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# Adolescents' perceptions of media messages and their preventive health behaviors: a longitudinal study

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**BACKGROUND:** This study examines how adolescents' media message perceptions during a pandemic were associated with preventive health behaviors (PHBs; e.g., mask wearing).
**METHODS:** A U.S. sample of 154 adolescents aged 13–17 were asked to complete surveys every two weeks over 6 months (May 2021–December 2022). Multilevel models tested associations of five media message perceptions (feeling informed, feeling connected, positive perceptions of government leadership, negative impressions of public health measures, and feeling afraid) with PHBs, adjusting for covariates.
**RESULTS:** Boys, vaccinated adolescents, higher-SES youth, and those living in more Republican counties showed fewer PHBs. Feeling informed and afraid in response to COVID-19 media messages were associated with more PHBs. Negative impressions of public health measures were linked to fewer PHBs, particularly among older adolescents. The association between feeling afraid and PHBs was stronger in older adolescents. Feeling informed was linked to more PHBs in non-Asian adolescents, while feeling connected was linked to more PHBs in non-White adolescents.
**CONCLUSION:** Adolescents' PHBs are shaped by how they perceive and emotionally respond to media messages. Messages that emphasize clear information, establish the credibility of public health measures, cultivate appropriate risk perceptions, and consider demographic differences may increase adolescents' PHBs and preparedness.

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**IMPACT:**

- Adolescents' perceptions of media messages and demographic characteristics may relate to their preventive health behaviors (PHBs) such as mask wearing over time.
- Using longitudinal data from 154 U.S. adolescents across six months and 13 surveys, this study extends prior cross-sectional work during the pandemic.
- Findings show PHBs declined but media message perceptions remained influential. Feeling informed or afraid by media messages predicted greater PHBs, while negative impressions of media messages predicted lower PHBs.
- Age and racial/ethnic differences emerged, underscoring the need for tailored communication for adolescents.
- Results can inform health campaigns to better support adolescents' protections during future health crises.

## INTRODUCTION

The past decades have witnessed recurring large-scale infectious disease outbreaks, including severe acute respiratory syndrome (SARS), swine flu, Ebola virus, and COVID-19.[1] Recent analyses of epidemic history and disease emergence suggest a lifetime probability of about 38% for an individual experiencing a pandemic like COVID-19, a risk expected to double in coming decades.[2] Meanwhile, research has shown that during infectious disease crises, media has become a central channel to communicate with the public, influence health behaviors, and control disease transmission across the world.[3–5] The increasing risks of experiencing infectious disease outbreaks and the influential role of media underscore the importance of understanding how media messages influence public health preparedness and response.[6,7]

As the COVID-19 pandemic illustrated, adolescents represent a particularly vulnerable group whose development can be profoundly influenced by large-scale infectious disease outbreaks.[8] The impact on adolescents extended well beyond immediate health risks, to include increased levels of anxiety, depression, and loneliness, as well as decreased physical activity and social engagement.[9,10] Moreover, adolescence is such a formative developmental stage that these disruptions may carry long-lasting consequences such as altering college aspirations, delaying career plans, and increasing risks for persistent mental health challenges extending into adulthood.[8,10] Given these

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widespread impacts on health and development, protective measures became especially critical for this vulnerable population. More importantly, understanding factors related to adolescents adoption and maintenance of preventive health behaviors (PHBs) during the COVID-19 pandemic, such as wearing masks, washing hands, and maintaining social distancing,[11] can help guide strategies to safeguard health and reduce lasting adverse effects on adolescents from future pandemics. These PHBs have also been shown to reduce virus transmission, protect vulnerable populations, and minimize burden on healthcare systems.[12]

Prior research has identified personal, social, and environmental factors that may influence adolescents' PHBs engagement.[13,14] Media exposure warrants particular attention given its pervasive presence in adolescents' lives and its documented influence on their physical and mental health outcomes.[15,16] Media platforms also have been used to raise public health awareness about the pandemic and promote behavioral changes.[5,17] For example, a study in U.S. adolescents found that exposure to COVID-19 related information on television or social media was associated with constant masking.[18] Yet, despite its recognized importance, research examining how media messages operate to shape adolescents' PHBs and whether such messages are effective remains limited.

This study uses longitudinal data from a national sample of U.S. adolescents collected every two weeks in 13 repeated surveys over 6 months between May 2021 to December 2022 to examine how adolescents' perceptions of media messages about COVID-19 were related to their PHBs. We assessed the degree to which media messages made them feel informed, feel connected, feel afraid, and influenced their perceptions of government leadership and public health measures, along with their use of PHBs (e.g., hand washing/sanitizing, maintaining 6-foot distance, avoiding public gatherings, wearing masks indoors and outdoors).

Informed by findings from prior research,[18–21] we hypothesized that adolescents who felt more informed, more connected, or held more positive perceptions of government leadership in response to COVID-19 media messages would engage in more PHBs, whereas more negative impressions of public health measures would be associated with fewer PHBs, when compared to other adolescents (i.e., between-person association) and as they varied within individual adolescents over time (i.e., within-person association). Specifically, at the between-person level, we expected that adolescents who on average felt more informed, more connected, and held more positive perceptions of government leadership in response to COVID-19 media messages would engage in more PHBs than their peers, whereas those with more negative impressions of public health measures would engage in fewer PHBs than their peers. At the within-person level, we expected that on occasions where adolescents felt more informed, more connected, or held more positive perceptions than was typical for themselves, they would be more likely to engage in PHBs, and less likely to do so during periods when they held more negative impressions than their own average.

The moderating effects of several individual and contextual factors in the associations between media message perceptions and PHBs were also carefully hypothesized based on prior theory and empirical research.[14,22–26] Specifically, we examined whether demographic characteristics (age, gender, race/ethnicity, and socioeconomic status [SES]), COVID-19 experiences (vaccination status, testing, and symptoms), county-level political orientation, and county-level COVID-19 mortality and infection rates moderated associations between media message perceptions and PHBs among adolescents. We hypothesized that positive media perceptions (i.e., feeling informed, connected, and positive perceptions of government leadership) would more strongly predict more PHBs among older adolescents, girls, White and Asian adolescents, youth from higher-SES families, and those living in Democratic-leaning counties and counties with higher COVID-19 infection and mortality rates. Conversely, negative media perceptions (i.e., negative impressions of public health measures) would show weaker negative associations with PHBs in these populations. Because evidence related to the association between feeling afraid and PHBs is mixed,[27,28] we did not have specific hypothesis for the association between feeling afraid and PHBs and kept the testing of this association as exploratory. We also explored the cross-level interactions of media message perceptions to understand if the person's average level of media message perception might moderate the association between their time-specific deviations and PHBs. All hypotheses and the analysis plan were preregistered at the Open Science Framework (OSF) on June 5th, 2024 and full materials, analysis code, and documentation are available in our preregistration form (OSF Preregisters).[29]

