7]. However, up until December 2023[1] the percentage of fully vaccinated individuals, particularly in certain age categories (e.g., under 40), is still suboptimal. Notably, adherence to the second and third booster doses remains below 20 % for most age-groups [3], indicating a possible phase of stagnation in the vaccination campaign. Given the presence of external factors, such as changes in vaccine accessibility (e.g., initially available in multiple locations, then limited to hospitals or specific sites), the evolving level of disease circulation, the growing understanding of immunity, and the frequent changes in government policies and regulations regarding vaccination requirements and mandates, it is reasonable to consider that these externalities may have impacted on the psychological acceptability of Covid-19 vaccination, especially during the height of the pandemic. Therefore, it is important to examine how intention to get vaccinated and the variables predicting it changed during the emergency, providing insights that may inform effective vaccination strategies even in the post-pandemic era.

In light of the above, our investigation focused on three time points: before (T1: November–December 2020), during (T2: March–May 2021), and after (T3: February–March 2022) the beginning of the Italian vaccination campaign. This decision was based on selecting time points that marked its different phases. At T1, the campaign had not yet started, and complete and clear information on the characteristics of the candidate vaccines was not yet available. At T2, vaccination was open to a large part of the population, though adherence rates were still relatively low (30 % of the eligible individuals were vaccinated with two doses [3]). At T3, however, 90 % of the population was vaccinated with two doses, and 84 % had received the booster dose; thus, while in the first two phases the priority was to explore factors influencing intention to receive an initial dose of the vaccine against Covid-19 – a future eventuality at T1 and a practical possibility at T2 – in the last phase (T3), with the great majority of the population already vaccinated, an interesting subject of investigation was intention to *continue* to be vaccinated, especially given the presumable future authorisation for additional doses (which, in fact, has occurred). Therefore, focusing on these three time points has allowed us to analyse three different facets of the intention: intention to 1) receive the future vaccine against Covid-19, 2) receive the current vaccine against Covid-19, and 3) to continue vaccination.

The choice to focus on intention is grounded on psychosocial studies showing that vaccination intention strongly predicts actual uptake for both general [8–10] and Covid-19 [11–14] vaccinations. Regarding Covid-19 vaccination, in a recent work by Griffin et al. [11], scholars found a strong association ($r = 0.68$) between vaccination intention and subsequent behaviour (reported three months later). Moreover, in a two-stage study by Wang and colleagues [13], 81.8 % of the participants who declared they were highly willing to receive the vaccine actually got vaccinated six months later. Similarly, in a study by Preis et al. [14], vaccination intention represented the strongest predictor of vaccination uptake after four months. Finally, Shiloh et al. [12] demonstrated that 82.4 % of the variance in Covid-19 vaccination behaviour was explained by intention. Overall, these results suggest that it is plausible to expect high levels of intention to translate into effective vaccination uptake, highlighting the value of focusing on intention. Thus, in order to examine the differences between the three aforementioned time points in relation to vaccination intention and its psychological predictors, the present study assessed the efficacy of an extended version of the Theory of Planned Behaviour [15] in predicting intention to receive the Covid-19 vaccine during these distinct phases. Specifically, we aimed to identify the key variables on which future interventions aimed at promoting vaccination could focus, taking into account the possible changes that, with the progress of the campaign, may have affected intentions and its predictors.

1.1. The Theory of Planned Behaviour and vaccine acceptance

The Theory of Planned Behaviour (TPB) is widely recognised as one of the most prominent socio-cognitive models applied in the psychosocial literature to predict health intention and behaviours [16]. Notably, as shown by a recent systematic review [17], TPB has commonly been employed for understanding Covid-19 preventive behaviours.

Socio-cognitive models of health behaviour not only contribute to identifying the key determinants of behaviour but also take into consideration how external factors can influence behaviour change [18]. One of the notable advantages of these models lies in their ability to provide a foundation for planning interventions that leverage specific behavioural change techniques targeting such variables [19]. It has been consistently demonstrated that theory-based interventions are more effective than those manipulating single variables [20]. Thus, by adopting the TPB, we aimed not only to understand the decision-making process leading to vaccination intentions but also to inform future theory-based vaccination promotion campaigns.

[1] As of the current date, the Italian Covid-19 vaccination campaign is ongoing with a particular emphasis on the elderly and vulnerable populations, along with a simultaneous influenza vaccination program.

TPB builds on the assumption that intention is the most proximal predictor of an individual's behaviour (e.g., vaccination) and is hypothesised to mediate the effects of three key cognitions on behaviour: attitude (favourable or unfavourable evaluation of the behaviour), subjective norms (perception of social pressure to adopt that behaviour), and perceived behavioural control (PBC; belief of having the possibility/abilities to perform that behaviour) [15]. TPB validity in predicting vaccination intentions and behaviours has been well supported across several types of vaccines, including those against human papillomavirus [21], swine flu [22,23] and also Covid-19 [24–28]. In particular, attitude has consistently emerged as the strongest predictor of vaccination intention, followed by subjective norms [29,30]. This means that when vaccination is evaluated favourably in terms of safety, efficacy, and utility, and when individuals perceive that getting vaccinated is approved by significant others or important social groups, their intention to get vaccinated increases. In contrast, the relationship between PBC and vaccination intention seems less predictable, as some studies showed a significant impact of PBC on vaccination intention [25,31,32], whereas others have reported a non-significant relationship [29,33].

1.2. Extending the TPB model

Despite the proven effectiveness of the TPB model in predicting and explaining vaccination intention, this theory has some limitations. Firstly, it assumes that human behaviours result from rational cognitive decisions, thus overlooking the role of affective processes. Furthermore, it includes only the most proximal determinants of behavioural intention and does not consider the potential influence of "distal factors", i.e., constructs that are stable over time and capture individual differences and broader beliefs, which in turn contribute to the prediction of specific beliefs within the TPB model. In other words, these variables act as sources from which individuals draw information to develop their personal beliefs about the behaviour [34]. Hence, psychosocial literature (e.g. Ref. [35]) has proposed potential theoretical extensions of the model, emphasising how its predictive efficacy can be enhanced by integrating additional variables tailored to the specific behaviour under consideration. In this context, we will explore the role of two categories of variables that have proven to be valuable additions to the TPB when applied to understanding vaccination intention [41]: 1) anticipated affective reactions and 2) distal predictors of vaccination intention, namely, risk perception, trust in vaccine information sources, and religiosity. These variables consistently exhibited strong associations with Covid-19 vaccination intention and attitude, as elaborated below.

1.2.1. Anticipated affective reactions

A recognised limitation of the TPB is that it does not consider affective determinants of health behaviours, which have proven to explain large portions of variance in intention and behaviour [36]. To fill this gap, recent studies have started including, into the TPB, anticipated affective reactions, i.e., emotions that the person expects to feel following the adoption (or non-adoption) of the behaviour [37]. In the context of vaccination, several studies have identified a strong relationship between anticipated *negative* affective reactions and vaccination intention (e.g. Ref. [38]). Notably, significant attention has been dedicated to *anticipated regret*. Regret is an emotional state experienced when contemplating the possibility that a certain situation could have turned out better if one had chosen to behave differently [39]. Anticipating regret involves imagining the future negative consequences that may result from the choice to adopt or not adopt a particular behaviour. This anticipation tends to evoke the same emotion in the present, consequently influencing motivation to act in a particular direction [40]. Anticipated regret has emerged as a key factor in influencing the decision to get vaccinated [38] and to vaccinate children [41] in the context of traditional vaccinations. It also plays a significant role in shaping intention to get vaccinated against Covid-19 [42].

