Psychometric development of the COVID-19 vaccine misinformation scale and effects on vaccine hesitancy

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ABSTRACT

To help inform post-COVID-19 pandemic practical health policies, the researchers created the COVID-19 vaccine misinformation scale (CVMS). During the COVID-19 pandemic, falsehoods spread online which casted doubt and concerns about the vaccine. Example misconceptions included vaccination leads to greater vulnerability to other illness and would alter someone's DNA. The researchers performed two large surveys with U.S. participants. The researchers reviewed debunked COVID-19 vaccine falsehoods online. Construction of the CVMS followed standard psychometric scale development steps. Statistical analysis provided support for the 10-item CVMS with satisfactory reliability, discriminant validity, and convergent validity. Predictive validity regression analysis demonstrated the CVMS associated with higher vaccine hesitancy. The prevalence of vaccine misbeliefs broadened pandemic healthcare challenges. On top of existing duties, healthcare workers had to explain vaccine efficacy and safety to dispel fallacies. The researchers discuss implications for the CVMS within the context of motivated reasoning theory.

1. Introduction

1.1. COVID-19 vaccine misinformation

The COVID-19 pandemic altered the world economy and impacted countless of lives through infections. Across the globe, misinformation negatively impacted COVID-19 vaccine perceptions (Feleszko et al., 2021; Lazarus et al., 2021). In India, health and allergic reactions to COVID-19 vaccines was a major concern discussed on social media (Praveen et al., 2021). In the U.K., qualitative research found negative stories, personal knowledge, and safety concerns generated confusion and mistrust towards COVID-19 vaccines (Lockyer et al., 2021). In the Democratic Republic of Congo, 24.1 % of research participants (996/4,131) denied the existence of COVID-19 which associated with a lower likelihood to accept legitimacy of the COVID-19 vaccine (Ditekemena et al., 2021). Ditekemena et al. (2021) found health falsehoods (e.g., will cause death and sterilization) as reasons against the COVID-19 vaccine. The development of the COVID-19 vaccine misinformation scale (CVMS)

equips researchers with a psychometric measure to study individuals with these misbeliefs. It becomes possible to assess individual differences and develop preventative health marketing materials to influence the decision-making process.

1.2. Theory of motivated reasoning and COVID-19 vaccine misinformation

The theory of motivated reasoning explains individuals have predetermined goals and evaluate new (mis)information to serve these goals (Leeper and Slothuus, 2014; van der Linden, 2022). Individuals will interpret or seek information that supports preexisting opinions. Individuals are likely to arrive at their preconceived conclusions when bits of information are present to substantiate outcomes (Kunda, 1990). Misinformation propagated during the COVID-19 pandemic provided the false justifications to cast doubts about COVID-19 vaccines and the institutions advocating for them (Bruns et al., 2022; Jennings et al., 2021). Vaccine conspiracies shared as social media posts gave

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individuals what they needed to believe false claims. For instance, Nicki Minaj's tweet to her over 22 million followers of her cousin's story stating, "… his friend got it [the COVID-19 vaccine] & became impotent. His testicles became swollen…." was shared around the world (Hall Jamieson, 2021; Minaj, 2021). This provided faulty support to existing concerns that vaccines harm someone's reproductive system. Health institutions publicly spoke out to counter these claims (Hall Jamieson, 2021). Unfortunately, lower trust in institutions dealing with the COVID-19 pandemic was found to associate with lower vaccine intent (Dal and Tokdemir, 2022). Similarly, lower trust in government and higher conspiracy beliefs was found to associate with lower COVID-19 vaccine intent (Van Oost et al., 2022). This posed a problem to combat COVID-19 because mass vaccinations was a major public health policy to reach safe levels of herd immunity (Randolph and Barreiro, 2020).

Moreover, motivated reasoning attributed to the spread of online COVID-19 vaccine misinformation (Pennycook et al., 2022; Sylvester, 2021). These goals are often politically motivated based on the set of established beliefs (Rousseau and Tijoriwala, 1999). Conservative news outlets contributed to the spread of doubt and misinformation about the COVID-19 vaccine in the U.S. (Sylvester, 2021). Sylvester (2021) found lower COVID-19 knowledge and conservative ideology both independently associated with lower vaccine acceptance. Stricken, Taber, and Lodge (2011) argued those more knowledgeable about an issue and politically engaged are more determined to defend their beliefs. The mechanisms in operation include prior beliefs, confirmation bias, and disconfirmation bias (Strickland et al., 2011). The politicization of COVID-19 vaccines in the U.S. contributed to online misinformation campaigns that dampened public vaccine acceptance (Bolsen and Palm, 2022). This politization made COVID-19 vaccine misinformation widely shared, viewed, and unnecessarily contemplated by the general U.S. population.

