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A socio-ecological perspective on parents' intentions to vaccinate their children against COVID-19

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ABSTRACT

Introduction: Vaccinating children against COVID-19 protects children's health and can mitigate the spread of the virus to other community members.
Objective: The primary objective of this study was to use a socio-ecological perspective to identify multi-level factors associated with US parents' intention to vaccinate their children.
Methods: This study used a longitudinal online cohort. Multinomial logistic regression models assessed socio-ecological predictors of negative and uncertain child COVID-19 vaccination intentions compared to positive intentions.
Results: In June 2021, 297 parents were surveyed and 44% reported that they intended to vaccinate their children while 25% expressed uncertainty and 31% did not intend to vaccinate their children. The likelihood of reporting uncertain or negative intention, compared to positive intention to vaccinate their children was higher among parents who had not received a COVID-19 vaccination and those who did not have trusted information sources. Parents who talked to others at least weekly about the COVID-19 vaccine were less likely to endorse uncertain compared to positive vaccine intentions (aRRR: 0.44; 95% CI: 0.20–0.93). A sub-analysis identified that parents had significantly higher odds of intending to vaccinate older children compared to younger children (children ages 16–17 years v. 0–4 years OR: 2.01, 95% CI: 1.05–3.84). An additional sub-analysis assessed the stability of parents' intention to vaccinate their children between March 2021 and June 2021 (N=166). There was transition within each intention group between the study periods; however, symmetry and marginal homogeneity test results indicated that the shift was not statistically significant. Parents expressing uncertainty in March 2021 were the most likely to change their intention, with 24% transitioning to positive intention and 23% to negative intention in June 2021.
Conclusion: Study findings suggest that programs to promote vaccination uptake should be dyadic and work to promote child and parent vaccination. Peer diffusion strategies may be particularly effective at promoting child vaccination uptake among parents expressing uncertainty.

1. Introduction

In the United States, over 12.6 million cases of COVID-19 were reported in children as of Winter 2022, representing approximately 19% of total national cases since the beginning of the pandemic [1]. Child vaccination against COVID-19 is critical at both the child and community level as it is highly effective at preventing severe disease for children and can reduce spread to others [2]. The emergency use authorization (EUA) for the Pfizer COVID-19 vaccine was expanded to include children 16 years and older in December 2020 and expanded again to include adolescents aged 12–15 in May 2021 as well as children 5–11 in October 2021 [3]. Yet, as of February 2022, only 25% of children ages 5–11 and 57% of children ages 12–17 had completed the 2-dose vaccine series [4]. Child COVID-19 vaccination trends showed a precipitous decline after a peak at the end of May 2021 [5]. Given findings that adult COVID-19 vaccine behaviors and attitudes are determined in part by multi-level influences; in this study, we used a social-ecological model (SEM) to assess determinants of parents' intentions to vaccinate their children that incorporates intrapersonal, interpersonal, institutional, and community levels [6,7]. Under-

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standing the multi-level influences can aid in the development of COVID-19 prevention interventions which aim to increase vaccine uptake. These understandings can help determine, for example, whether efforts should be focused on parental perceived risk of COVID-19 for their children or on promoting pro-vaccine social norms to improve vaccination rates among children.

In the SEM, the intrapersonal level refers to the demographic and attitudinal factors that influence engagement in prevention strategies [6]. Parents' intention to vaccinate their children may be impacted by parents' sex, race, and political identities as well as attitudes and beliefs towards the vaccine. The sex of the reporting parent has been found to have a mixed effect, with some studies identifying no significant differences and others finding that female parents report lower intention than male parents to get their children vaccinated against COVID-19 [8,9]. Racial and ethnic disparities in parental intentions to vaccinate their children against COVID-19 have been identified, with Black parents less likely to express vaccination intention than white parents [8,9]. These disparities are important to monitor and understand as COVID-19 has a higher incidence among Black young people, though this trend appears to be dissipating over time as incidence has increased among white young people [10]. Political ideology has long been associated with parental vaccination attitudes, with parents espousing conservative ideology less likely to vaccinate than those with liberal ideologies, yet less is known about whether political ideology has the same impact on parental attitudes towards the vaccination of their children [11]. Another key set of intrapersonal level factors is perceived COVID-19 related risks. Studies drawing on behavioral theories such as the Social Amplification of Risk Framework, Expected Utility Theory, and Protection Motivation Theory have found that perceptions of susceptibility to and severity of infection, as well as barriers, impact vaccine intention [6,12,13]. This relationship may be particularly strong for child vaccination against COVID-19 as some parents have expressed that they do not believe their children are at risk. A behavioral attribute associated with child vaccination intention is parental vaccination status. While some parents feel that vaccine risks are less tolerable for children than themselves, parents' COVID-19 vaccination status has previously been found to be a predictor of willingness to get their children vaccinated against COVID-19 [9,12]. Parents who are partially versus fully vaccinated may also differ in their vaccination intentions for their children. Beliefs about the dangers of vaccinations can also serve as a barrier to COVID-19 vaccine uptake for their children [6].

The interpersonal level of the SEM refers to social influence and identifies peer networks as playing a critical role in health behaviors [6]. Social norms have been found to influence child vaccination in general but have not been well explored in the context of COVID-19 vaccination. Social network analysis has shown that parents interact with others whose vaccination behaviors for their children are similar, with vaccine accepters more likely to be surrounded by accepters and refusers by other refusers [14]. A study in China identified that support for vaccination by other family members was associated with positive child COVID-19 vaccination intentions [15]. Another component of social influence is communication about vaccines among peers. Peer communication about vaccination is a critical component of social diffusion of information and may influence vaccine attitudes and behaviors [16]. Diffusion of information through social networks may be particularly critical for some individuals in the context of a lack of trusted information sources about COVID-19.