Conversely, anticipated *positive* affective reactions (e.g., *anticipated pride* for getting vaccinated) have received less attention, although recent studies have suggested their potential impact on fostering Covid-19 vaccination intention [43]. This implies that integrating both components into the TPB could provide a more comprehensive understanding of vaccination motivation.

1.2.2. Risk perception

Risk perception is a multi-faceted construct, including cognitive (e.g., perceived probability of getting sick) and affective (e.g., worry about getting sick) dimensions that impact health decisions and behaviours [44]. A substantial body of research [45,46] has consistently demonstrated the significant influence of both components of risk perception on vaccine acceptance or hesitancy. Moreover, ample evidence supports the indirect relationship between risk perception and intention, mediated by attitude, within the TPB framework [24,47,48]. For instance, Li and Li [47] examined factors influencing intention to receive human papillomavirus vaccination and incorporated risk perception as a distal predictor in their extended TPB model. The findings revealed that risk perception significantly predicted both attitude and intention, with a stronger association observed with attitude.

Similar results have emerged in studies investigating intention to get vaccinated against Covid-19. In this respect, Fan et al. [24] integrated the TPB model with risk perception as an antecedent of vaccination attitude, coming to the conclusion that risk perception positively influenced attitude towards vaccination, which, in turn, emerged as the strongest predictor of intention to get vaccinated. Similarly, Seddig et al. [48] examined an extended TPB model which included the affective component of risk perception as a predictor of vaccination attitude and demonstrated that this variable was one of the strongest positive predictors of attitude. Overall, these findings underscore the utility of integrating risk perception within the TPB model as a distal predictor of Covid-19 vaccination intention.

1.2.3. Trust in vaccine information sources

Individuals' attitudes towards Covid-19 vaccination are likely to be affected by their levels of trust in the sources of information about vaccination. Extensive evidence suggests that trust in science and institutions (e.g., health authorities) plays a pivotal role in vaccination decision-making. Beliefs that science provided sufficient evidence to support the efficacy of the vaccine and/or that the institutions responsible for managing the vaccination campaign did it properly are somehow prerequisites for holding positive attitudes towards vaccines [49]. Recently, studies focusing on Covid-19 vaccination have provided further evidence for the relationships between trust and attitude towards vaccination [50–53]. For instance, Paul et al. [52] conducted a study with 32,361 British adults to explore predictors of negative attitudes towards the Covid-19 vaccine. The findings revealed that lower levels of trust in institutions (such as the health system and government) were associated with increased distrust in vaccine safety and greater concerns about vaccination side effects.

Moreover, several studies have integrated such a variable into the TPB model [25,48,54]. Seddig et al. [48], for instance, demonstrated that trust in science, followed by affective risk perception, emerged as the strongest predictor of favourable attitudes towards Covid-19 vaccination. Similarly, Servidio et al. [54], testing an integrated TPB model in a sample of 276 Italian cancer patients, found that higher levels of trust in healthcare institutions were associated with more favourable attitudes towards Covid-19 vaccination. These findings highlight the role of trust, both in science and institutions, as another key distal predictor of vaccine intention.

1.2.4. *Religiosity*

Finally, a recent body of research has explored the relationship between religiosity and the acceptability of scientific discoveries,

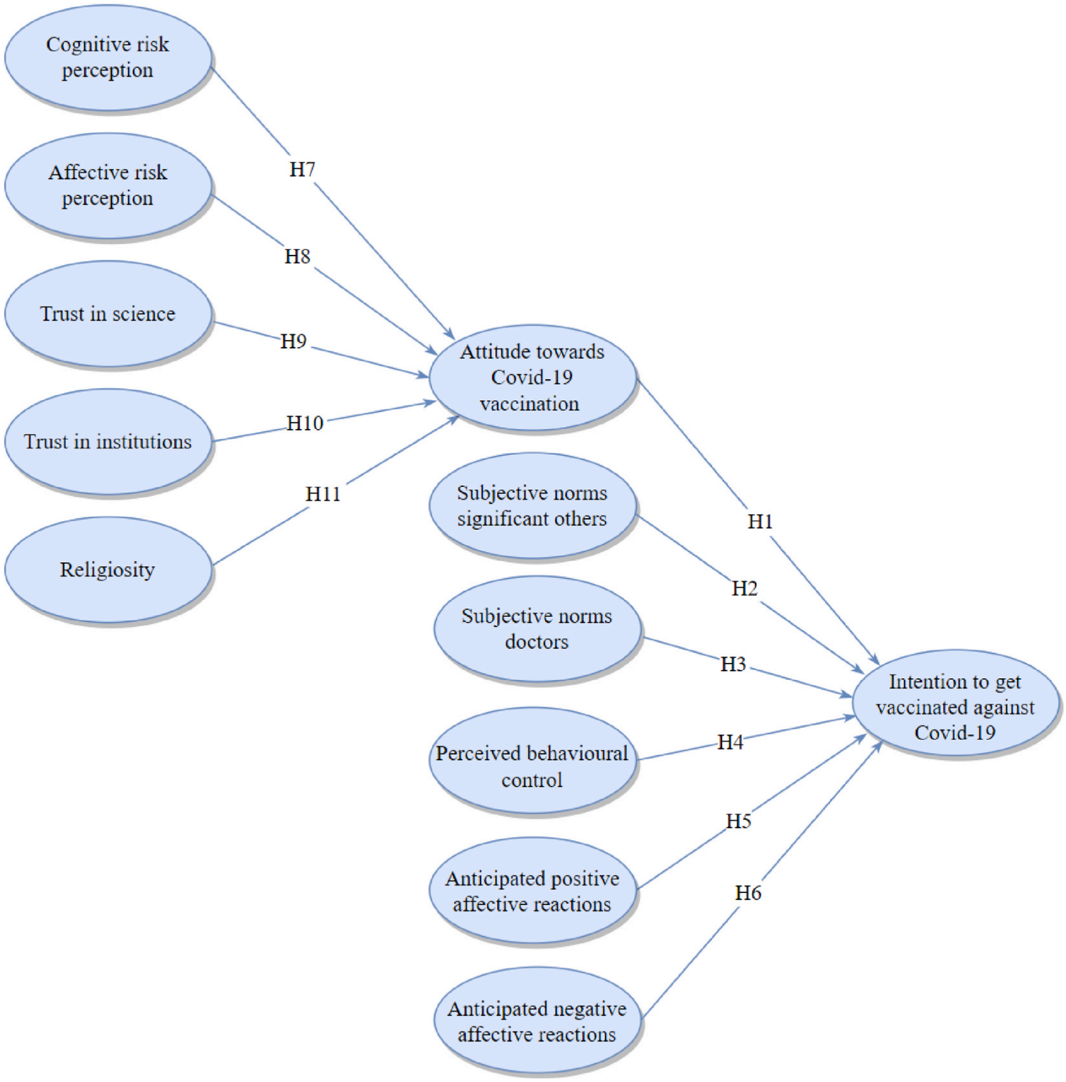

Fig. 1. Hypothesised extended TPB model.
Note. It is important to note that the operationalisation of intention partially differed based on the study phase (see Paragraph 2.2). The figure represents the overall “intention to get vaccinated against Covid-19” for the sake of simplicity and synthesis.

including vaccines [55]. Concerning Covid-19 vaccination, most studies have consistently demonstrated a negative impact of religiosity on vaccination attitudes and intentions [56–58]. For instance, Andrade [56] conducted a study with college students, revealing that religious affiliation significantly and negatively predicted vaccine acceptance. Specifically, participants without religious affiliation were more likely to express willingness to get vaccinated compared to Catholics and Protestants. In addition, Dahan et al. [58] investigated the immunisation status of mental health workers, observing that both religious affiliation and religiosity (i.e., their degree of religious orthodoxy) influenced vaccination rates, with the lowest rates reported among participants with more orthodox religious beliefs. Similarly, Berg and Lin [57], in a study testing an integrated TPB model in a representative sample of US adults, revealed that those with higher levels of religiosity were less likely to intend to get vaccinated.