Users have the flexibility and freedom to share (mis)information on social media platforms (like Facebook) without substantial third party filtering (Allcott and Gentzkow, 2017). Active users, known as 'super-sharers' and 'superconsumers' are exposed to greater amounts of online content (Grinberg et al., 2019). Social media platforms reinforce preexisting beliefs. Platform algorithms curate content with opinion-confirming content so users spend more time online (Kitchens et al., 2020). Information on social media is often opinion-based, largely unfiltered, and easily shareable by users with an account (Kumar and Shah, 2018). Researchers have found fake news spreads 70 % more likely than accurate news on Twitter (Vosoughi et al., 2018). Higher instances of sharing negative posts applied to COVID-19 vaccine related content. For example, a review of 5,000 COVID-19 vaccine related tweets found 182 tweets to have a negative behavioral intent compared to 97 positive behavioral intent tweets (Liu and Liu, 2021). Users search, consume, follow, and believe what suits their goals. Skepticism and anti-vaccine narratives fit individuals' motivated reasoning goals to share vaccination misinformation and resist COVID-19 vaccination. Because of widespread COVID-19 vaccine misinformation we recognized the prevalence of these misbeliefs and negative impact on public inoculations. Hence, this study designed and validated the COVID-19 vaccine misinformation scale (CVMS). The purpose was to provide researchers a psychometric tool to study those with the shared misbeliefs and relevant behavioral outcomes.

1.3. Pervasive COVID-19 vaccine hesitancy

Vaccine hesitancy stems from distrust in government and pharmaceutical reports of vaccine safety and efficacy (Wagner et al., 2020). For example, individuals falsely believed hurtful metals are in vaccines despite medical institutions stating their absence in vaccines (Center for Disease Control and Prevention, 2018). This distrust in the medical institutions and concerns about vaccine safety has spurred individuals to avoid COVID-19 inoculation. Some individuals falsely believe getting sick is a safer way for the immune system to naturally develop resistance for diseases (Wagner et al., 2020). For instance, people have claimed most children recover from illnesses like the common cold as evidence that proves children will develop immunity to other diseases. However, debilitating (e.g., Polio, Hib, Rotavirus) and life-threatening (e.g., Hepatitis B, Whooping Cough/Pertussis, Tetanus) diseases are unsafe for natural exposure. Vaccines have saved countless lives by activating one's natural immune system to develop resistance (Henao-Restrepo et al., 2015; Koirala et al., 2020; World Health Organization, 2020).

Regrettably, vaccine misinformation was notably prevalent online (Steffens et al., 2019; Waszak et al., 2018). Narratives created by the anti-vaccination movement posed a problem for health care providers and organizations that must first untangle this misinformation (Steffens et al., 2019). Unfortunately, vaccine misinformation captivated the public compared to factual information (Loomba et al., 2020). This is partly explained by unsubstantiated case studies (e.g., a sewage system blamed for a Hong Kong high-rise housing outbreak) (Han et al., 2020) and social media connections sharing distressing fake news (e.g., Columbia health care COVID cartel received cash for deaths) (Taylor, 2020). Misinformation grabbed attention with flashy headlines compared to technical facts like biomedical statistics on vaccine effectiveness rates. This environment of misinformation created mistrust in medicine and the health care institutions dedicated to saving lives (Sanfilippo et al., 2020). Thereby, we hypothesize COVID-19 vaccine misinformation beliefs will have a positive relationship to vaccine hesitancy, where higher COVID-19 vaccine misinformation beliefs will relate to higher vaccine hesitancy. Fig. 1 illustrates the hypothesized relationship of CVMS with vaccine hesitancy.

2. Methodology

2.1. Overview of studies

The creation of the CVMS followed recommended scale development processes using two studies and two samples (Carpenter, 2018; Worthington and Whittaker, 2006). The first step formulated and revised scale items. The authors compiled COVID-19 vaccine misbeliefs from online sources (e.g., Center for Disease Control and Prevention) and published work studying debunked beliefs. The authors constructed construct items that succinctly represented misbeliefs. The second step examined reliability, discriminant validity, and convergent validity. The authors utilized IBM SPSS V26 scale reliability and bivariate correlation functions to perform this analysis. By following this standard practice, statistical analysis formed the new scale. The third step evaluated predictive validity and the proposed hypothesis (Hinkin, 2005). Predictive validity analysis assessed utility of the new scale by testing the CVMS with vaccine hesitancy. We conducted two large surveys with U.S. participants to follow standard psychometric scale development practice. The studies met the institution's guidelines for the protection of human subjects concerning safety and privacy. Two studies provided several benefits: collect a large array of measures for discriminant and convergent validity analysis without over burdening participants, assess a larger sample, and replicate predictive validity results across two samples (Donnellan et al., 2006; Schmidt et al., 2003). After psychometric development, we conducted regression analysis to assess for predictive validity.