At the institutional/community level of the SEM, parents' intentions to vaccinate their children may be influenced by the institutions that provide information on vaccines and the perceived prevalence of the virus in their community [6]. Institutions that provide information on vaccine safety can foster trust or mistrust in vaccinations. Mistrust of vaccinations is a long-standing issue. A 2005 study of pediatricians found that 85% reported encountering vaccine refusal in the past year, which they largely attributed to parental concerns about vaccine safety and misinformation [17]. The politicized nature of the COVID-19 pandemic, historical trends in beliefs about the validity of science, and rapid vaccine development process have led to diminished trust in the COVID-19 vaccines [18,19]. Also fueling mistrust is the siege of misinformation about COVID-19, which has been propagated by prominent politicians and celebrities, as well as by peers and advocates on social media [20]. Another community-level factor is the perceived level of the disease in the community. The social context of risk perception is an understudied construct within the vaccine uptake literature [6]. In this study, we assess how having social network members who have tested positive for COVID-19 is associated with parents' vaccine intention for their children.

Parents' intentions to vaccinate their children against COVID-19, or not, may be shaped by individual and socioecological factors; thus, examining the multi-level factors influencing parents' intention to vaccinate their children is the primary aim of this study. In this research study, we explore three additional aims. The second aim of the study is to assess if there is a difference in child vaccination intention among parents who are partially versus fully vaccinated. Parents who are not yet fully vaccinated themselves may not have as firm opinions on their attitudes towards vaccination for themselves and their children as compared to parents who are fully vaccinated. The third aim is to assess if there is a difference in parents' intention to vaccinate their children by their child's age. The disparate vaccination rates for children aged 5–11 compared to 12–17 years suggests that parents of older children may feel more comfortable getting their child vaccinated against COVID-19 than younger children. The fourth aim examines the stability of child vaccination intention over time. An element not captured with the SEM is how behaviors may change with time. The COVID-19 pandemic has transformed dramatically in both the prevalence of the disease as well as in the availability and promotion of prevention strategies. New information is constantly being received and processed by parents about COVID-19 and vaccination; thus, examining changes in parents' intentions to vaccinate their children is the final aim of this study. During the COVID-19 pandemic, there have been major shifts in opinions and behaviors due to infection rates, political events, and other factors. Little is known about the stability of parental vaccine attitudes. One of the weaknesses of prior studies is that they only use cross-sectional data. In the current study, we used two waves of data, which increases the study's scientific rigor and may address questions regarding attitudinal change over time. To address this aim, we report on a subgroup of parents who reported vaccination intentions for their children in March 2021 and June 2021, during which time an EUA for COVID-19 vaccination was granted for children aged 12 and older based on data about vaccine's safety and effectiveness [3].

2. Study population

Respondents participated in the longitudinal "COVID-19 and Well-Being Study" which began in March 2020. The study aims to examine individual, social, and societal-level fluctuations in experiences and perceptions amidst the rapidly changing landscape of the COVID-19 pandemic. Participants in this longitudinal cohort study completed online surveys every few months, and study periods aimed to capture changes in scientific knowledge of infection, extent of infectious spread, and progress in vaccine development. Participants were eligible for the study if they were aged 18 years or older, resided in the United States, spoke and read

English, and had heard of the coronavirus. All participants in the baseline survey (N = 809) were invited to participate in subsequent surveys, and retention from baseline was 68% at wave 5 (March 4th−15th, 2021) and 61% at wave 6 (June 14th−23rd, 2021). Furthermore, at both waves 5 and 6, additional participants were recruited to increase the racial, socioeconomic, and political diversity of the sample (n = 94 at wave 5 and n = 251 at wave 6). This analysis focuses on a sub-sample of parents who report having a child under the age of 18 in their household who completed wave 6 data collection, which occurred between June 14th−23rd, 2021 (N = 297). Three sub-analyses were conducted. One sub-analysis assessed if child vaccination intention differed among parents who were partially versus fully vaccinated. This analysis used the sub-sample of parents who reported receiving at least one dose of the vaccination by the time of the wave 6 survey (N = 178). An additional sub-analysis examined vaccination intention by child age and included parents who agreed to complete supplemental questions about their intention to vaccinate each child in their household at wave 6 (N = 262 parents reporting on 422 children). The final sub-analysis assessed change in parents' intention to vaccinate their children and included a sub-sample of parents who participated in both wave 5 and wave 6 (N = 166). This window captures the period before and after the COVID-19 vaccine approval for children ages twelve and older by the Food and Drug Administration [21]. Retention of parents between the fifth and sixth waves was 77%. Respondents did not differ from non-respondents based on parental race, sex, or intention to vaccinate their children; however, non-respondents were significantly younger than respondents. Three participants reported having a child under the age of 18 in the household at wave 5 but not at wave 6 and were not included in the analysis.

Study participants were recruited online through Amazon's Mechanical Turk (MTurk). This recruitment strategy is used by health researchers to rapidly collect diverse samples [22]. Previous studies have indicated that samples collected through MTurk provide better quality data in less time than other methods used for recruiting convenience samples [23]. Study populations recruited through MTurk are not nationally representative but outperform other opinion samples on several dimensions [24,25]. Compared to national samples, MTurk participants tend to be younger, more educated, underemployed, and underrepresent Black and Hispanic participants [26]. The study design protocols followed MTurk's best practices for research, which included ensuring participant confidentiality, integrating attention checks throughout the survey, repeating study-specific qualification questions, and removing disqualified participants [21,27,28]. The study protocols were approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

3. Measures

To examine parents' intention to get their children vaccinated, each parent of a child under the age of 18 years was asked, "When a coronavirus vaccine is available for children, I will get my children vaccinated." Response options were "yes," "no," and "not sure.".