## METHODS

### Study design

The study used secondary data from the Adolescent and Family Screenome Study, a part of the Human Screenome Project, that was designed to understand media behaviors, pandemic experiences, family relationships, health behaviors, and well-being among U.S. adolescents and their parents.[30] Eligible adolescents were U.S. residents who were sole and regular users of Android smartphones and aged 13–17 years at enrollment, per the requirements of the parent study. Both adolescent assent and parental informed consent and HIPAA authorization for adolescent participation were obtained during online video conference onboarding meetings with research staff. Once enrolled, adolescents received text messages and/or emails prompting them to complete surveys every two weeks via REDCap for up to 6 months (13 surveys in total, baseline plus 12 subsequent timepoints). Compensation was provided for each successfully submitted survey. The study was approved by the Administrative Panel on Human Subjects in Medical Research at Stanford University.

### Measures

*Perceptions of media messages related to the COVID-19 pandemic*. Twelve questions about perceptions of media messages were measured on 0–100 slider scales anchored from much less (0) to much more (100). Questions included, "During the past two weeks, when you looked at stories about the novel coronavirus (SARS-CoV-2, COVID-19), did they make you feel less or more (1) afraid; (2) informed; (3) like I know what was happening in the world; (4) that I was doing the right things; (5) that I was connected to other people; (6) that we are all in this together; (7) that our local government leaders are doing a good job; (8) that our state government leaders are doing a good job; (9) that our national government leaders are doing a good job; (10) that the media are providing accurate information; (11) that stay at home orders and closing businesses are more damaging than the disease itself; (12) that current government and public health rules are more damaging than the disease itself."

We conducted an Exploratory Factor Analysis (EFA) to identify underlying dimensions and explore whether these 12 items measured distinct constructs.[31] Results of EFA and agreement for this factor analysis are presented in Appendix A. The final solution suggested five factors: "feeling informed" (Items 2, 3, 4, and 10: feeling informed, like I know what was happening in the world, that I was doing the right things, and that that the media are providing accurate information; Cronbach's alpha = 0.55 to 0.81 over the 13 survey assessments); "feeling connected" (Items 5 and 6: that I was connected to other people, and that we are all in this together, Cronbach's alpha = 0.50 to 0.94); "positive perceptions of government leadership" (Items 7, 8, and 9: that local, state, and national government leaders are doing a good job, Cronbach's alpha = 0.76 to 0.88); "negative impressions of public health measures" (Items 11 and 12: that stay at home orders and closing businesses are more damaging than the disease itself, and that current government and public health rules are more damaging than the disease itself, Cronbach's alpha = 0.74 to 0.95); and "feeling afraid" (Item 1 only). Item 1 (afraid) did not load together with any of the other items and was therefore treated as an independent factor. For each multi-item factor, items were averaged to obtain a scale score. Then, for ease of comparison with the PHBs scale, all five factors were divided by 20 to make coefficients more interpretable (transforming the 0–100 scale to a 0–5 scale). This scale and the corresponding factor structure of all items are provided in Table B1, Appendix B.

*Preventive health behaviors*. Engagement in PHBs was measured using a set of items based on U.S. Centers for Disease Control and Prevention (CDC) recommended infection control measures for COVID-19, developed with input from members of the research team.[11] Adolescents responded on a 5-point scale (1= *Never*, 5 = *Almost all or all the time*) to 7 questions assessing adherence to PHBs, including hand sanitizing, avoiding public spaces and gatherings, maintaining physical distance, and mask-wearing (e.g., "In the past two weeks, how often did you avoid public spaces, gatherings, and crowds indoors?"). Ratings were averaged across items to create a composite score representing overall PHBs (Cronbach's alpha = 0.87 to 0.94 over the 13 survey assessments). All items for this scale are listed in Table B2 from Appendix B.

*Covariates and potential moderators*

Demographics characteristics: Adolescents reported their date of birth, gender, race/ethnicity, and SES. Age was calculated based on the date of birth. Gender was coded 1 = boy, and 0 = girl or other gender. Race/ethnicity was represented by two dummy variables: White (1 = White, 0 = non-White) and Asian (1 = Asian, 0 = non-Asian), with non-White and non-Asian racial/ethnic groups serving as the reference category.

SES was constructed as a composite z-score comprising parents' education and employment status and household income.[32,33] Parental education was reported by the adolescent for their parent with the highest education level and coded as a continuous variable reflecting estimated years of schooling: 8th grade or less = 8 years, some high school = 10 years, high school graduate or GED = 12 years, some college = 14 years, technical college = 14 years, associate's degree = 15 years, bachelor's degree = 16 years, and master's or doctoral degree = 18 years. This approach preserved unequal spacing between education levels rather than assuming equal ordinal intervals, consistent with prior research on health behaviors among adolescents.[34,35] Parental employment status was also reported by the adolescent for the same parent with the highest education level and coded as 0 = not working for pay, 1 = working part-time, and 2 = working full-time. The range of household income was reported by parents of the adolescent participants and coded as the midpoint or the bound of the reported range ($14,999 or less = $15,000; $15,000–$24,999 = $20,000; $25,000–$34,999 = $30,000; $35,000–$49,999 = $42,500; $50,000–$74,999 = $62,500; $75,000–$149,999 = $112,500; $150,000–$199,000 = $175,000; $200,000 or more = $200,000). All values were then divided by $10,000, such that one unit corresponds to a $10,000 increment in household income, which aids in the interpretation of model coefficients by avoiding very small decimal values. All three indicators (i.e., parents' highest education level, parents' employment status, and household income) were standardized to z-scores and averaged to compute the final SES composite, with the composite computed whenever at least one indicator was available.[36]

COVID-19 health experiences: The following questions assessed the COVID-19 related health experiences such as vaccination status, test results, and symptoms. These measures served as indicators of the COVID-19 impact on individual physical health.

*Vaccination status*. In each survey, participants were asked "Have you received a SARS-CoV-2 (COVID-19) vaccine?" until they answered "yes." At each time point, vaccination status was coded as 0 if the participant had not been vaccinated, and as 1 if they had received at least one dose of any COVID-19 vaccine.

*Test result*. Participants were asked if they had been tested for COVID-19 in the past two weeks. If they answered "yes," they were then asked to provide the date of their most recent test and chose the test result from "positive for current infection," "positive for past infection (antibody test)," "negative," or "results pending." Responses were recoded into 0 = no positive result (including no test), 1 = positive infection test result.