Interestingly, some studies suggested that religious beliefs may enhance hesitant attitudes towards vaccines when associated with less confidence in science or poor scientific literacy, which may prevent understanding the reasons that make vaccination a necessity [59]. In this sense, the belief that there is a Divinity controlling all domains of one's life (including health), along with scientific scepticism, could be drivers of vaccine hesitancy [60].

In conclusion, in light of the well-acknowledged relationship between religiosity and attitude towards vaccination and taking into account that science and religion can represent explanatory frameworks of reality with similar functions [55], the inclusion of religiosity as a further distal predictor of vaccination intention in the TPB model could significantly enrich the understanding of the factors influencing the acceptability of Covid-19 vaccination.

1.3. The present study

In light of the above, the theoretical framework of this study is constituted by an extended version of the TPB, considering: 1) anticipated affective reactions (positive and negative) as additional predictors of intention to get vaccinated against Covid-19; 2) risk perception (both in its cognitive and affective components), trust in science, trust in institutions and religiosity as additional predictors of attitude towards vaccination. Specifically, the present study aimed to test the efficacy of this hypothesised extended TPB model in predicting intention to get vaccinated against Covid-19 in three different convenience samples recruited at three time points (T1: November–December 2020; T2: March–May 2021; T3: February–March 2022).

More in detail, our investigation focused on two research questions. First, we aimed to test the differences between the three time points in the mean scores of the variables included in the model (*RQ1*). Regarding this, it was reasonable to expect that the mean scores of the constructs would not have been stable in the three phases of the study. Firstly, this is because they were not measured on the same sample. Secondly, acquiring new information about vaccines (e.g., their effectiveness over time) may have modified people's beliefs about vaccination behaviour, increasing or reducing its acceptability.

A further objective of this study was to test the effectiveness of the extended TPB model (Fig. 1) in predicting intention to get vaccinated against Covid-19. In particular, it has been hypothesised that intention to get vaccinated was positively predicted by attitude (H1), subjective norms about significant others (H2) and about doctors (H3), PBC (H4), anticipated positive (H5) and negative (H6) affective reactions. In addition, it has been hypothesised that attitude towards vaccination was positively predicted by cognitive (H7) and affective (H8) risk perception, trust in science (H9), and trust in institutions (H10), and negatively predicted by religiosity (H11). Finally, we tested the stationarity of model predictors, i.e., whether the relationships between the variables in the model varied over time. We did so by analysing the invariance of structural relationships across the considered three time points (*RQ2*). In this regard, we did not formulate specific predictions based on the existing literature.

2. Method

2.1. Participants and procedure

In the present study, we adopted a repeated cross-sectional research design, administering self-report questionnaires to three convenience samples at the three previously described time points.

Using a medium-sized effect ($\delta = 0.30$, which indicates the smallest correlation between latent variables that the researcher aims to detect based on sample and model [61]), alpha = .05, power = .80, and taking into account the number of observed (41) and latent variables (12), an *a priori power analysis* for Structural Equation Models [62] indicated that a minimum sample size of 200 per survey would have been appropriate to achieve the specified effect. Overall, $N = 2080$ participants took part into the study ($N = 657$ for T1, $N = 818$ for T2, and $N = 605$ for T3). Thus, our actual sample sizes were more than adequate to test the hypotheses.

The research was conducted online using the "Google Forms" platform. Specifically, the questionnaires were shared through various generic Italian Facebook groups. Prior to sharing, the purpose of the study was explained to the administrators of these groups, and their approval was obtained. Once the administrators granted permission, an invitation post was published in the groups. The post included information about the institutional affiliation of the research team and invited members of the groups to participate in a study that aimed to investigate the psychological factors influencing the acceptability of Covid-19 vaccination. In the post, we also provided details about the criteria for participation and the estimated time required to complete the questionnaire, and assured respondents about the anonymity of data collection and the confidential nature of their participation. A link to access the questionnaire was included in the invitation post. Participation was voluntary, and no incentive for participation was offered.

Regarding inclusion criteria, at T1, no vaccine against Covid-19 was authorised for administration; thus, vaccination represented only a *future eventuality*. For this reason, the questionnaire was addressed to all unvaccinated people who met the following characteristics: being of legal age (≥18 years) and residing in Italy. In this phase, participants answered items about the *future* vaccine against

Covid-19.

At T2, four vaccines were authorised (Comirnaty, Spikevax, Vaxzevria, Jcovden [63]) and offered to the population based on the order of priority defined by the *National strategic plan of vaccines for the prevention of SARS-CoV-2 infections* drawn up and disseminated by the Italian Ministry of Health [64]. Net of such order of priority, at this stage, vaccination became a *practical possibility* for all Italian adults, although certain groups (for example, the younger ones) might have had to wait a few months to schedule their vaccination. Thus, we administered the second questionnaire to all Italians who, according to the indications of the Strategic Plan, currently had or would have had, in a few months, the opportunity to get vaccinated, i.e., all individuals of legal age (≥18 years) and residing in Italy (as we did for the first questionnaire). For the second questionnaire, participants were asked to respond to items by considering the vaccine they believed would actually be administered to them based on the vaccination plan.

At T3, in Italy, the administration of a booster dose was already authorised for people who had completed the primary vaccination cycle. At the start of the third data collection (February 22, 2022), the recorded vaccination rate for the first booster dose was 84 % [3]. Therefore, considering the high vaccination rate and the consequent considerable difficulty in recruiting individuals who have not yet been vaccinated, we decided to administer the last questionnaire to individuals of legal age (≥18 years), residing in Italy, and who had already received the booster dose. Participants, in this case, were asked about their intention to *continue vaccinating* and answered questions about the future opportunities to get vaccinated, regardless of the possible authorities' provisions (e.g., authorisation of further booster doses).

Respondents completed questionnaires after being informed of the anonymity of the data collection and giving their informed consent. A subset of the data from T1 and T2 has been published previously [43,49] for investigating different hypotheses.

2.2. Measures

2.2.1. Socio-demographic data and past vaccination behaviour

In the first section of the questionnaires, we collected participants' socio-demographic characteristics, such as age, gender, socio-economic status, education, marital status, political and religious orientation. In addition, participants were asked to indicate whether they knew people who had contracted Covid-19, whether they had ever tested positive for the virus, and their past vaccination behaviour. This included information on whether they received vaccinations which are mandatory in Italy (poliovirus, diphtheria, tetanus, hepatitis B, pertussis, Haemophilus influenzae type b, measles, rubella, mumps, and varicella vaccinations), flu vaccination, and other recommended vaccinations (e.g., papillomavirus and meningococcal vaccinations).