3.1. Intrapersonal-level

Demographics included parent age, parent sex at birth, and household income dichotomized at the mean. Participants' race was analyzed as "White," "Black," "Hispanic," and "Other." The "Other" category included participants identifying as "Asian," "Mixed," or "Other" due to the small sample size of these groups. Political orientation was assessed on a 7-point scale from "very liberal" to "very conservative" with higher scores indicating a more conservative ideology. Four participants were missing political orientation data and were coded at the median of "moderate." To assess personal experience with COVID-19, parents were asked the yes/no question, "Have you tested positive for the coronavirus?" Parental vaccination status was assessed with the question, "How many doses of the coronavirus vaccine have you received?" Participants reporting zero doses were compared to participants who reported receiving one or two doses. Parental concern about COVID-19 was assessed through the Likert question, "I am very worried about my children getting the coronavirus." Concern about the vaccine for children was examined on a Likert scale with the statement, "We need to know more about the long-term side effects of the coronavirus vaccines before encouraging children to get vaccinated." For each of the Likert scale statements, responses of "Strongly agree" and "Agree" were compared to "Neither agree nor disagree," "Disagree," and "Strongly disagree.".

3.2. Interpersonal-level

Three measures assessed COVID-19 vaccination social norms and communication. Parents were asked, "How many family or friends have told you they will not get vaccinated?" Responses of "All" and "Most" were compared to "None," "A few," and "Some." Parents were also asked to respond to the question, "My family/friends discourage me from getting the coronavirus vaccine" and responses of "Strongly agree" and "Agree" were compared to "Neither agree nor disagree," "Disagree," and "Strongly disagree." Parents who reported talking to family members or friends at least weekly about the COVID-19 vaccine were compared to parents who communicated with peers less frequently.

3.3. Institutional/Community-level

Trusted information sources were examined with the statement, "It is hard to know who to believe about the safety of the coronavirus vaccine." Responses of "Strongly agree" and "Agree" were compared to "Neither agree nor disagree," "Disagree," and "Strongly disagree." Exposure to COVID-19 in the community was examined with the yes/no question, "Do you personally know anyone who has had the coronavirus?".

4. Analysis

Descriptive statistics were used to assess the frequency of parental vaccine intentions and predictors. Bivariable and multivariable multinomial logistic regression was used to model potential predictors of parental intentions to get children vaccinated. Multinomial logistic regression models provide relative risk ratios (RRR) by exponentiating the multinomial logit coefficients. A RRR indicates the risk of the outcome occurring in the comparison group compared to the risk of the outcome occurring in the referent group for the variable of interest. A RRR < 1 indicates that the outcome is more likely to be in the referent group than the comparison group. Variables significant at the $p < 0.10$ level in bivariate models were included in the multivariable model. Three sub-analyses were conducted. In the first sub-analysis, we assessed if child vaccination intention differed between parents who were fully versus partially vaccinated. For this analysis, we conducted a multinomial logistic regression model using a sub-sample of participants who reported receiving one or two vaccine doses (N = 178). Child vaccination intentions among parents who were partially versus fully vaccinated (2 doses or 1 dose of the Johnson and Johnson vaccination) were compared. In an additional sub-

analysis, we assessed vaccination intention by child age, and parents were asked to report their vaccination intention for each child in their household. Parents' responded to the question, "For each of the children in your household (from oldest to youngest), which will you get vaccinated with the coronavirus vaccine when it is available to them?" with the dichotomous response "Yes, will get vaccinated" and "No, will not get vaccinated." Children were categorized based on vaccination age groups. Generalized estimating equations were used to account for clustering of children within families. In the final sub-analysis, we examined the stability of parental vaccine intentions between March and June 2021 using descriptive statistics. Additionally, a Baker's symmetry test and Stuart–Maxwell marginal homogeneity test were utilized to assess if there was a significant shift between the two time periods [29-31]. All analyses were conducted using STATA 17.

5. Results

Parents showed wide variation in intentions to get their children vaccinated with 44% intending to vaccinate their children, 31% opposed to vaccination, and 25% unsure in June 2021 (Table 1). Parents reported on their children under the age of 18 in their household and had on average 1.6 children (Range: 1–6 children). Parents also reported the age of each of their children. The age of one child was missing. The age distribution of the children included 23% ages 0–4 years, 44% 5–11 years, 24% 12–15 years, and 10% 16–17 years. Over half of parents (60%) reported having received at least one dose of a COVID-19 vaccine, with 11% reporting having received only one dose and 49% reporting having received two doses of the vaccine or the Johnson and Johnson vaccination. Only 9% of participants reported ever testing positive for COVID-19. The mean age of parents was 39 years (SD: 9 years; Range: 20–64 years), 59% were female, and 46% reported a household income of less than $60,000. The majority of participants identified as White (64%), followed by 18% Black, 10% Hispanic, and 8% other. Political affiliation represented a diverse distribution across the seven-item range, with 46% identifying as very liberal/liberal/slightly liberal, 23% as moderate, and 31% as very conservative/conservative/slightly conservative. Half of the parents reported that they were very worried about their children getting COVID-19 (52%), and 71% felt they needed to know more about the long-term side effects of COVID-19 vaccines before getting children vaccinated. Within the domain of social norms, 16% reported that most or all of their family/friends were not vaccinated, and 13% reported that their friends/family would discourage them from getting vaccinated. Half of the respondents (50%) talked to family or friends at least weekly about the COVID-19 vaccine, and 51% reported that it was hard to know who to believe about the safety of the COVID-19 vaccines. The majority (79%) of participants knew someone who had COVID-19.

Table 2 shows multinomial logistical models of socio-ecological factors associated with parents' intention to vaccinate their children against COVID-19. Parental COVID-19 vaccination status was a strong and consistent predictor of child vaccination intention in both bivariate and multivariate models when comparing parents who intended to get their children vaccinated with parents who did not intend to get their children vaccinated (aRRR: 0.03, 95% CI: 0.01–0.08) and were unsure about vaccination for their children (aRRR: 0.27, 95% CI: 0.11–0.67). Demographic variables, such as race, parent sex, and income were attenuated in the multivariable model and not significant predictors of parents' intention to get their children vaccinated. However, a more conservative political orientation (aRRR: 1.55, 95% CI: 1.21–1.99), reduced worry about children getting COVID-19 (aRRR: 0.18, 95% CI: 0.07–0.45), and younger age was associated with negative vaccine intention (aRRR: 0.94, 95% CI: 0.89–0.99) but not vaccine uncertainty in both bivariate and adjusted models. Concerns about the vaccine's long term side effects was uniquely associated with an increased likelihood of parents being unsure about vaccinating their children against COVID-19 (aRRR: 4.35. 95% CI: 1.76–10.71).