*Symptoms*. Participants were asked to indicate if they experienced any of the following COVID-19-related symptoms in the past two weeks: fever; cough; shortness of breath; muscle aches; sore throat; nasal congestion or runny nose; loss of smell and/or taste; headache; diarrhea; nausea; dizziness; eye problems. The response was coded: 0 = no symptoms; 1 = at least one symptom.

County-level political orientation: We captured the political orientation of the county where each adolescent resided based on their reported zip code at baseline. Specifically, we calculated the difference score in the percentage of votes to Republican versus Democratic presidential candidates in the 2020 U.S. presidential election results.[37] Higher scores indicate more Republican-leaning and less Democratic-leaning. This approach has been used in prior COVID-19 research to capture county-level political orientation.[38,39]

COVID-19 county-level mortality and infection rates: We obtained the number of new confirmed COVID-19 deaths and cases in the 14 days prior to each survey completion date in the adolescent's residency county (based on their reported zip code) from the Johns Hopkins COVID-19 Dashboard.[40] The county-level COVID-19 mortality and infection rate were respectively calculated as the number of new confirmed deaths and cases per 100,000 residents. A logarithmic transformation was applied to the rates to correct for skewness.[41] The wording and coding of all covariates and moderators are detailed in Table B3, Appendix B.

## Statistical analysis

With 13 repeated measures within individuals over six months, we used multilevel modeling for analysis of the associations between media perceptions and PHBs between-persons on average and within-persons over time.[42] For each media message perception factor, we computed the between-person variable as the person mean across time, centered around the sample mean, and the within-person variable as occasion-specific deviations from those individual person means. The continuous variables included in the analysis, including baseline age, county-level political orientation, county-level mortality and infection rates, and media message perceptions were centered around their sample means. Missing data were handled using multiple imputations (5 imputation datasets, 100 iterations) through multivariate imputation by chained equations,[43] with multilevel model results from these imputed datasets pooled using Rubin's rules.[44] The multiple imputation approach accounts for the uncertainty of missing data and produces more accurate parameter estimates, valid standard errors, and reduces potential bias.[44] Before testing the hypothesized associations, models with only the covariates as predictors were used to understand how the covariates may contribute to PHBs.

We estimated separate two-level multilevel models predicting PHBs with each of the five media message perception factors, with a sandwich estimator to account for the non-independence of adolescents from the same households.[45] We also estimated main effects and moderation effects in separate models because including interaction terms makes main effects conditional and potentially misleading.[46] For each factor, we first tested its main within-person and between-person associations with PHBs, adjusted for demographic characteristics, COVID-19 health experience variables, and county-level contextual factors. Next, we tested possible moderators of these associations by including interaction terms between each of eleven potential moderator variable (i.e., age, gender, race and ethnicity, and SES; vaccination status, test result, and symptoms; county-level political orientation, COVID-19 county-level mortality and infection rates) and both the between-person and within-person media message perception factors, plus one within-person-by-between-person interaction. This resulted in 23 interaction terms per model. Nonsignificant interactions were trimmed from the final models to improve parsimony and interpretability of results, while all main effects of predictors and moderators were retained to avoid bias.[46,47] Significant interactions were probed for interpretation with simple slope tests.[47] In addition, descriptive statistics (means and standard deviations) for the study variables at baseline before and after imputation are presented in Table C1, Appendix C. *Appendix* D shows equations for all the models. *Appendix* E presents a posteriori power analysis, indicating adequate statistical power ( > 80%) to detect small within-person and small-to-medium between-person effects, as well as medium cross-level interactions.[48] All analyses were conducted in R, primarily using *mice, merTools, and lme4* packages.[43,49–51]

## RESULTS

A total of 163 adolescents from 151 households enrolled to participate in the study. Nine participants were excluded from analysis because they provided no data on either the primary outcome measure (PHBs) or the key predictors (media message perceptions) across all 13 surveys. After excluding these 9 adolescents, final analysis included 154 adolescents from 142 different households. Among the 154 adolescents retained in the analytic sample, we used an intention-to-treat approach by including all available data even if some participants provided

only partial information. Specifically, some adolescents missed parts of some surveys or all the follow-up surveys except for the baseline survey, and some discontinued participation before completing the study. To maximize use of the information collected, all available observations were retained and missing data were handled through multiple imputation. Of the 2002 possible observations (154 participants × 13 time points), 1872 surveys were completed, yielding an average survey completion rate of 65.98% (SD = 34.63%). Missing observations were addressed through multiple imputation. Detailed information on the completion rate of all variables at each time point is provided in Table C2, Appendix C. Demographic characteristics are presented in Table 1. The data collection period was from May 2021 to December 2022.

Correlations among the study variables are presented in Table 2. Feeling informed ($r = 0.21$, $p = 0.01$), negative impressions of public health measures ($r = -0.33$, $p < 0.001$), and feeling afraid ($r = 0.23$, $p = 0.01$) were significantly correlated with PHBs.

As shown in Fig. 1, over the study period, adolescents' overall PHBs declined over time, consistent with the evolving COVID-19 context as pandemic restrictions eased, vaccination became available and public health messaging shifted. Also, individual trajectories of PHBs showed substantial variations around this overall decline trend (Panel A). Media message perceptions exhibited more modest temporal changes (i.e., Panel B–F). Notably, all these factors exhibit substantial within-person and between-person variations, underscoring the necessity of examining effects at both levels in our analytical approach.

### Associations between perceptions of COVID-19 media messages and PHBs

The covariates-only model (Model 1) presented in Table 3 reveals that PHBs significantly decreased over time (time: $\beta = -0.03$, 95% CI [−0.05, −0.02]), and that fewer PHBs were adopted by adolescents who self-identified as boy ($\beta = -0.36$, 95% CI [−0.65, −0.06]), came from higher SES families ($\beta = -0.22$, 95% CI [−0.41, −0.03]), were vaccinated for COVID-19 ($\beta = -0.17$, 95% CI [−0.33, −0.00]), and lived in counties with stronger Republican tendencies ($\beta = -0.67$, 95% CI [−1.10, −0.24])

Results for models testing the main effect associations between each of the five media message perception factors and PHBs (i.e., Models 2a to 2e) are also presented in Table 3.