At T2 and T3, we asked participants to indicate if they belonged to a population category for which Covid-19 vaccination was mandatory in Italy (e.g., health workers [7]). Despite collecting this information, we made the deliberate decision not to exclude these participants from the analysis, based on two main reasons. First, the number of participants in these categories was relatively small compared to the overall sample size (1.8 % of T2 participants and 6.6 % of T3 participants). Second, we believe that getting vaccinated due to obligation does not necessarily indicate a positive attitude towards vaccination, considering the complex nature of vaccine hesitancy [65]. By including these individuals, we aimed to capture the full spectrum of experiences and attitudes towards vaccination within our study sample. We controlled for this variable in ANCOVA analyses, as specified in the related section.

2.2.2. Psychological variables

In the subsequent sections of the questionnaires, we measured extended TPB variables. As for the traditional TPB constructs and anticipated affective reactions, item formulations showed minor variations depending on whether the questionnaire evaluated intention to receive the future vaccine (T1), the vaccine currently planned by the vaccination campaign (T2), or additional doses of the vaccine in the future (T3). All TPB (and anticipated affective reactions) items were formulated following the guidelines proposed by Ajzen [66] and adapted to each phase of data collection. In contrast, items related to distal predictors of intention were formulated identically in the three questionnaires.

Intention (3 items; $\alpha = 0.98$ at T1, 0.96 at T2, 0.97 at T3), subjective norms about significant others (3 items; $\alpha = 0.94$ at T1, 0.94 at T2, 0.96 at T3) and doctors (3 items; $\alpha = 0.91$ at T1, 0.94 at T2, 0.95 in at T3), PBC (2 items; $\alpha = 0.87$ at T1, 0.90 at T2, 0.93 at T3), anticipated positive (3 items; $\alpha = 0.91$ at T1, 0.90 at T2, 0.94 at T3) and negative affective reactions (3 items; $\alpha = 0.90$ at T1, 0.87 at T2, 0.90 at T3) were evaluated using 5-point Likert scales from *completely disagree* (1) to *completely agree* (5).

Attitude ($\alpha = 0.91$ at T1, 0.90 at T2, 0.94 at T3) was measured with 5 items using a semantic differential scale from 1 (negative pole) to 5 (positive pole).

Risk perception was measured by adapting the "Covid-19 Perceived Risk Scale" [67]. The scale evaluates cognitive and affective dimensions of risk perception about contracting Covid-19. Specifically, the cognitive component ($\alpha = 0.82$ at T1, 0.85 at T2, 0.90 at T3), which measures the perceived probability of getting sick, was evaluated using 2 items on a 5-point scale from *negligible* (1) to *very large* (5). The affective component ($\alpha = 0.86$ at T1, 0.86 at T2, 0.89 at T3), which instead refers to the worry of getting sick (or that loved ones get sick), was measured with 4 items on a 5-point scale from *not at all worried* (1) to *very worried* (5).

Trust in science ($\alpha = 0.91$ at T1, 0.92 at T2, 0.94 at T3) was measured using 7 items [68] assessing trust and general acceptance of the scientific method, using a 6-point Likert scale from *completely disagree* (1) to *completely agree* (6).

Trust in institutions ($\alpha = 0.83$ at T1, 0.86 at T2, 0.87 at T3) was measured through 3 items [69], which were evaluated on a 5-point scale from *not at all* (1) to *very much* (5) and referred to trust in the authorities' ability to respond effectively to the pandemic emergency.

Religiosity ($\alpha = 0.92$ at T1, 0.94 at T2, 0.93 at T3) was measured using the "Intrinsic Religiosity" subscale of the "Duke University Religion Index" [70], which includes 3 items assessing the degree of religious "commitment," i.e., practising religion as an end in itself, rather than as a means to achieve other goals (e.g., maintaining a certain social status). Items were evaluated on a 5-point scale from *definitely not true* (1) to *definitely true* (5).

Full questionnaire is reported in Appendix (Section 1).

2.3. Data analysis

Before conducting statistical analyses, we checked the data using Microsoft Excel, which involved eliminating duplicated data and transforming raw data into coded form. Data consistency was further ensured through Google Forms, where predefined ranges and response constraints minimised the risk of invalid values, particularly for psychological variables. Open-ended variables (e.g., demographic variables with the "other" option) were carefully examined to ensure the absence of invalid responses and to enhance consistency among similar responses with potential typing errors. Statistical analyses were then conducted using R 4.1.2 and SPSS 29 statistical softwares, beginning with an examination of descriptive statistics for all study variables. Therefore, before exploring any differences in the mean scores of the psychological variables, Chi-square (χ^2) tests were carried out to verify whether the participants' socio-demographic characteristics significantly differed between the time points.

Subsequently, to answer *RQ1*, we conducted ANCOVAs (Analysis of Covariance) to compare the three time points on the dependent variables, controlling for socio-demographic characteristics that proved to be significantly different between the three data collections. Following Barbaranelli [71], we first examined the key assumptions of ANCOVA: 1) linearity of the relationship between the dependent variable and covariates, and 2) homogeneity of the regression coefficients (i.e., absence of interactions between the independent variable and covariates). The first assumption was verified by visually inspecting the distribution of residuals through scatterplots for each dependent variable. Then, we checked the second assumption by calculating interaction terms between each covariate and group factor and tested their effect on each dependent variable. Where the interaction terms were not significant, we considered the assumption verified. As we found minor violations (i.e., some interaction terms revealed to be significant), we conducted nonparametric tests (i.e., Quade's tests) to confirm the observed pattern of results from the ANCOVAs. The results from parametric and nonparametric tests showed almost complete comparability. Therefore, we present the findings from the ANCOVAs below, noting any discrepancies observed in the nonparametric tests. Finally, post-hoc comparisons (Bonferroni) were performed to clarify the direction of the significant differences.

In order to test the hypothesised model and answer *RQ2*, a multi-group *Structural Equation Modeling* (SEM [72]) analysis was carried out with the R package lavaan [73]. Since our data were not completely normally distributed (Skewness and Kurtosis values $> |1|$ for attitude, perceived behavioural control, and religiosity), parameters were estimated using the robust version of the maximum likelihood method (MLM) [74]. In fact, MLM enables computing goodness-of-fit statistics even when assumptions of normality are not met, providing robust standard errors and a mean-adjusted chi-square test statistic [75]. The goodness of the fit for the overall model was evaluated with the following fit indices: Chi-square (χ^2) test, CFI (Comparative Fit Index), TLI (Tucker-Lewis Index), RMSEA (Root Mean Square Error of Approximation), and SRMR (Standardised Root Mean Square Residual). Not significant Chi-square, CFI and TLI $\geq$0.90, and RMSEA and SRMR $\leq$0.08 are indicative of an adequate fit [76].