Social norms had varying associations with parents' intentions to get their children vaccinated. For example, increased communication with peers about the COVID-19 vaccine was significantly related to reduced negative and uncertain vaccine intention, com-

Table 1
Socio-ecological levels by parent intention to vaccinate their children against COVID-19 (N = 297).

Variables	n (%)			
	Total (N = 297)	**Yes (N = 131; 44%)**	**No (N = 93; 31%)**	**Unsure (N = 73; 25%)**
Intrapersonal-level				
Age, M (SD)	39.1 ± 8.6	39.9 ± 8.4	37.2 ± 8.9	39.8 ± 8.5
Female	174 (58.6)	65 (49.6)	60 (64.5)	49 (67.1)
Race				
White	189 (63.6)	76 (58.2)	66 (70.9)	47 (64.4)
Black	52 (17.5)	23 (17.6)	18 (19.4)	11 (15.1)
Hispanic	31 (10.4)	15 (11.5)	7 (7.5)	9 (12.3)
Other	25 (8.42)	17 (12.9)	2 (2.2)	6 (8.2)
Received 1 or 2 doses	178 (59.9)	118 (90.1)	16 (17.2)	44 (60.3)
Political ideology				
Liberal	136 (45.9)	76 (58.1)	23 (24.7)	37 (51.4)
Moderate	67 (22.6)	29 (22.1)	20 (21.5)	18 (25.0)
Conservative	93 (31.4)	26 (19.8)	50 (53.8)	17 (23.6)
Household income > $60,000	158 (53.2)	78 (59.5)	43 (46.2)	37 (50.7)
Has ever tested positive for COVID-19	28 (9.4)	11 (8.4)	8 (8.6)	9 (12.3)
Worried about children getting COVID-19	155 (52.2)	89 (67.9)	24 (25.8)	42 (57.5)
Concerned about side effects	211 (71.0)	63 (48.1)	85 (91.40)	63 (86.3)
Interpersonal-level				
Most/all peers not vaccinated	48 (16.2)	17 (13.0)	30 (32.3)	1 (1.4)
Peers discourage vaccination	38 (12.8)	13 (9.9)	19 (20.4)	6 (8.2)
Talk weekly about vaccine	150 (50.5)	79 (60.3)	41 (44.1)	30 (41.1)
Institutional/community-level				
Unsure about who to trust about COVID-19 vaccine	152 (51.2)	36 (27.5)	66 (71.0)	50 (68.5)
Personally know anyone who has had COVID-19	233 (78.5)	99 (75.6)	73 (78.5)	61 (83.6)

Table 2
Bivariate and multivariate multinomial regression models of parents' intentions to vaccinate their children against COVID-19 (N = 297).

Variable	Unsure (ref: Yes)		No (ref: Yes)	
	RRR (95% CI)	aRRR (95% CI)	RRR (95% CI)	aRRR (95% CI)
Intrapersonal-level				
Age	0.99 (0.97, 1.03)	0.99 (0.96, 1.04)	**0.96 (0.93, 0.99)**	**0.94 (0.89, 0.99)**
Sex (ref: male)	**2.07 (1.14, 3.76)**	1.25 (0.60, 2.62)	**1.85 (1.07, 3.19)**	0.78 (0.32, 1.92)
Race (White)				
Black	0.77 (0.25, 1.73)	0.85 (0.29, 2.41)	0.90 (0.45, 1.81)	1.01 (0.33, 3.14)
Hispanic	0.97 (0.39, 2.39)	0.88 (0.28, 2.72)	0.54 (0.21, 1.40)	0.44 (0.11, 1.92)
Other	0.57 (0.21, 1.55)	0.72 (0.22, 2.43)	**0.14 (0.03, 0.61)**	0.27 (0.04, 1.84)
Received 1 or 2 vaccine doses	**0.17 (0.08, 0.35)**	**0.27 (0.11 0.67)**	**0.02 (0.01, 0.05)**	**0.03 (0.01, 0.08)**
Political ideology	1.08 (0.92, 1.27)	0.98 (0.80, 1.21)	**1.61 (1.38, 1.89)**	**1.55 (1.21, 1.99)**
Household income	0.70 (0.39, 1.24)	0.91 (0.42, 1.98)	**0.58 (0.34, 0.99)**	0.74 (0.29, 1.87)
Has ever tested positive	1.53 (0.60, 3.89)	–	1.03 (0.40, 2.66)	–
Worry about children getting COVID	0.64 (0.35, 1.56)	0.67 (0.32, 1.44)	**0.16 (0.09, 0.30)**	**0.18 (0.07, 0.45)**
Concern about long-term side effects	**6.80 (3.21, 14.40)**	**4.35 (1.76, 10.71)**	**11.47 (5.14, 25.57)**	2.70 (0.83, 8.77)
Interpersonal-level				
Most/all peers not vaccinated	**0.09 (0.01, 0.72)**	**0.06 (0.01, 0.52)**	**3.19 (1.63, 6.24)**	1.38 (0.40, 4.74)
Peers discourage vaccination	0.82 (0.30, 2.24)	0.51 (0.15, 1.75)	**2.33 (1.09, 4.99)**	0.84 (0.24, 2.92)
Weekly communication about vaccine	**0.46 (0.26, 0.82)**	**0.44 (0.20, 0.93)**	**0.52 (0.31, 0.89)**	0.74 (0.29, 1.86)
Institutional/Community-level				
Unsure about who to trust about COVID-19 vaccine	**18.21 (6.89, 48.14)**	**4.29 (1.97, 9.31)**	**14.23 (6.37, 31.77)**	**3.00 (1.18, 7.65)**
Personally know anyone who has had COVID-19	1.64 (0.79, 3.43)	–	1.18 (0.63, 2.23)	–