First, feeling more informed by media stories about COVID-19 was associated with more engagement with PHBs both within-persons ($\beta = 0.07$, 95% CI [0.00, 0.14]) and between-persons ($\beta = 0.29$, 95% CI [0.05, 0.53]; Model 2a). In other words, on occasions when adolescents reported feeling more informed from media stories related to the pandemic than their own usual level of feeling informed, they also reported more PHBs than usual and adolescents who on average felt more informed than other adolescents also reported more PHBs overall than others. More PHBs were also reported by adolescents on occasions when they reported feeling more afraid than usual in response to media stories about the pandemic (within-person association: $\beta = 0.06$, 95% CI [0.01, 0.10]) and by adolescents who reported feeling more afraid in response to media stories about the pandemic overall compared to other adolescents (between-persons association: $\beta = 0.25$, 95% CI [0.09, 0.42]; Model 2e). In contrast, adolescents who had more overall negative feelings about public health measures from seeing media stories about the pandemic reported significantly fewer PHBs than other adolescents (between-persons association: $\beta = -0.29$, 95% CI [−0.44, −0.14]; Model 2 d).

### Moderators of the associations between media message reactions and PHBs

Final models testing interactions between possible moderators and perceptions about media messages related to the pandemic on reported PHBs (i.e., Models 3a to 3 d) are shown in Table 4.

**Table 1.** Demographic characteristics of the study sample of 154 adolescents.

| Demographic Characteristic | *n* (%) or Mean (SD) |
|---|---|
| *Age (Baseline)* | 15.51 (1.46) |
| *Gender* | |
| Girl | 74 (48.05%) |
| Boy | 67 (43.51%) |
| Other | 11 (7.14%) |
| Unspecified | 2 (1.30%) |
| *Race* | |
| American Indian or Alaskan Natives | 2 (1.30%) |
| Asian | 12 (7.79%) |
| Black or African American | 21 (13.64%) |
| Hispanic or Latino | 12 (7.79%) |
| Multiracial | 24 (15.58%) |
| White | 82 (53.25%) |
| Unspecified | 1 (0.65%) |
| *Parental Education* | |
| 8th grade or less | 0 (0%) |
| Some high school without graduation | 1 (0.65%) |
| High school graduate or GED | 13 (8.44%) |
| Some college | 12 (7.79%) |
| Technical college | 6 (3.90%) |
| Associate's degree | 12 (7.79%) |
| Bachelor's degree | 35 (22.73%) |
| Master's or doctoral degree | 54 (35.06%) |
| Unspecified | 21 (13.64%) |
| *Parental Employment Status* | |
| Not working for pay | 32 (20.78%) |
| Working part-time | 14 (9.09%) |
| Working full-time | 87 (56.49%) |
| Unspecified | 21 (13.64%) |
| *Household Income* | |
| $14,999 or less | 6 (3.89%) |
| $15,000–$24,999 | 5 (3.25%) |
| $25,000–$34,999 | 6 (3.89%) |
| $35,000–$49,999 | 9 (5.84%) |
| $50,000–$74,999 | 9 (5.84%) |
| $75,000–$149,999 | 44 (28.57%) |
| $150,000–$199,000 | 7 (4.55%) |
| $200,000 or more | 9 (5.84%) |
| Unspecified | 59 (38.31%) |

Because no significant interaction effects were observed for positive perceptions of government leadership, we did not include any model of this predictor in this table.

First, age moderated the association between adolescents' average overall negative impressions of public health measures in reaction to media messages and PHBs (between-persons interaction: $\beta = -0.12$; 95% CI [−0.21, −0.04]; Model 3c). Simple slope analyses revealed a stronger inverse association among older (+1 SD age: $\beta = -0.46$, 95% CI [−0.64, −0.28], $p < 0.001$) than younger adolescents (−1 SD age: $\beta = -0.10$, 95% CI [−0.30, 0.10], $p = 0.32$). Age was also a possible moderator for the association between adolescents' cross-time average levels of feeling afraid in response to pandemic media stories and PHBs (between-person interaction: $\beta = 0.09$, 95% CI [0.00, 0.18]; Model 3 d). This

**Table 2.** Correlations of all study variables with means and standard deviations.

| Variables | M(SD) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Baseline Age | 15.51 (1.46) | 1.00 | | | | | | | | | | | | | | | |
| 2. Boy | 0.44 (0.5) | −0.03 | 1.00 | | | | | | | | | | | | | | |
| 3. White | 0.54 (0.5) | –0.02 | −0.00 | 1.00 | | | | | | | | | | | | | |
| 4. Asian | 0.08 (0.27) | 0.10 | 0.11 | **−0.31** | 1.00 | | | | | | | | | | | | |
| 5. Socioeconomic Status (SES) | 0.00 (0.82) | 0.10 | 0.16 | 0.11 | 0.06 | 1.00 | | | | | | | | | | | |
| 6. COVID-19 Vaccine_BP | 0.77 (0.4) | 0.08 | **−0.25** | 0.11 | 0.04 | 0.07 | 1.00 | | | | | | | | | | |
| 7. COVID-19 Test_BP | 0.08 (0.21) | −0.09 | 0.03 | 0.07 | -0.07 | -0.07 | -0.09 | 1.00 | | | | | | | | | |
| 8. COVID-19 Symptoms_BP | 0.26 (0.31) | 0.10 | **−0.20** | **0.19** | 0.02 | -0.05 | 0.08 | **0.17** | 1.00 | | | | | | | | |
| 9. Republican Tendency_BP | −0.07 (0.31) | −0.12 | −0.01 | **0.26** | −0.10 | −0.06 | **−0.17** | 0.05 | 0.10 | 1.00 | | | | | | | |
| 10. County-level Mortality Rate (Log) _BP | 1.15 (0.61) | 0.06 | −0.02 | 0.10 | −0.12 | −0.10 | 0.03 | -0.04 | -0.04 | **0.25** | 1.00 | | | | | | |
| 11. County-level Infection Rate (Log) _BP | 5.65 (0.69) | 0.04 | 0.02 | 0.08 | –0.14 | –0.03 | 0.10 | 0.04 | 0.04 | −0.00 | **0.48** | 1.00 | | | | | |
| 12. COVID-19 PHBs_BP | 2.69 (1.06) | 0.03 | **-0.20** | **-0.21** | −0.03 | **−0.24** | 0.00 | -0.09 | -0.09 | **-0.18** | 0.01 | -0.03 | 1.00 | | | | |
| 13. Feeling Informed_BP | 2.73 (0.66) | -0.03 | −0.05 | −0.10 | **0.17** | 0.06 | **0.17** | −0.13 | −0.02 | **−0.21** | −0.02 | 0.01 | **0.21** | 1.00 | | | |
| 14. Feeling Connected_BP | 2.5 (0.86) | −0.10 | 0.12 | **−0.20** | **0.18** | -0.01 | 0.03 | −0.01 | −0.07 | −0.12 | −0.10 | −0.00 | −0.02 | **0.63** | 1.00 | | |
| 15. Positive Perceptions of Government Leadership_BP | 2.18 (0.85) | −0.06 | 0.02 | −0.11 | 0.12 | 0.10 | −0.04 | −0.00 | −0.02 | −0.07 | −0.08 | −0.05 | 0.01 | **0.52** | **0.58** | 1.00 | |
| 16. Negative Impressions of Public Health Measures_BP | 2.24 (1.07) | 0.05 | **0.22** | −0.04 | 0.09 | **0.19** | **−0.24** | 0.04 | −0.12 | 0.08 | 0.13 | 0.13 | **−0.33** | **−0.22** | 0.14 | 0.08 | 1.00 |
| 17. Feeling Afraid_BP | 2.11 (0.91) | 0.10 | **−0.25** | 0.05 | -0.05 | 0.07 | **0.30** | 0.02 | 0.14 | −0.13 | −0.08 | 0.06 | **0.23** | −0.09 | **−0.26** | −0.01 | **−0.28** |

The BP variables were created as cross-time averages for each individual. Bolded values refer to effects that are significant at $p < 0.05$.
*BP* between-person, *M* mean, *SD* standard deviation.