After testing the overall model in relation to the measurement model and the hypothesised structural relationships (Fig. 1), a multi-group analysis was performed, considering the time point as the grouping variable. Differently from how we proceeded for the comparison between variables mean scores at the three time points (i.e., comparing each pair of means), for this analysis, we proceeded iteratively, first testing the invariance of structural relationships in the T1 *vs* T2 samples and subsequently between the T1 + T2 *vs* T3 samples. We selected to proceed this way after analyses indicated invariance across the first two time points, negating the value of separately comparing each of T1 and T2 with the T3 sample. In both steps, we first tested factor loadings invariance, comparing the model in which the latters were constrained to be equal in the two groups (*weak invariance* model) with the model in which they were free to vary (*configural invariance* model). Indeed, weak invariance is a minimum requirement to test the invariance of structural coefficients [77]. Measurement invariance tests were conducted relying on the criteria proposed by Chen [78], according to which invariance is supported when the fit of the most constrained model is not significantly worse than the fit of the least constrained model, i.e., when the difference between the CFIs (ΔCFIs) of the two models is ≤ -0.010 and the difference between the two RMSEAs (ΔRMSEA) is ≤ 0.015. Finally, once factor loadings invariance was confirmed, to test the possible effect moderation of the time point (i.e., whether time point influenced the strength and significance of the structural relationships), the *weak invariance* model was compared with a model in which structural coefficients were also constrained to be equal in the two groups (*structural invariance* model), using Chi-square difference ($\Delta\chi^2$) tests. Where differences in Chi-square reached significance ($p < .05$), we constrained one path at a time to identify which ones differed between the two groups. All responses to the three questionnaires were mandatory, so there were no missing values.

3. Results

3.1. Participants' characteristics and preliminary analyses

Participants' characteristics across the three samples are summarised in Table 1. Chi-square tests showed that participants at the three time points significantly differed on all considered variables except marital status and past vaccination behaviour (mandatory and recommended vaccinations).

Table 1
Participants' characteristics and Chi-square tests.

	T1 *n* (%)	T2 *n* (%)	T3 *n* (%)	χ^2	Cramer's V
Age range					
18–29	305 (14.7)	340 (16.3)	174 (8.4)	136.27***	.18***
30–39	83 (4)	62 (3)	110 (5.3)		
40–49	95 (4.6)	203 (9.8)	126 (6.1)		
50–59	148 (7.1)	155 (7.5)	101 (4.9)		
>59	26 (1.3)	58 (2.8)	94 (4.5)		
Gender					
Women	426 (20.5)	551 (26.5)	434 (20.9)	40.46***	.10***
Men	231 (11.1)	263 (12.6)	154 (7.4)		
Other	0 (0)	4 (0.2)	17 (0.8)		
Socio-economic status					
Low	89 (4.3)	144 (6.9)	97 (4.7)	15.85**	.06**
Middle	477 (22.9)	608 (29.2)	448 (21.5)		
High	91 (4.4)	66 (3.2)	60 (2.9)		
Education					
Compulsory education	53 (2.5)	84 (4)	34 (1.6)	41.15***	.10***
High school diploma	254 (12.2)	383 (18.4)	285 (13.7)		
Degree	283 (13.6)	306 (14.7)	212 (10.2)		
Post-degree training	67 (3.2)	45 (2.2)	74 (3.6)		
Marital status					
Single	188 (9)	228 (11)	176 (8.5)	17.71	.06
Married	217 (10.4)	305 (14.7)	240 (11.5)		
In a romantic relationship	213 (10.2)	226 (10.9)	156 (7.5)		
Separated	17 (0.8)	27 (1.3)	10 (0.5)		
Divorced	13 (0.6)	23 (1.1)	17 (0.8)		
Widow/Widower	9 (0.4)	9 (0.4)	6 (0.3)		
Political orientation					
Left-wing	252 (12.1)	288 (13.8)	206 (9.9)	16.84*	.06*
Centre	73 (3.5)	78 (3.8)	66 (3.2)		
Right-wing	77 (3.7)	116 (5.6)	87 (4.2)		
Apolitical	228 (11)	314 (15.1)	209 (10)		
Other	27 (1.3)	22 (1.1)	37 (1.8)		
Religious orientation					
Practising Catholic	130 (6.3)	167 (8)	98 (4.7)	56.11***	.12***
Non-practising Catholic	291 (14)	375 (18)	273 (13.1)		
Atheist	180 (8.7)	205 (9.9)	122 (5.9)		
Agnostic	33 (1.6)	36 (1.7)	79 (3.8)		
Other	23 (1.1)	35 (1.7)	33 (1.6)		
Mandatory vaccinations					
Yes	624 (30)	787 (37.8)	587 (28.2)	3.57	.04
No/Do not remember	33 (1.6)	31 (1.5)	18 (0.9)		
Flu vaccination in the past year					
Yes	140 (6.7)	141 (6.8)	157 (7.5)	15.92***	.09***
No/Do not remember	517 (24.9)	677 (32.5)	448 (21.5)		
Flu vaccination in past flu seasons					
Yes	197 (9.5)	228 (11)	228 (11)	16.44***	.09***
No/Do not remember	460 (22.1)	590 (28.4)	377 (18.1)		
Recommended vaccinations					
Yes	232 (11.2)	314 (15.1)	250 (12)	4.82	.05
No/Do not remember	425 (20.4)	504 (24.2)	355 (17.1)		
Knowing someone infected with Covid-19					
Yes	586 (28.2)	770 (37)	603 (29)	63.10***	.17***
No	71 (3.4)	48 (2.3)	2 (0.1)		
Tested positive for Covid-19					
Yes	35 (1.7)	77 (3.7)	144 (6.9)	110.07***	.23***
No	622 (29.9)	741 (35.6)	461 (22.2)		

Note. *$p < .05$; **$p < .01$; ***$p < .001$.

3.2. Comparison between the time points

ANCOVAs on extended TPB variables were performed controlling for the effect of age, gender, socio-economic status, education, political orientation, religious orientation, adherence to the flu vaccine in the last year and past flu seasons, knowledge of Covid-19 positive people, having tested positive to the virus and belonging to a population category subject to vaccination obligation (1.8 % of T2 participants and 6.6 % of T3 participants). In response to *RQ1*, results (Table 2) showed statistically significant differences between the time points for all considered variables. Full results, including the effects of covariates, are reported in Appendix (Section 2).

Table 2
Differences in psychological variables between the three time points.

Variable	T	M (SD)	F	Partial η^2	Sig. pairwise comparisons
Intention	1	3.86 (1.19)	118.61***	.10	T1<T2***; T2>T3***; T3<T1***
	2	4.32 (1.00)			
	3	3.32 (1.36)			
Attitude	1	3.89 (0.92)	71.64***	.07	T1<T2***; T2>T3***; T3<T1***
	2	4.13 (0.81)			
	3	3.48 (1.13)			
Subjective norms (significant others)	1	3.59 (0.94)	113.43***	.10	T1<T2***; T2>T3***; T3<T1[a]**
	2	4.17 (0.93)			
	3	3.39 (1.19)			
Subjective norms (doctors)	1	4.00 (0.93)	70.26***	.06	T1<T2***; T2>T3***; T3<T1***
	2	4.27 (0.84)			
	3	3.63 (1.06)			
PBC	1	3.41 (1.15)	25.91***	.02	T1>T2**; T2<T3***; T3>T1***
	2	3.18 (1.29)			
	3	3.67 (1.31)			
Anticipated positive affective reactions	1	3.57 (1.13)	56.85***	.05	T1<T2***; T2>T3***; T3<T1[a]**
	2	3.94 (1.01)			
	3	3.31 (1.26)			
Anticipated negative affective reactions	1	3.60 (1.11)	64.28***	.06	T1<T2***; T2>T3***; T3<T1***
	2	3.90 (1.01)			
	3	3.18 (1.24)			
Cognitive risk perception	1	2.91 (0.78)	6.01**	.01	T1>T2[b]*; T3<T1**
	2	2.83 (0.76)			
	3	2.86 (0.96)			
Affective risk perception	1	3.70 (0.80)	84.11***	.08	T2>T3***; T3<T1***
	2	3.63 (0.77)			
	3	3.05 (0.93)			
Trust in science	1	3.88 (1.58)	14.65***	.01	T1<T2**; T1<T3**
	2	4.15 (1.09)			
	3	4.05 (1.23)			
Trust in institutions	1	2.21 (0.78)	8.97***	.01	T2<T3***; T1<T3**
	2	2.18 (0.77)			
	3	2.38 (0.87)			
Religiosity	1	2.48 (1.33)	15.96***	.02	T2>T3***; T3<T1***
	2	2.52 (1.29)			
	3	2.28 (1.26)			