pared to positive intention to vaccinate children, in the bivariate model. However, peer communication only retained significance as an indicator of reduced uncertainty in the adjusted analysis (aRRR: 0.44, 95% CI: 0.20–0.93). Reporting that most/all of their friends would not get vaccinated was significantly associated with increased likelihood that parents would report negative vaccination intention in the bivariate model. When comparing uncertain to positive vaccine intentions, reporting that most/all of their friends would not get vaccinated was significantly related to a reduced likelihood that parents reported unsure intention in both bivariate and adjusted models (aRRR: 0.06, 95% CI:0.01–0.52). Peers discouraging vaccination was a significant predictor of reporting negative, compared to positive, vaccination intention for children in the bivariate model, but this relationship did not retain significance in the adjusted model.

Not having trusted information sources was also a consistent predictor of not intending to get children vaccinated (aRRR: 3.00, 95% CI: 1.18–7.65) and reporting uncertainty about getting children vaccinated (aRRR: 4.29, 95% CI: 1.97–9.31).

The first sub-analysis examined if child vaccination intention differed between parents who were fully versus partially vaccinated and found that parents who were fully vaccinated had significantly reduced odds of negative child vaccine intention compared to partially vaccinated parents (RRR: 0.26, 95% CI: 0.09–0.79). Parental partial versus full vaccination status did not have a significant association with child vaccination uncertainty (data not shown).

An additional sub-analysis assessed the association between children's age and parents' intention to vaccinate their children (Table 3). Parents had significantly higher odds of intending to vaccinate older children compared to younger children (children ages 16–17 years v. 0–4 years OR: 2.01, 95% CI: 1.05–3.84; children ages 12–15 years v. 0–4 years OR: 1.63, 95% CI: 1.01–2.63). Approximately 70% of parents intended to vaccinate their 16–17 year old child, while 48% of parents intended to vaccinated their 0–4 year old child.

The final sub-analysis on the stability of parents' intention to vaccinate their children found that 70% of parents did not change their intention over time. Results from the symmetry test and marginal homogeneity test were not significant, indicating that there was not a significant shift in parents' opinions between March and July 2021. Among the 34% of parents who were "unsure" in March 2021, half (53%) remained "unsure" while a relatively equal number transitioned to "yes" (25%) and "no" (23%) by July 2021 (Fig. 1). For the 43% of parents with positive vaccine intentions in March 2021, the majority (78%) remained vaccine supporters while

Table 3
Generalized estimating equation models of parents' intentions to vaccinate their children against COVID-19 for each child in their household (N = 422 children).

Children's age	Yes, will vaccinate n(%)	No, will not vaccinate n(%)	OR (95% CI)
0–4 years	47 (48.45)	50 (51.55)	**Ref**
5–11 years	97 (52.12)	89 (47.85)	1.18 (0.92–1.50)
12–15 years	57 (55.34)	46 (44.66)	**1.63 (1.01–2.63)**
16–17 years	25 (69.44)	11 (30.56)	**2.01 (1.05–3.84)**

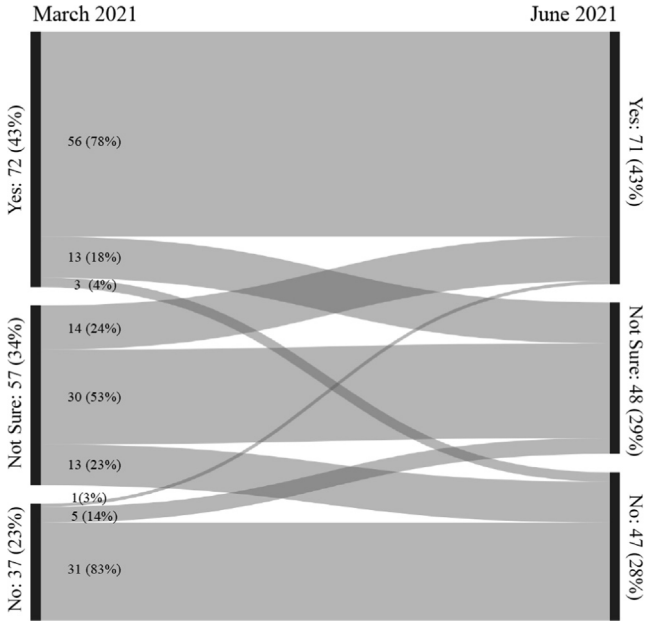

Fig. 1. Change in parents' intentions to vaccinate their children against COVID-19 from March to June 2021 (N = 166).

a small number (4%) transitioned to "no" while 18% transitioned to "unsure" in July 2021. The smallest frequency of transition occurred among the 22% of parents who endorsed negative vaccination intention in March 2021, with most (83%) remaining opposed and 3% transitioning to "yes" and 14% to "not sure" in July 2021.

6. Discussion

This study uncovered several significant findings with respect to the multiple levels of factors associated with parents' intention to vaccinate their children against COVID-19 and how their intentions changed over time. Factors at multiple levels of the socio-ecological model are associated with parental vaccine intentions, and several of the factors differ among parents who express opposition as compared to those who expressed uncertainty. Some parents' intentions to vaccinate their children against COVID-19, or not, changed over time; however, this change was not found to be significant. These findings are important to public health practice as they can inform multi-level interventions and identify sub-groups for which interventions should be targeted.