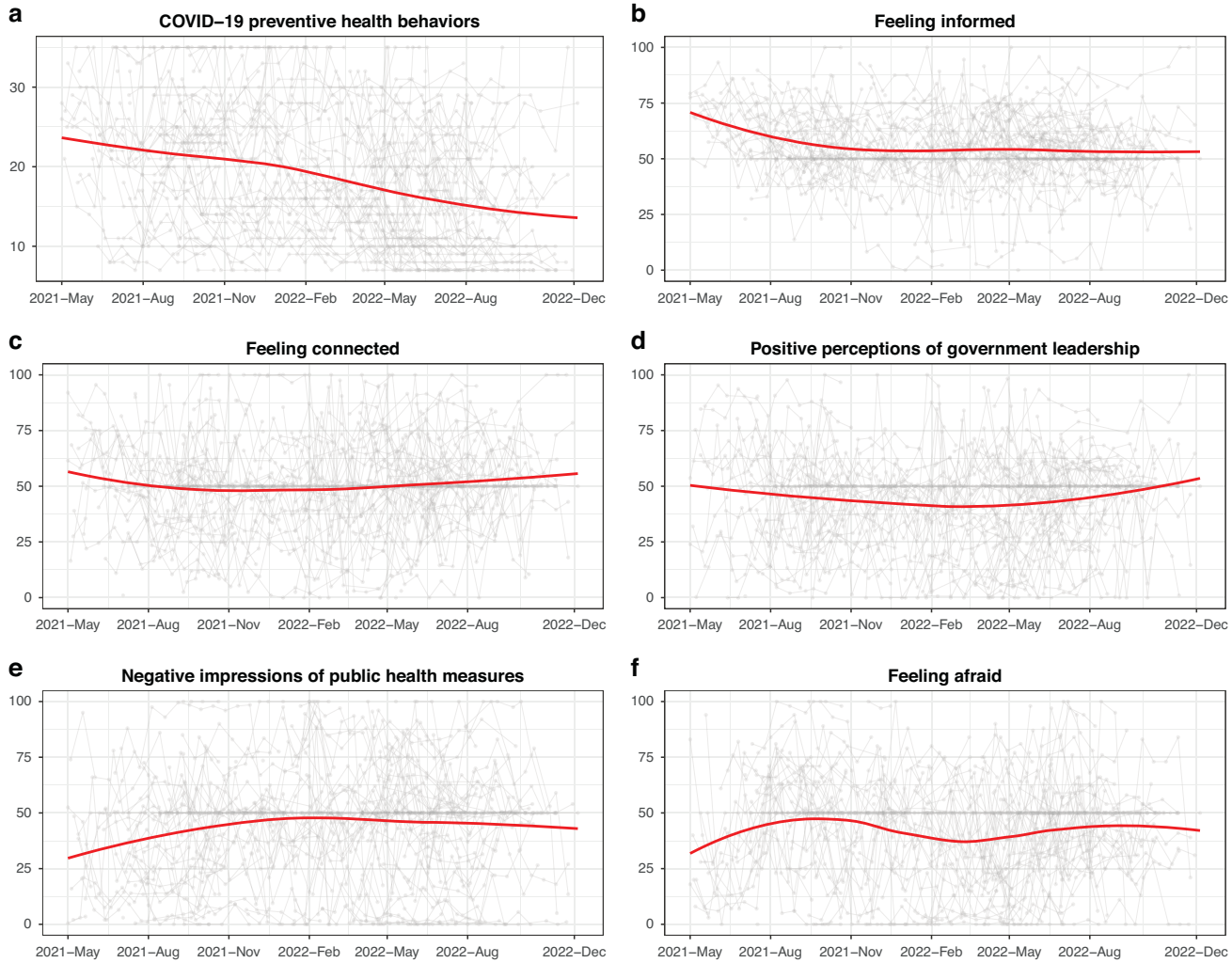


**Fig. 1 Spaghetti plots for adolescents' COVID-19 preventive health behaviors and five media message perception factors from May 2021 to December 2022.** Individual trajectories (thin gray lines) and sample-level mean trends (thick red lines, LOESS smoothed) for **A** = COVID-19 preventive health behaviors, **B** = feeling informed, **C** = feeling connected, **D** = positive perceptions of government leadership, and **E** = negative impressions of public health measures, and **F** = feeling afraid.

association was stronger among older (+1 SD age: $\beta = 0.38$, 95% CI [0.18, 0.59], $p < 0.001$) than younger adolescents (−1 SD age: $\beta = 0.12$, 95% CI [−0.10, 0.33], $p = 0.28$).

Race and ethnicity were also possible moderators of the associations linking both feeling informed (Asian versus non-Asian, between-persons interaction: $\beta = -1.01$, 95% CI [−1.72, −0.30]; Model 3a) and feeling connected (White versus non-White between-persons interaction: $\beta = -0.65$, 95% CI [−0.99, −0.32]; Model 3b) to reported PHBs. Simple slope follow-up tests showed that for non-Asian adolescents, feeling more informed than peers was significantly associated with higher PHBs ($\beta = 0.36$, 95% CI [0.10, 0.62], $p = 0.007$), while this association was nonsignificant among Asian adolescents ($\beta = -0.52$, 95% CI [−1.21, 0.17], $p = 0.13$). For non-White adolescents, feeling more connected in response to media stories about the pandemic was associated with reporting more PHBs ($\beta = 0.24$, 95% CI [0.01, 0.47], $p = 0.041$) while among White adolescents ($\beta = -0.33$, 95% CI [−0.56, −0.11], $p = 0.004$), feeling connected in response to media stories was associated with fewer PHBs.