Note. *$p < .05$; **$p < .01$; ***$p < .001$. [a]Comparison not found to be statistically significant in the Quade's test. [b]Comparison statistically significant only in the Quade's test.

3.3. *Testing the extended TPB model*

Except for the Chi-square test ($\chi^2 = 4741.410$, df = 723, $p < .001$), the overall fit statistics for the extended TPB model ($N = 2080$) all indicated adequate fit (CFI = 0.948; TLI = 0.941; RMSEA = 0.052; SRMR = 0.086). Concerning the measurement model, all factorial loadings were statistically significant ($p < .001$), with standardised values ≥ 0.70. Regarding the structural model, almost all the hypothesised paths were statistically significant. Specifically, intention was positively predicted by attitude (β = 0.48; $p < .001$), subjective norms about significant others (β = 0.20; $p < .001$), anticipated positive (β = 0.15; $p < .001$) and negative affective reactions (β = 0.24; $p < .001$), confirming H1, H2, H5 and H6. Contrary to the hypotheses (H3 and H4), we found no statistically significant effect of subjective norms about doctors and PBC on intention. In addition, as hypothesised (H8, H9, H10 and H11), attitude was significantly and positively predicted by affective risk perception (β = 0.52; $p < .001$), trust in science (β = 0.19; $p < .001$) and trust in institutions (β = 0.21; $p < .001$), and negatively influenced by religiosity (β = −0.09; $p < .001$). Contrary to what was hypothesised (H7), the cognitive component of risk perception did not affect attitude. Overall, the variables included in the model explained a high percentage of variance in intention to get vaccinated (R^2 = 75 %) and attitude towards vaccination (R^2 = 41 %).

Finally, considering that in the previous analyses we found some covariates to be significantly correlated with intention (i.e., age, socio-economic status, political orientation, and adherence to flu vaccination in the last year and the past flu seasons; see Appendix, Section 2), we repeated the full model test by controlling for their effect on intention. Results revealed that the estimated regression coefficients remained unchanged even with the inclusion of these variables, confirming the consistency of the structural relationships regardless of the impact of the socio-demographic characteristics considered.[2] Thus, to avoid unnecessary complexity in the subsequent analysis, we proceeded with multi-group tests without including these covariates.

[2] Control variables effects on intention: age: β = −0.05, $p < .001$; socio-economic status: β = 0.01, $p = .67$; political orientation: β = −0.02, $p = .21$; adherence to flu vaccination in the last year: β = −0.03, $p < .05$; adherence to flu vaccination in the past flu seasons: β = 0.00, $p = .94$.

3.4. Multi-group analysis

To answer RQ2, we first estimated the model independently for each group. Results indicated that the model adequately fitted in all three time points (T1: $\chi^2 = 2285.179$, df = 723, $p < .001$; CFI = 0.931; TLI = 0.922; RMSEA = 0.057; SRMR = 0.089; T2: $\chi^2 = 2277.602$, df = 723, $p < .001$; CFI = 0.945; TLI = 0.937; RMSEA = 0.051; SRMR = 0.085; T3: $\chi^2 = 2223.631$, df = 723, $p < .001$; CFI = 0.940; TLI = 0.932; RMSEA = 0.059; SRMR = 0.095). To test the moderation of time point (i.e., whether time point influenced the strength and significance of the structural relationships), we first compared T1 with T2 samples, then T1+T2 with T3 samples, as described below. Standardised factor loadings and regression coefficients – specific to the three time points and those deriving from the aggregation of T1 and T2 data – are reported in Appendix (Section 3).

In the first step (T1 *vs* T2), comparing *weak invariance* model ($\chi^2 = 4681.009$, df = 1487, $p < .001$; CFI = 0.937; TLI = 0.931; RMSEA = 0.054; SRMR = 0.089) with *configural invariance* model ($\chi^2 = 4562.780$, df = 1446, $p < .001$; CFI = 0.939; TLI = 0.930; RMSEA = 0.054; SRMR = 0.086), results showed a non-significant worsening of CFI (ΔCFI = −0.002) and RMSEA (ΔRMSEA = 0), thus supporting factor loadings invariance across T1 and T2. Then, comparing fully *structural invariance* model ($\chi^2 = 4708.942$, df = 1498, $p < .001$; CFI = 0.937; TLI = 0.931; RMSEA = 0.054; SRMR = 0.091) with *weak invariance* model, the Chi-square difference test was statistically significant ($\Delta\chi^2 = 27.933$, Δdf = 11, $p = .02$); therefore, we constrained one path at a time to identify which ones differed between the two time points. As shown in Table 3, the only difference approaching statistical significance was for the path "religiosity → attitude". Hence, it can be concluded that the structural relationships were invariant across T1 and T2, supporting the merging of data from the first two data collections.

In the second step (T1+T2 *vs* T3), we proceeded the same way, starting with the comparison between the *weak invariance* model ($\chi^2 = 6019.392$, df = 1487, $p < .001$; CFI = 0.940; TLI = 0.934; RMSEA = 0.054; SRMR = 0.104) and the *configural invariance* model ($\chi^2 = 5718.923$, df = 1446, $p < .001$; CFI = 0.944; TLI = 0.936; RMSEA = 0.053; SRMR = 0.088). Constraining factorial loadings to be equal in the two groups did not cause a significant worsening of CFI (ΔCFI = −0.004) and RMSEA (ΔRMSEA = 0.001); therefore, factor loadings invariance was also verified for this comparison. Moreover, comparing fully *structural invariance* model ($\chi^2 = 6062.837$, df = 1498, $p < .001$; CFI = 0.940; TLI = 0.934; RMSEA = 0.054; SRMR = 0.106) with weak invariance one, the Chi-square difference test was statistically significant ($\Delta\chi^2 = 43.445$, Δdf = 11, $p < .001$). Hence, we constrained one path at a time to identify which ones differed between the two groups. Results (Table 3) showed that the only path where invariance did not hold was "trust in institutions → attitude", indicating a stronger effect of trust in institutions on attitude at T3 ($\beta = 0.33$; $p < .001$) compared to the other two time points ($\beta = 0.19$; $p < .001$). Therefore, it can be concluded that, except for such a path, the structural relationships were invariant between the three stages of the study.

4. Discussion

The present study aimed to test the validity of an extended version of the Theory of Planned Behaviour [15] in predicting intention to get vaccinated against Covid-19 at three different stages of the pandemic (before, during and after the start of the vaccination campaign in Italy).