The first aim of this study used a socio-ecological model to examine the multi-level factors that are associated with parents' vaccination intentions for their children. This study identified multiple intrapersonal level factors that differentiated parents expressing negative intention to vaccinate their children compared to positive vaccine intention, including political ideology and concern about side effects. Parents expressing conservative ideology and less concern about their children contracting COVID-19 were associated with negative intentions to vaccinate their children against COVID-19, but these factors were not associated with vaccine uncertainty. This finding highlights that ideological differences may drive the decision not to vaccinate children. Previous studies have identified that political ideology may affect vaccination decisions through multiple mechanisms. Conservatives have been found to exhibit lower trust in scientific recommendations than liberals [32]. Rabinowitz and colleagues also found that political ideology was associated with judgments about others' attitudes towards childhood vaccination, with conservatives more likely to overestimate the extent to which other conservatives share their attitudes about vaccination compared to liberals [33]. Political ideology also affects engagement in news sources, and some news sources have been found to highlight misinformation on the seriousness of the COVID-19 pandemic and the effectiveness of vaccinations [34]. COVID-19 vaccination campaigns must, therefore, take into account ideological differences in perceptions of facts about the pandemic and engagement in news sources. Communication campaigns that engage conservative leaders to speak about the risk of COVID-19 infection and the importance of vaccinating children against COVID-19 may be effective tools to enhance COVID-19 vaccination uptake for children.

Another factor at the intrapersonal level which differentiated negative from unsure intentions to vaccinate children against COVID-19 was concern about the vaccine side effects. Previous studies have identified that concern about vaccine novelty was associated with vaccine refusal [35]. However, the present study provides more nuance and identifies that concern about long-term side effects increased the likelihood that parents would express uncertainty to vaccinate their children but was not a predictor of negative vaccine intentions. These data suggest that health researchers and practitioners should provide ongoing information about the COVID-19 vaccine's safety and side effects over time and relative safety compared to other common vaccinations. Communication campaigns can also emphasize that COVID-19 vaccines may reduce parental and child worries about COVID-19.

One factor at the intrapersonal level was associated with both negative and uncertain vaccination intention. Parental COVID-19 vaccination status was significantly associated with both uncertain and negative vaccination intentions for children. The association between parental and child vaccination status is well supported and suggests that intervention campaigns designed to promote child vaccination must target the parent-child dyads [9]. In the sub-analysis, we found that fully vaccinated parents had significantly reduced odds of reporting negative child vaccination intentions compared to partially vaccinated parents. This may suggest that partially vaccinated parents may still have uncertainty about their opposition to the vaccine for themselves and their children. Future research using qualitative methods should further explore this question. These study findings demonstrate that it is critical to ensure that vaccination clinics can provide both child and adult vaccination. Additionally, training healthcare providers to talk about the importance of vaccinating all members of the family who are eligible may be one strategy to enhance vaccine uptake for both parents and children.

Another salient intrapersonal factor is child age. The sub-analysis that examined intention to vaccinate by child age identified that parents were more willing to vaccinate older children compared to young children, aligning with findings from Szilagyi and colleagues [9]. This is perhaps not surprising as vaccinations for children under the age of five had not been approved at the time of this study. Future studies should examine if the intention to vaccinate young children changes when COVID-19 vaccinations for children under five years are approved. Additionally, assessing the correlates of intentions to vaccinate as a function of age is an important area for future study.

At the interpersonal level, frequent peer communication about COVID-19 vaccines was a strong predictor of reduced child vaccine uncertainty but was not a significant predictor of child vaccine opposition. Notably, this was also the only factor that was associated with uncertain but not negative child vaccination intention in the multivariable models. This is a novel finding as communication about vaccination is a critical component of social diffusion of information [16]; yet, there is limited research on peer communication within the context of parents' intention to vaccinate their children against COVID-19. Parents expressing child COVID-19 vaccine uncertainty were also less likely to talk to their peers about vaccination on a weekly basis compared to parents who supported child COVID-19 vaccination. This finding suggests that vaccination campaigns focused on parents who are uncertain about vaccinating their children should develop interventions that aim to foster peer communication about vaccination. Peer educator interventions that include parents as educators may be an effective methodology to target this group and provide information about the safety and efficacy of the COVID-19 vaccination for children.

At the institutional level, not having a trusted information source about COVID-19 vaccines was a significant predictor of parents expressing both negative and uncertain intentions to vaccinate their children. Mistrust in information sources has been identified as a predictor of vaccine hesitancy in the context of other vaccinations [36], and mistrust is particularly high in the context of COVID-19. In this study, five out of ten parents agreed or strongly agreed that it is hard to know who to believe about the safety of the coronavirus vaccine. To address low rates of trust in the COVID-19 vaccine, vaccination promotion efforts should both involve and be informed by health professionals, such as physicians, nurses, pharmacists, and community health workers, who have ongoing relationships with patients and likely have increased capacity to build trust. These individuals can also personalize messages by talking about vaccinating their own children and the experiences of children who have been hospitalized for COVID-19. Training medical providers on vaccine communication can

increase physician comfort talking to vaccine-hesitant parents [37]. Currently, most pediatric residency training programs in the US do not provide training on vaccine safety [38]. A barrier to fostering trust that should be considered in future research is the utilization of telemedicine, which has increased during the pandemic. Virtual settings may make it more difficult for healthcare professionals to have effective conversations with patients to address concerns and encourage COVID-19 vaccine acceptance [39-41].

This study did not identify a statistically significant change in child vaccination intention over time. However, a small proportion of individuals transitioned between positive, uncertain, and negative child vaccination intentions over the study period. While this is one of the first studies, to our knowledge, that looks at change in child vaccination intention using a longitudinal sample, longitudinal research on adults' vaccination intention has found mixed results with some reporting an increase and others a decrease in vaccination intention over time [42,43]. Our research identified that parents expressing uncertainty about the COVID-19 vaccine for their children represent a potentially important target group for intervention campaigns as this group showed the least stability over time, with equal numbers transitioning to both positive and negative intentions to vaccinate their children. Notably, the current study also identified substantial transition among the child COVID-19 vaccine positive and the opposition groups, with 18% and 14% transitioning to unsure status, respectively. This finding indicates that interventions should also be tailored to parents with positive intentions, who have not yet vaccinated their children, as well as to parents who are vaccine-resistant.