Two significant between-person × within-person interactions also emerged. Both feeling connected ($\beta = -0.07$, 95% CI [−0.13, −0.01]) and negative impressions of public health measures ($\beta = -0.07$, 95% CI [−0.13, −0.01]) showed a significant between-person × within-person interaction. Simple slope analyses revealed that the within-person effect of feeling connected was nonsignificant when adolescents' cross-time average feeling of connection was high (+1 SD: $\beta = -0.03$, 95% CI [−0.11, 0.05], $p = 0.45$), but positive when it was low (−1 SD: $\beta = 0.09$, 95% CI [0.02, 0.16], $p = 0.01$), suggesting that increases (compared to usual) in feeling connected were more strongly associated with higher-than-usual engagement with PHBs among adolescents who generally felt less connected to others on average. Also, the within-person association with PHBs was nonsignificant when adolescents' cross-time average negative impressions of public health measures were high (+1 SD between-person value: $\beta = -0.05$, 95% CI [−0.14, 0.05], $p = 0.24$), but positive when the average negative impressions were low (−1 SD between-person value: $\beta = 0.10$, 95% CI [0.01, 0.18], $p = 0.02$). This suggests that increases (compared to usual) in negative media impressions were more strongly associated with greater-than-usual PHBs engagement only among adolescents who generally held more positive impressions of public health measures. The random effects of all models are presented in *Appendix* F.

## DISCUSSION

We followed a U.S. nationwide sample of 154 adolescents over six months during the critical period of COVID-19 pandemic, with

**Table 3.** Results of two-level models testing the main effect of each factor of COVID-19 media messages on PHBs at both the between- and within-person levels (Fixed effects only).

| Predictors | Model 1 Covariates Only | Model 2a Feeling Informed | Model 2b Feeling Connected | Model 2c Positive Perceptions of Government Leadership | Model 2 d Negative Impression of Public Health Measures | Model 2e Feeling Afraid |
|---|---|---|---|---|---|---|
| | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) |
| Fixed Effects | | | | | | |
| Time | **−0.03 (−0.05, −0.02)** | **−0.03 (−0.04, −0.02)** | **−0.03 (−0.05, −0.02)** | **−0.03 (−0.05, −0.02)** | **−0.03 (−0.04, −0.02)** | **−0.03 (−0.04, −0.02)** |
| Baseline Age | 0.02 (−0.08, 0.12) | 0.03 (−0.07, 0.12) | 0.02 (−0.08, 0.11) | 0.02 (−0.07, 0.12) | 0.03 (−0.06, 0.12) | 0.01 (−0.09, 0.10) |
| Boy | **−0.36 (−0.65, −0.06)** | **−0.33 (−0.62, −0.05)** | **−0.35 (−0.65, −0.05)** | **−0.36 (−0.65, −0.07)** | −0.25 (−0.54, 0.04) | −0.25 (−0.56, 0.05) |
| Race/Ethnicity: White | −0.35 (−0.70, 0.01) | **−0.35 (−0.69, −0.00)** | −0.36 (−0.71, 0.00) | −0.33 (−0.68, 0.02) | **−0.39 (−0.72, −0.06)** | **−0.35 (−0.69, −0.00)** |
| Race/Ethnicity: Asian | −0.28 (−0.81, 0.26) | −0.37 (−0.93, 0.18) | −0.25 (−0.80, 0.29) | −0.26 (−0.80, 0.29) | −0.21 (−0.71, 0.28) | −0.23 (−0.73, 0.26) |
| Socioeconomic Status (SES) | **−0.22 (−0.41, −0.03)** | **−0.23 (−0.42, −0.05)** | **−0.22 (−0.41, −0.03)** | **−0.22 (−0.41, −0.03)** | −0.16 (−0.34, 0.02) | **−0.24 (−0.43, −0.06)** |
| COVID-19 Vaccine | **−0.17 (−0.33, −0.00)** | −0.17 (−0.33, 0.00) | −0.17 (−0.33, 0.00) | −0.16 (−0.34, 0.01) | **−0.19 (−0.35, −0.02)** | **−0.18 (−0.34, −0.02)** |
| COVID-19 Testing | 0.11 (−0.06, 0.27) | 0.11 (−0.05, 0.28) | 0.11 (−0.06, 0.27) | 0.10 (−0.06, 0.26) | 0.11 (−0.05, 0.27) | 0.08 (−0.07, 0.23) |
| COVID-19 Symptoms | −0.04 (−0.13, 0.04) | −0.04 (−0.13, 0.04) | −0.04 (−0.13, 0.04) | −0.04 (−0.12, 0.05) | −0.05 (−0.13, 0.03) | −0.04 (−0.12, 0.05) |
| Republican Tendency | **−0.67 (−1.10, −0.24)** | **−0.52 (−0.96, −0.09)** | **−0.68 (−1.11, −0.25)** | **−0.65 (−1.08, −0.22)** | **−0.56 (−1.01, −0.10)** | **−0.60 (−1.03, −0.17)** |
| County-level Mortality Rate (Log) | 0.08 (−0.01, 0.17) | 0.08 (−0.01, 0.17) | 0.08 (−0.01, 0.17) | 0.08 (−0.01, 0.17) | 0.08 (−0.01, 0.18) | 0.09 (−0.01, 0.18) |
| County-level Infection Rate (Log) | 0.01 (−0.05, 0.08) | 0.01 (−0.05, 0.07) | 0.01 (−0.05, 0.08) | 0.01 (−0.05, 0.08) | 0.01 (−0.05, 0.08) | 0.01 (−0.06, 0.07) |
| Perceptions of Media Messages_BP | −−− | **0.29 (0.05, 0.53)** | −0.05 (−0.24, 0.14) | 0.02 (−0.17, 0.22) | **−0.29 (−0.44, −0.14)** | **0.25 (0.09, 0.42)** |
| Perceptions of Media Messages_WP | −−− | **0.07 (0.00, 0.14)** | 0.03 (−0.03, 0.09) | 0.04 (−0.01, 0.09) | 0.01 (−0.04, 0.07) | **0.06 (0.01, 0.10)** |

Table presents coefficient estimates, 95% confidence intervals, significance levels for predictors. Bolded values refer to effects that are significant at $p < .05$.
*BP* between-person, grand mean-lefted, *WP* within-person, person mean-lefted, *Cor* covariance.