In response to *RQ1*, we found statistically significant differences between the time points in relation to all the psychological variables investigated, highlighting, in general, an improvement trend in the mean scores of the latters between T1 and T2, followed by a worsening at T3 compared to the other two. Intention, attitude, subjective norms and anticipated affective reactions significantly increased from the phase where vaccination against Covid-19 represented only a *future* eventuality (T1) to the one in which the vaccination campaign was open to a large part of the population (T2). These results align with international studies [12,13,25,79,80] carried out between February and June 2021. This improvement could be attributed to the fact that, during this period, the benefits of vaccination began to be evident, translating into a substantial reduction in the number of infected, hospitalisations, and deaths from Covid-19 [81]. However, unexpectedly, PBC decreased significantly with the start of the vaccination campaign (T2), probably because in this initial phase it was not possible to express a preference for the type of vaccine to receive (e.g., mRNA vaccine *vs* viral vector vaccine). In addition, the timing and modalities of vaccination strictly depended on the availability of vaccines, which was not always

Table 3
Tests of invariance of path coefficients across time points.

Constrained path	T1 *vs* T2		T1+T2 *vs* T3	
	$\Delta\chi^2_{(1)}$	*p*	$\Delta\chi^2_{(1)}$	*p*
Attitude → Intention	0.01	.91	1.44	.23
Subjective norms (significant others) → Intention	0.03	.87	0.35	.55
Subjective norms (doctors) → Intention	1.39	.24	0.80	.37
PBC → Intention	0.02	.88	1.21	.27
Anticipated positive affective reactions → Intention	0.08	.78	1.43	.23
Anticipated negative affective reactions → Intention	2.39	.12	1.19	.27
Cognitive risk perception → Attitude	1.07	.30	0.52	.47
Affective risk perception → Attitude	0.32	.57	2.00	.16
Trust in science → Attitude	2.17	.14	0.03	.87
Trust in institutions → Attitude	1.63	.20	14.06	.00
Religiosity → Attitude	3.47	.06	1.84	.18

sufficient to promptly meet the population's demand [82].

On the other hand, results showed a decrease in vaccination intention and most of its proximal predictors one year after the start of the vaccination campaign. A noteworthy finding pertains to the comparison between T1 and T3: vaccination intention levels in 2022 were significantly lower even than those detected in 2020, when complete information on the characteristics of candidate vaccines was not yet available. As suggested by Hagger and Hamilton [34], intention to continue vaccinating (and variables predicting it) could be negatively influenced by beliefs developed in response to new information about the virus and previous experience with vaccination. Such beliefs could include the idea that the virus has become less dangerous, that the vaccine is no longer as effective as before, or that receiving an additional dose is unsafe [83].

Trends related to the distal predictors showed less linearity. Cognitive risk perception remained almost unchanged in the first two samples and was significantly lower in the T3 sample compared to the T1 sample. Additionally, affective risk perception was significantly lower at T3 than at the other two time points. Overall, these data could further support a shift in the representation of the severity of the virus, which probably occurred due to the spread of more contagious – yet less dangerous – mutations of Sars-Cov-2 [5]. Moreover, trust in science increased from T1 to T2 (when clearer and more reliable information on the vaccine was available) and did not show substantial changes one year after the start of the vaccination campaign. Conversely, trust in institutions remained stable in the first two phases. Such a result may align with studies [50] revealing that, during the pandemic, distrust in institutions was motivated by the perception that they were unable to make correct and effective decisions regarding the management of the pandemic. This distrust may have reached its peak in the first two phases of the study, i.e., when the government was faced with the need to make quick decisions to control the spread of the virus, often perceived as confusing or non-transparent by the population [84]. Instead, trust in institutions increased in the third phase, characterised by fewer sudden changes related to the approval of new regulations to contain the pandemic. Finally, concerning religiosity, the lowest levels were reported at T3. These differences are likely independent of any potential changes in vaccination acceptability and may be attributed to the slightly lower proportion of practising Catholics in the T3 sample compared to T1 and T2 samples. Indeed, it is worth noting that religious commitment is often higher among individuals who actively attend church [85]. Therefore, the reduced number of churchgoers in the T3 sample may have contributed to the lower levels of religiosity observed at that time point.

In response to *RQ2*, the findings of the multi-group SEM analysis confirmed the predictability of the hypothesised extended TPB model and, above all, the almost complete invariance of structural relationships in the three phases of the study. This result is consistent with studies that have demonstrated the effectiveness of TPB in predicting vaccination intention before [31,42,86,87] and during [24,25,54] the vaccination campaign, as well as intention to receive additional doses of the vaccine [34,88,89]. Furthermore, it indicates that although vaccination intention may decline over time, its key predictors (proximal and distal) shape it with the same strength and importance. Thus, compared to the existing literature, the results of this study are particularly innovative since they not only support the predictive potential of the extended TPB in three different phases of the vaccination campaign but also demonstrate stationarity in predictions of intention and attitude. This reinforces the idea that, regardless of the phase of the vaccination campaign, interventions aimed at promoting the acceptability of vaccination against Covid-19 should continue to focus on a series of target variables, for example, attitude, anticipated affective reactions, subjective norms, risk perception and trust, as detailed below.

As for the "proximal" predictors of vaccination intention, at all three time points, the most impactful was represented by attitude, followed by anticipated affective reactions and subjective norms related to the significant others. As for attitude, this result is in line with studies (e.g. Refs. [32,90]) showing that favourable attitude is among the most important factors in determining Covid-19 vaccination intention and uptake. The pivotal role of attitude underscores that the promotion of a positive representation of a new vaccine, based on clear, unambiguous and reliable information, is of crucial importance both when such a vaccine is introduced and approved for administration and in the later stages, when the levels of vaccination intention may decrease. In addition, the association identified, across all stages, between anticipated affective reactions and vaccination intention further suggests that the feelings that a person expects to experience after deciding (or not) to get vaccinated represent key predictors not only of intention to get vaccinated against Covid-19 for the first time but also to *continue* to do so over time. Such a result also aligns with a recent scoping review of studies conducted between 2021 and 2022 [91], showing a strong association between anticipated affective reactions – particularly inaction anticipated regret – and Covid-19 vaccination intention and behaviour.

Surprisingly, subjective norms about doctors and PBC did not significantly impact intention at any research stage. In this regard, some studies [92] showed that Italians did not count health workers as key sources of information on the Covid-19 vaccine. It is possible to speculate that the moderate levels of vaccine hesitancy among Italian health professionals [93] might have diminished the trustworthiness of doctors' opinions in the eyes of citizens, making them less influential on the choice to get vaccinated. Such finding suggests a need for interventions to enhance doctors' communicative and relational skills in the Italian context [99,100] in order to bolster their credibility and promote adherence to prevention and vaccination processes. As for PBC, it could be argued that adherence to vaccination does not require particular skills or commitment by individuals, unlike some other health behaviours [12]. Given the absence of significant practical barriers to vaccination in Italy, perceived control may align closely with individuals' *actual control* over the behaviour [18]. Consequently, it is likely that PBC has a direct impact on vaccination adherence to Covid-19.