This study is not without limitations as the study population may also not be representative of all US parents; however, the recruitment methodology has been found to improve upon other opinion samples on several dimensions [25]. The focus of this study was on parents' overall perceptions of vaccinating their children. Future studies should examine child-level factors, which could play into parents' intention to vaccinate their children such as being up-to-date on routine vaccinations. Future research could also examine children's perceptions of vaccination. Currently, most states require parental consent for child vaccination [44]. However, as some states have different requirements and as others move towards allowing minor self-consent, the perceptions of young people and factors influencing their COVID-19 vaccine intentions must be examined. Another limitation of this study is that due to the sample size, we are not able to detect small effect sizes. Additionally, the sample size for parents transitioning intention to vaccinate their children between study waves was low; therefore, we could not assess correlations of change from one intention group to another. Future research should assess what motivates parents to change their opinions about vaccinating their children.

The present research illuminates several factors that have implications for public health interventions. Importantly and aligning with previous research, this study identified that predictors of parents' intentions to vaccinate their children against COVID-19 differ among parents who express negative child COVID-19 vaccine intention and those who express uncertain intention, indicating a need for tailored interventions [45,46]. Peer diffusion strategies may be particularly effective at promoting child COVID-19 vaccination uptake among parents expressing uncertainty. Conservative leaders may play an important role among parents who express child COVID-19 vaccine opposition as they can promote confidence in vaccines. Interventions must also focus on parents with positive intentions who have not yet vaccinated their children, as intentions may change over time. Programs to promote COVID-19 vaccination uptake should be dyadic and work to promote children and parent vaccination. Finally, communication campaigns are needed to ensure that parents have access to trusted information sources about the COVID-19 vaccine.

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.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2022.05.089.

References

[1] Cull B, Harris M. *Children and COVID-19: State Data* Report [Data Report]; 2022. https://downloads.aap.org/AAP/PDF/AAP%20and%20CHA%20-%20Children%20and%20COVID-19%20State%20Data%20Report%202.24.22%20FINAL.pdf [accessed 27 October 2021].

[2] Center for Disease Prevention and Control (October 21, 2021). *COVID-19 Vaccines for Children and Teens*. Retrieved October 26, 2021 from https://www.cdc.gov/coronavirus/2019-ncov/vaccines/recommendations/adolescents.html [accessed 4 November 2021]

[3] Food and Drug Administration (2021, October 29, 2021). *FDA Authorizes Pfizer-BioNTech COVID-19 Vaccine for Emergency Use in Children 5 through 11 Years of Age.* [Press Release]. Accessed November 10, 2021 from https://www.fda.gov/news-events/press-announcements/fda-authorizes-pfizer-biontech-covid-19-vaccine-emergency-use-children-5-through-11-years-age [accessed 4 November 2021].

[4] American Academy of Pediatrics (2022). *Children and COVID-19 Vaccinations Trends: AAP Analysis of Data Posted by the Centers for Disease Control and Prevention as of Febryary 23, 2022* https://downloads.aap.org/AAP/PDF/Child%20Vaccinations%20Report%20US%20and%20by%20State%20Feb%2023.pdf.

[5] Tang SF. *Children and COVID-19 Vaccinations Trends: AAP analysis of Data Posted by the Centers for Disease Control and Prevention* [Conference Presentation]; 2021. https://downloads.aap.org/AAP/PDF/Child%20Vaccinations%20Report%20US%20and%20by%20State%20Sept%201%20updated.pdf.

[6] Kumar S, Quinn SC, Kim KH, Musa D, Hilyard KM, Freimuth VS. The social ecological model as a framework for determinants of 2009 H1N1 influenza vaccine uptake in the United States. Health Educ Behav 2012;39(2):229–43.

[7] Latkin C, Dayton LA, Yi G, Konstantopoulos A, Park J, Maulsby C, et al. COVID-19 vaccine intentions in the United States, a social-ecological framework. Vaccine 2021;39(16):2288–94.

[8] Scherer AM, Gedlinske AM, Parker AM, Gidengil CA, Askelson NM, Petersen CA, et al. Acceptability of adolescent COVID-19 vaccination among adolescents and parents of adolescents—United States, April 15–23, 2021. Morb Mortal Wkly Rep 2021;70(28):997–1003.

[9] Szilagyi PG, Shah MD, Delgado JR, Thomas K, Vizueta N, Cui Y, et al. Parents' intentions and perceptions about COVID-19 vaccination for their children: results from a national survey. Pediatrics 2021;148(4).

[10] Van Dyke ME, Mendoza MC, Li W, Parker EM, Belay B, Davis EM, et al. Racial and ethnic disparities in COVID-19 incidence by age, sex, and period among persons aged< 25 years—16 US jurisdictions, January 1–December 31, 2020. Morb Mortal Wkly Rep 2021;70(11):382.

[11] Baumgaertner B, Carlisle JE, Justwan F, Rabinowitz M. The influence of political ideology and trust on willingness to vaccinate. PLoS ONE 2018;13(1):e0191728.

[12] Bond L, Nolan T. Making sense of perceptions of risk of diseases and vaccinations: a qualitative study combining models of health beliefs, decision-making and risk perception. BMC Public Health 2011;11(1):1–14.

[13] Kasperson JX, Kasperson RE, Pidgeon N, Slovic P. The social amplification of risk: assessing fifteen years of research and theory. In *The feeling of risk* (pp. 345-372). Routledge; 2013.

[14] Brunson EK. The impact of social networks on parents' vaccination decisions. Pediatrics 2013;131(5):e1397–404.

[15] Zhang KC, Fang Y, Cao H, Chen H, Hu T, Chen YQ, et al. Parental acceptability of COVID-19 vaccination for children under the age of 18 years: cross-sectional online survey. JMIR pediatrics and parenting 2020;3(2):e24827.

[16] Rogers EM. Diffusion of preventive innovations. Addict Behav 2002;27(6):989–93.

[17] Flanagan-Klygis EA, Sharp L, Frader JE. Dismissing the family who refuses vaccines: a study of pediatrician attitudes. Arch Pediatr Adolesc Med 2005;159(10):929–34.