**Table 4.** Results of two-level models testing the moderation effect of individual and contextual factors on the associations between each factor of COVID-19 media messages and PHBs at both the between- and within-person levels (Fixed effects only).

| Predictors | Model 3a Moderations for Feeling Informed | Model 3b Moderations for Feeling Connected | Model 3c Moderations for Negative Impression of Public Health Measures | Model 3 d Moderations for Feeling Afraid |
|---|---|---|---|---|
| | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) | Estimate (95% CI) |
| Fixed Effects | | | | |
| Time | **−0.03 (−0.04, −0.02)** | **−0.03 (−0.04, −0.02)** | **−0.03 (−0.04, −0.02)** | **−0.03 (−0.04, −0.02)** |
| Baseline Age | 0.02 (−0.08, 0.12) | 0.02 (−0.08, 0.11) | 0.03 (−0.06, 0.11) | 0.01 (−0.09, 0.10) |
| Boy | **−0.30 (−0.58, −0.01)** | −0.27 (−0.56, 0.01) | −0.22 (−0.51, 0.08) | −0.25 (−0.55, 0.05) |
| Race/Ethnicity: White | **−0.37 (−0.71, −0.04)** | **−0.37 (−0.70, −0.03)** | **−0.37 (−0.69, −0.05)** | −0.33 (−0.68, 0.02) |
| Race/Ethnicity: Asian | −0.12 (−0.76, 0.52) | −0.02 (−0.80, 0.76) | −0.18 (−0.66, 0.30) | −0.21 (−0.73, 0.31) |
| Socioeconomic Status (SES) | **−0.21 (−0.39, −0.03)** | **−0.24 (−0.42, −0.07)** | −0.12 (−0.31, 0.08) | **−0.23 (−0.41, −0.05)** |
| COVID-19 Vaccine | **−0.17 (−0.34, −0.00)** | **−0.17 (−0.34, −0.00)** | **−0.20 (−0.37, −0.03)** | **−0.17 (−0.33, −0.01)** |
| COVID-19 Testing | 0.11 (−0.05, 0.27) | 0.10 (−0.06, 0.26) | 0.10 (−0.05, 0.26) | 0.09 (−0.07, 0.26) |
| COVID-19 Symptoms | −0.04 (−0.13, 0.04) | −0.05 (−0.13, 0.04) | −0.05 (−0.13, 0.04) | −0.04 (−0.13, 0.04) |
| Republican Tendency | **−0.46 (−0.88, −0.04)** | **−0.63 (−1.04, −0.22)** | **−0.58 (−1.01, −0.16)** | **−0.63 (−1.05, −0.21)** |
| County-level Mortality Rate (Log) | 0.08 (−0.01, 0.17) | 0.09 (−0.01, 0.18) | 0.09 (−0.01, 0.18) | 0.09 (−0.00, 0.18) |
| County-level Infection Rate (Log) | 0.01 (−0.05, 0.07) | 0.01 (−0.05, 0.07) | 0.02 (−0.05, 0.08) | 0.01 (−0.05, 0.07) |
| Perceptions of Media Messages_BP | **0.60 (0.36, 0.83)** | **0.32 (0.08, 0.55)** | **−0.28 (−0.42, −0.14)** | **0.25 (0.09, 0.42)** |
| Perceptions of Media Messages_WP | **0.07 (0.00, 0.14)** | 0.03 (−0.03, 0.09) | 0.02 (−0.03, 0.08) | **0.05 (0.00, 0.11)** |
| Baseline Age x Perceptions of Media Messages_BP | — | — | **−0.12 (−0.21, −0.04)** | **0.09 (0.00, 0.18)** |
| White x Perceptions of Media Messages_BP | −0.46 (−0.92, 0.01) | **−0.65 (−0.99, −0.32)** | — | — |
| Asian x Perceptions of Media Messages_BP | **−1.01 (−1.72, −0.30)** | −0.76 (−1.57, 0.06) | — | — |
| SES x Perceptions of Media Messages_WP | — | — | 0.06 (−0.00, 0.13) | — |
| Perceptions of Media Messages_BP x Perceptions of Media Messages_WP | — | **−0.07 (−0.13, −0.01)** | **−0.07 (−0.13, −0.01)** | — |

Nonsignificant interactions were omitted from the final models. Table presents coefficient estimates, 95% confidence intervals, significance levels for predictors. Bolded values refer to effects that are significant at $p < 0.05$.
*BP* between-person, grand mean-lefted, *WP* within-person, person mean-lefted.

consecutive surveys administered every two weeks. Our findings indicate that adolescents' responses to COVID-19 related media messages were meaningfully associated with their adoption of PHBs over time. Adolescents who felt more informed, held fewer negative impressions of public health measures, and experienced greater fear in response to media messages were more likely to engage in PHBs such as mask wearing, hand washing, and social distancing, whereas feeling connected and having positive perceptions of government leadership were not associated with PHBs. We also observed temporal, demographic, and contextual differences in PHBs adoption, with evidence that age and race/ethnicity moderated associations between media message perceptions and PHBs among adolescents. Overall, the current study highlights the importance of how adolescents' perceptions of media messages about infectious diseases are associated with their health-protecting behaviors. These findings collectively underscore the need for tailored public health communication strategies that account for adolescents' psychological responses to media messages and are tailored to their demographic and contextual characteristics. Such efforts by public health officials, communicators, healthcare providers, and policymakers can improve the effectiveness of media-based interventions for adolescents during infectious disease outbreaks.

This study advances our understanding of whether and how adolescents' experiences with media messages may influence their PHBs during pandemics, specifically highlighting the implications of media messages that make adolescents feel more informed, more afraid, and more positive about public health measures than others. Further, moving beyond the between-person associations, within-person associations based on our longitudinal data also highlighted how changes in adolescents' perceptions of media messages — specifically when they feel

more informed or more afraid than usual — are associated with changes in their PHBs. Notably, the result of feeling afraid was exploratory rather than hypothesized and warrants further investigation. Prior studies have found that greater exposure to COVID-19 information predicted mask-wearing behaviors early in the pandemic among U.S. adolescents,[18] and that adolescents in Norway mainly used the Internet for COVID-19 information and expressed a desire to be better informed about the virus.[52] Our study adds to the existing research by highlighting the importance of moving beyond the amount and source of information to focus on how adolescents' exposure and perception of media messages is related to PHBs.