Concerning the "distal" predictors of vaccination intention, results indicated that attitude was positively predicted by risk perception (but only in its affective component), as well as trust in science and institutions. Conversely, religiosity exerted a negative, albeit weak, effect on attitude. These results are consistent with a prior study from our research group [41] testing the efficacy of a similar extension of the TPB in predicting intentions not to vaccinate their children among a sample of Italian parents who defined themselves as "anti-vaxxers", before the outbreak of the Covid-19 pandemic. In that study, trust in healthcare institutions emerged as the most influential factor associated with parents' attitude towards vaccines, followed by religiosity, trust in science and risk perception. Going beyond that very specific focus (and sample), the results of the present study demonstrated that the hypothesised relationships between these distal factors and attitude might also be valid in the context of Covid-19 vaccination, as detailed below.

Regarding risk perception, some studies [45,88] have shown that the cognitive component can indirectly impact vaccination intention through the mediation of the affective one. In other words, individuals who perceive a greater susceptibility to contracting the disease are more likely to experience negative emotions such as worry, anxiety, or fear of getting sick, which, in turn, could reinforce the choice to adopt the recommended behaviour [94]. This could potentially explain the absence of a direct relationship between cognitive risk and vaccination attitude at any of the three time points.

The positive relationship identified between trust (in science and institutions) and attitude further supports the existing literature demonstrating that a lack of trust is linked to hesitant attitudes towards vaccines, including those against Covid-19 [51–53]. Such distrust could lead people to question the safety and efficacy of vaccines and, as a result, to delay or refuse vaccination [95], even in the advanced stages of the vaccination campaign. Therefore, this finding suggests that enhancing trust in science and institutions through continuous efforts to convey the idea that scientists and policymakers have skills and knowledge, and act transparently and effectively, can result in a more favourable attitude towards Covid-19 vaccination [49].

Ultimately, the weak yet significant negative relationship between religiosity and attitude confirms that a high level of religious commitment, which often entails the belief that one's health depends on an external deity rather than the individual agency, can contribute to scepticism towards scientific discoveries and reduce motivation for vaccination. As argued by Upenieks and colleagues [60], while religiosity may positively impact coping with highly stressful situations, it is also associated with lower levels of analytical thinking and problem-solving skills. These skills are crucial for making informed decisions about one's health, particularly in emergency contexts such as a pandemic. However, it is important to note that the relationship between religiosity and attitude towards vaccination is complex and multi-faceted. Examining a single dimension, as this study did, may not provide a comprehensive understanding of the phenomenon. In fact, research has demonstrated that other dimensions of religiosity, such as active participation in the religious community, can positively influence trust in science, health professionals, and scientific discoveries [96]. Therefore, future studies should explore the relationship between vaccination attitudes and various dimensions of religiosity to gain a deeper understanding of this finding.

5. Limitations

Some drawbacks of the present study must be acknowledged. First, using a repeated cross-sectional design, while offering "snapshots" of the trends related to the acceptability of the Covid-19 vaccine during the pandemic, does not allow changes at intra-individual levels to be identified, a possibility achievable only through a longitudinal design. Second, the non-probabilistic sampling technique employed reduces the generalisability of the results. Third, we relied on different inclusion criteria in the three time points (unvaccinated Italian adults at T1 and T2 *vs* vaccinated Italian adults at T3). Although the constantly evolving nature of the vaccination campaign (and the differences in vaccination rates) made it impossible to use the same inclusion criteria in the three times considered (i.e., at T1, we could only interview the unvaccinated; at T2, the Italians were almost all unvaccinated; at T3, the Italians were almost all vaccinated with the third dose), we are aware that this issue makes the three samples more difficult to compare in absolute terms. As a consequence of using different inclusion criteria, the operationalisations of the TPB variables slightly differed between the three questionnaires. Although the results of the multi-group analysis supported the invariance of the measurement model, from a conceptual point of view, intention (and the related predictors) to receive the *future vaccine*, intention to get the vaccine *currently* provided by the vaccination plan, and intention to *continue* vaccinating may not be completely overlapping. Therefore, it cannot be excluded that the differences identified between the variables mean scores at the three time points reflect, in part, these different facets.

A further limitation concerns the absence of a behavioural measure. However, although healthy intentions do not necessarily translate into behaviour [97], as previously pointed out, several studies [11–14] have shown high associations between Covid-19 vaccination intention and uptake, suggesting that the intention-behaviour "gap" may be less relevant in the context of Covid-19 vaccination.

Finally, we recognise that our chosen background variables (risk perception, trust, and religiosity) may have predictive relationships not only with attitude but also with subjective norms, perceived behavioural control, and even intention directly. For instance, risk perception may affect individuals' subjective norms by shaping their perception of social pressures or expectations related to vaccination. Similarly, religiosity may impact perceived behavioural control by influencing individuals' confidence to overcome barriers and facilitate vaccine uptake. Additionally, these variables could potentially serve as direct predictors of individuals' intention to get vaccinated, independent of their effects on attitude. Exploring these associations in further research would provide valuable insights into the nuanced interplay between background variables and the various components of the TPB model. In addition, we also acknowledge that the hypothesised model, despite its complexity, does not encompass all the factors that may influence the decision to get vaccinated against Covid-19. Therefore, in future studies, it would be valuable to consider integrating the TPB with specific models of vaccine hesitancy, such as the behavioural and social drivers of vaccination (BeSD) model [98], to obtain a more complete understanding of the decision-making process leading (or not) to vaccination.

Despite these limitations, the present study is one of the few investigating the validity of the TPB model in predicting Covid-19 vaccination intention across different phases of the vaccination campaign, also taking into account the impact of a series of "distal" factors. Not only were the examined three stages somewhat distant from a material point of view, but they were also marked by distinct trends in the vaccination campaign. Therefore, it is possible to conclude that if, on the one hand, the difference in the operationalisations of the TPB constructs represents a limit of the research, on the other hand, it is an important strength insofar as results suggest that the hypothesised relationships hold consistently regardless of the phase in which the study was conducted, the participants' characteristics, and the differences in the mean scores of the variables between the three stages. Thus, whether it is an early or later stage of the vaccination campaign, attitude, anticipated affective reactions, and norms continue to be key predictors of intention, as high levels of affective risk perception and trust continue to translate into a favourable attitude towards vaccination.

6. Conclusions

In conclusion, the present study unfolds significant theoretical and practical implications for understanding and promoting Covid-19 vaccination. From a theoretical standpoint, the research affirms the robustness of TPB in predicting intention to vaccinate against Covid-19 at different stages of the vaccination campaign, extending its applicability beyond initial decision-making to the sustained commitment of individuals to continue vaccinating. On a practical note, results highlight that interventions to promote Covid-19 vaccination, to be effective, should focus primarily on attitude, emphasising the safety and efficacy characteristics of the vaccine, as well as addressing affective processes, prompting individuals to reflect on how they would feel if they decided to get vaccinated or not. Simultaneously, in light of the predictability of the considered distal variables, there is a clear need to address risk perception and encourage trust, both in science and institutions. As we navigate the post-pandemic phase, this multi-faceted strategy remains pivotal for fostering a positive environment for continued vaccine acceptance.

Ethics statement

The study was approved by the Ethics Committee of Psychological Research of the Department of Humanities of the University Naples “Federico II” (n° prot. 31/2021).

Data availability statement

Data will be made available on request from the first author. The data are not publicly available because of privacy restrictions, and requests will be handled in compliance with ethical standards to ensure participant confidentiality and data protection.

CRediT authorship contribution statement

Miriam Capasso: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mark Conner:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Daniela Caso:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24826.

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