[18] Hart PS, Chinn S, Soroka S. <? covid19?> politicization and polarization in COVID-19 news coverage. Sci Commun 2020;42(5):679–97.

[19] Latkin CA, Dayton L, Yi G, Konstantopoulos A, Boodram B. Trust in a COVID-19 vaccine in the US: A social-ecological perspective. Social Sci Med (1982) 2021; 270:113684.
[20] Brennen JS, Simon FM, Howard PN, Nielsen RK. Types, sources, and claims of COVID-19 misinformation University of Oxford]; 2020.
[21] Food and Drug Administration (2021, May 10, 2021). Coronavirus (COVID-19) Update: FDA Authorizes Pfizer-BioNTech COVID-19 Vaccine for Emergency Use in Adolescents in Another Important Action in Fight Against Pandemic [Press Release]. https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-authorizes-pfizer-biontech-covid-19-vaccine-emergency-use [accessed 4 November 2021]
[22] Créquit P, Mansouri G, Benchoufi M, Vivot A, Ravaud P. Mapping of crowdsourcing in health: systematic review. J Med. Int. Res 2018;20(5):e9330.
[23] Chandler J, Shapiro D. Conducting clinical research using crowdsourced convenience samples. Ann Rev Clin Psychol 2016;12(1):53–81.
[24] Follmer DJ, Sperling RA, Suen HK. The role of MTurk in education research: Advantages, issues, and future directions. Educ Res 2017;46(6):329–34.
[25] Huff C, Tingley D. "Who are these people?" Evaluating the demographic characteristics and political preferences of MTurk survey respondents. Res Polit 2015;2(3): 2053168015604648.
[26] Paolacci G, Chandler J. Inside the Turk: Understanding Mechanical Turk as a participant pool. Curr Direct Psychol Sci 2014;23(3):184–8.
[27] Strickland JC, Stoops WW. The use of crowdsourcing in addiction science research: Amazon Mechanical Turk. Exp Clin Psychopharmacol 2019;27(1):1.
[28] Young JA, Young KM. Don't get lost in the crowd: best practices for using amazon's mechanical turk in behavioral research. J Midwest Assoc Inform Syst 2019;2019(2):7.
[29] Bowker AH. A test for symmetry in contingency tables. J Am Stat Assoc 1948;43(244):572–4.
[30] Maxwell AE. Comparing the classification of subjects by two independent judges. Br J Psych 1970;116(535):651–5.
[31] Stuart A. A test for homogeneity of the marginal distributions in a two-way classification. Biometrika 1955;42(3/4):412–6.
[32] Blank JM, Shaw D. Does partisanship shape attitudes toward science and public policy? The case for ideology and religion. The Ann Am Acad Polit Soc Sci 2015;658(1):18–35.
[33] Rabinowitz M, Latella L, Stern C, Jost JT, Ahmed N. Beliefs about childhood vaccination in the United States: Political ideology, false consensus, and the illusion of uniqueness. PLoS ONE 2016;11(7):e0158382.
[34] Calvillo DP, Ross BJ, Garcia RJ, Smelter TJ, Rutchick AM. Political ideology predicts perceptions of the threat of COVID-19 (and susceptibility to fake news about it). Soc Psychol Person Sci 2020;11(8):1119–28.
[35] Goldman RD, Yan TD, Seiler M, Parra Cotanda C, Brown JC, Klein EJ, et al. Caregiver willingness to vaccinate their children against COVID-19: Cross sectional survey. Vaccine 2020;38(48):7668–73.
[36] Damnjanović K, Graeber J, Ilić S, Lam WY, Lep Ž, Morales S, et al. Parental decision-making on childhood vaccination. Front Psychol 2018;9:735.
[37] Schnaith AM, Evans EM, Vogt C, Tinsay AM, Schmidt TE, Tessier KM, et al. An innovative medical school curriculum to address human papillomavirus vaccine hesitancy. Vaccine 2018;36(26):3830–5.
[38] Williams SE, Swan R. Formal training in vaccine safety to address parental concerns not routinely conducted in US pediatric residency programs. Vaccine 2014;32(26):3175–8.
[39] Barbosa IdA, Silva MJPd. Nursing care by telehealth: what is the influence of distance on communication? Revista brasileira de enfermagem 2017;70 (5):928–34.
[40] Gordon HS, Solanki P, Bokhour BG, Gopal RK. "I'm not feeling like I'm part of the conversation" patients' perspectives on communicating in clinical video telehealth visits. J Gen Intern Med 2020;35(6):1751–8.
[41] Filbay S, Hinman R, Lawford B, Fry R, Bennell K. Telehealth by allied health practitioners during the COVID-19 pandemic: An Australian wide survey of clinicians and clients; 2021.
[42] Dorman C, Perera A, Condon C, Chau C, Qian J, Kalk K, et al. Factors associated with willingness to be vaccinated against COVID-19 in a large convenience sample. J Commun Health 2021;46(5):1013–9.
[43] Yasmin F, Najeeb H, Moeed A, Naeem U, Asghar MS, Chughtai NU, et al. COVID-19 Vaccine Hesitancy in the United States: A Systematic Review. Front. Public Health 2021 Nov;23(9):770985.
[44] Singer NK, Jennifer Tolbert, Jennifer. COVID-10 Vaccination and Parental Consent. *Kaiser Family Foundation*; 2021, May 26, 2021. https://www.kff.org/policy-watch/covid-19-vaccination-and-parental-consent/.
[45] Teasdale CA, Borrell LN, Shen Y, Kimball S, Rinke ML, Fleary SA, et al. Parental plans to vaccinate children for COVID-19 in New York city. Vaccine 2021;39 (36):5082–6.
[46] Hetherington E, Edwards SA, MacDonald SE, Racine N, Madigan S, McDonald S, Tough S. Covid-19 vaccination intentions among Canadian parents of 9-12 year old children: results from the All Our Families longitudinal cohort. medRxiv; 2020.