The absence of significant main effects for feeling connected or for positive perceptions of government leadership is also informative. Although prior research has shown that social connection[20] and trust in leadership and institutions[21] predict compliance with more PHBs, much of this evidence was derived from adult samples. Developmental research suggests that adolescents, who are characterized by heightened autonomy-seeking[53] and strong peer influence,[54] may be less likely to translate generalized connection and trust in government leadership into actual protective actions. Instead, health-related behaviors among adolescents appear more tightly linked to perceptions of personal understanding, perceived personal threat, and legitimacy of public guidance. Together, these results highlight the importance of tailoring public health messaging for adolescents in several ways. Messages should convey clear information (e.g., what adolescents can do and how the disease and infection may affect them, rather than adults or general populations in the short- and long- term), and the credibility of public health measures (e.g., the feasibility and effectiveness of recommended measures in protecting youth).[55] At the same time, messages should balance fear appeals with supportive communication, as excessive fear or information overload can undermine actions and negatively impact mental health.[55,56]

Beyond the main associations between media message perceptions and PHBs, we also observed temporal, demographic, and contextual differences in adolescents' engagement in PHBs. Over the course of the study from May 2021 to December 2022, we found adolescents' use of PHBs declined over time in general, consistent with the evolving COVID-19 context as pandemic restrictions eased, vaccination became available to youth, and public health messaging shifted. Also, demographic and contextual factors were associated with PHBs: Boys reported using fewer PHBs than girls; adolescents from higher-SES families reported fewer PHBs than those from lower-SES families; vaccinated adolescents reported fewer PHBs than unvaccinated adolescents; and adolescents in Republican-leaning counties reported fewer PHBs than those in Democratic-leaning counties. These demographic and contextual differences aligned with prior findings that girls, adolescents in Democratic-leaning counties engaged in more PHBs.[57–59] However, the pattern differed from the research suggesting that higher-SES and vaccinated adults may engage more PHBs,[60,61] underscoring the necessity of specific health communication strategies adapted to adolescents.

In addition, moderation of the associations between media message perceptions and PHBs highlights that the effectiveness of media messages may depend on adolescents' individual characteristics. The influence of media messages may vary by age and race, as evidenced by the significant moderating effects of race on the associations between feeling informed and PHBs and between feeling connected and PHBs, as well as the moderation effects of age on the associations between feeling afraid and PHBs and between negative impressions of public health measures and PHBs. Specifically, messages that make adolescents feel more afraid may be more effective for changing PHBs among older adolescents, whereas messages that make adolescents have less negative impression of public health measures may be more effective for older adolescents. Further, messages that make adolescents feel more informed may be more effective for non-Asian adolescents and those that make them feel more connected may have more inverse effects for White adolescents. Also, the significant moderation of between-person and within-person variables for feeling connected and having negative impression of public health measures further suggest that the effects of fluctuations in adolescents' perceptions may be shaped by their general perceptions over time, though these findings needs to interpreted cautiously given their exploratory nature.

Therefore, public health officials, communicators, healthcare providers, and policymakers should consider these demographic factors, such as age, race/ethnicity, gender, and SES when designing and implementing interventions to promote PHBs among adolescents.[62] Our findings suggest that one-size-fits-all messaging approaches may be insufficient. Instead, intervention strategies could be adapted to account for demographic subgroups of adolescents who may respond differently to health messages. Moreover, because the psychological mechanisms linking media message perceptions to PHBs and the demographic difference are not unique to COVID-19, the insights gained from this study may inform prevention intervention strategies for other infectious diseases outbreaks among adolescents in the future.

This study has several limitations. First, the study was conducted between May 2021 to December 2022, which did not cover the beginning of the pandemic in the U.S. in 2020 and early 2021. However, starting after the beginning of the pandemic gave us the opportunity to adjust for factors that only emerged later in the pandemic such as the vaccination status. It also took time for government agencies to release their full guidance on PHBs, and for these messages to diffuse into the population; By May 2021, it may have been more likely that those who did not adopt PHBs did so more based on their own experiences and choices than from limited availability of public information about PHBs.[63] Second, due to the lack of prior research on perceived media messages during the pandemic, our research team (including expertise in medicine, developmental psychology, and media psychology) constructed the media message perceptions scale specifically for this study based on the content of public health messaging and research at the time. The moderate internal consistencies of individual items in some media message perception factors during some time points may have limited the results. This highlights an important future direction to validate and refine this scale to raise its internal consistency in future studies. Third, the sample was also constrained to Android users in the U.S. and those who were willing to participate every two weeks for six months, because of the parent study's goals. Prior research indicates that adult Android users tend to have lower household incomes and education than iOS users.[64] This selection criterion may have limited the generalizability of our findings to other samples, such as those who use iOS devices, cannot access a phone or are unwilling to participate in a longitudinal study. Future research on this topic could expand to include more diverse and larger samples. Fourth, the study contribution could have been limited by the missing data. Although missingness across most variables was modest and was handled through multiple imputation, the relatively high proportion of missing data in certain variables (e.g., COVID-19 testing result) or at certain time points (e.g., later time points such as 8–13) may still introduce some degree of imprecision in the affected estimates and should be interpreted with caution. In addition, several limitations in the operationalization of SES should also be noted. First, although SES was constructed as a composite z-score of three indicators, complete data were unavailable for all participants. For instance, matched parent-reported household income was available for only 61.69% of the sample, which may have introduced inconsistency in how SES was captured across individuals. Second, adolescent-reported parental education and employment status were subject to recall

and reporting bias, which may have introduced measurement error into the composite. Third, converting categorical parental education to continuous years of schooling assumed unequal spacing between categories and treating ordinal employment status as continuous assumed equal intervals between levels. However, neither assumption may hold uniformly across all participants. Future research should operationalize SES using more objective and comprehensive measures, such as administrative records or multi-informant approaches, and retain original coding where possible, to more accurately capture socioeconomic circumstances.

In summary, this study provides valuable insights into how media message perceptions were associated with adolescents' PHBs in the face of a pandemic. The main findings indicate that adolescents' preventive actions are associated with how media messages affect their sense of actionable information, perceived threat, and the perceived legitimacy of public health guidance. Moderation analyses further suggested that these associations vary by developmental stage and social context. Together, these findings suggest that media messages targeting adolescents should prioritize clarity, credibility, and supportive guidance while avoiding communication that undermines legitimacy or fosters reactance. Meanwhile, by accounting for both individual-level perceptions and broader contextual factors such as age and race/ethnicity, public health interventions may be more effectively tailored to adolescent populations, ultimately strengthening PHB uptake, improving health outcomes, and reducing persistent vulnerabilities in current and future public health crises.

## DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Ting Xu: Conceptualization, Methodology, Formal analysis, Software, Validation, Visualization, Writing—original draft, Writing—review & editing. Xiaoran Sun: Conceptualization, Methodology, Funding acquisition, Data curation, Supervision, Writing—review & editing. Kimberly M. Molaib: Data curation, Resources, Project administration, Writing—review & editing. Nilàm Ram: Conceptualization, Methodology, Funding acquisition, Writing—review & editing. Byron Reeves: Conceptualization, Methodology, Funding acquisition, Writing—review & editing. Thomas N. Robinson: Conceptualization, Methodology, Funding acquisition, Supervision, Writing—review & editing.

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## COMPETING INTERESTS

The authors declare no competing interests.

## ADDITIONAL INFORMATION

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