2.2. Construction of items

We started with a comprehensive list of twenty-seven items from inductive and deductive reasoning (Hinkin, 2005). The exhaustive list of COVID-19 vaccine misbeliefs came from thoroughly debunked and dismissed misbeliefs reported by the Center for Disease Control and Prevention (CDC) (Center for Disease Control and Prevention, 2020). The list included a review of literature and revived vaccine misconceptions applied to the COVID-19 vaccine (Center for Disease
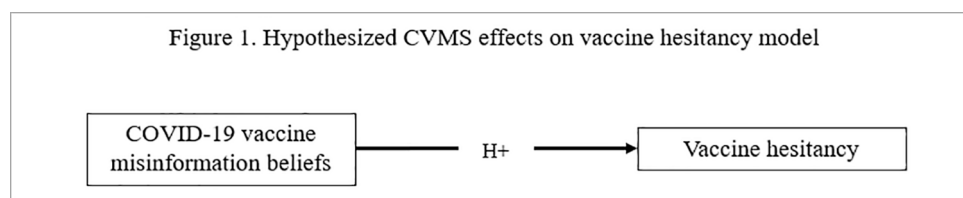
Note: COVID-19 vaccine misinformation beliefs was captured by the developed COVID-19 vaccine misinformation scale (CMVS). Control variables included gender, age, household size, household income, and college degree.

Fig. 1. Hypothesized CVMS effects on vaccine hesitancy model.

Control and Prevention, 2018; Grech et al., 2020; Jacobson et al., 2015; Loomba et al., 2020; May and Silverman, 2003). For example, some misbelieve vaccines contain harmful chemicals and the researchers designed statements to capture this idea applied to COVID-19 vaccines (e.g., "COVID-19 vaccines contain unsafe toxins"). A 5-point semantic differential scale suitable for true/false items was utilized (1 – Definitely not true, 2 – Probably not true, 3 – Not sure/Cannot decide, 4 – Probably true; 5 – Definitely true) (Brotherton et al., 2013). This type of scale allotted for variation in responses while identifying believers and non-believers of COVID-19 vaccine misinformation.

2.3. Participants

A total of 1,103 individuals across the U.S. participated on Amazon Mechanical Turk. The researchers followed standard practices for sampling participants on this platform (e.g., completed over 100 previous assignments with an approval rating greater than 97 %) (Buhrmester et al., 2016; Keith et al., 2017). Fifteen dropped out without completing. Eight failed attention checks (e.g., selecting 'disagree' between questions in the survey). Analysis was conducted with the remaining participants (N = 1,080, Study 1n = 508, Study 2n = 572). The age of participants ranged from 18 to 78 years old ($M = 41.2$, $SD = 12.5$) with 60 % identifying as female. Median household income was between $50,000 and $59,999. Participants viewed approximately 3.62 h of news each week. Sixteen percent of participants worked in healthcare or a science profession familiar with basic epidemiology (e.g., medical or healthcare professional). 834 participants identified as Caucasian, 122 as African American, 41 as Hispanic/Latino, 12 as Native American/American Indian, 54 as Asian/Pacific Islander, and 17 as other.

2.4. Regression variables

Independent variable. Based on the psychometric scale development process, the researchers used the validated COVID-19 vaccine misinformation scale (CVMS) in this analysis to assess for predictive validity.

Dependent variable. The Vaccine Hesitancy Scale (VHS) measured parental and personal beliefs towards vaccination (Domek et al., 2018; Larson et al., 2015; Shapiro et al., 2018). The scale was adapted with a U.K. population to a 9-item generic version focused principally on personal vaccine hesitancy beliefs (e.g., "I am concerned about serious adverse effects of vaccines.") (Luyten et al., 2019).

Control variables. The researchers controlled for gender, age, household size, household income, and college degree in the regression analysis.

3. Results

3.1. Inter-item correlations and reduction

The authors performed the SPSS dimension reduction factor function to access inter-item correlations. Based on inter-item correlations, thirteen of the twenty-seven items demonstrated adequate values ($|r|s <$ 0.30) (Tabachnick et al., 2007). There was a removal of fourteen items

below the threshold from the constructed list (Worthington and Whittaker, 2006). For instance, despite false claims "Those with the COVID-19 vaccine shed a protein linked to reproductive complications" it inadequately correlated with other items. Impartial statistical results determined reduction of the list (Boateng et al., 2018). Casting a large pool of initial items and reducing to beneath half decreases the odds of missing an item suitable for the new measure (Flight et al., 2011; Pommer et al., 2013). Kaiser-Meyer-Olkin's measure of sampling adequacy (0.972) and Bartlett's test of sphericity [$\chi^2(78) = 12,274.44$, $p <.001$] indicated the items as suitable for factor analysis (Cerny and Kaiser, 1977; Kaiser, 1981; Tobias and Carlson, 1969).

3.2. Factor loadings and descriptive statistics

The recommended threshold for factor loadings are at least between 0.40 and 0.70, with higher scores better (Hulland, 1999; Peterson, 2000). Auspicious factor loadings toped 0.70 and suited the criteria used in this study for the selected ten CVMS items (Chyung et al., 2017; Hair Jr Joseph et al., 2010, p. 125; Yong and Pearce, 2013) (see Table 1). Higher factor loadings indicate an item explains more variance of the variable and this threshold was considered appropriate in previous pathway analysis literature (Lin, 2012). Despite COVID-19 vaccine misconceptions that appear acceptable for the CVMS (e.g., "COVID-19 vaccination can infect someone with the disease they are trying to prevent") they did not meet the objective statistical analysis for inclusion. We followed these standards to evaluate items for inclusion based on SPSS dimension reduction factor analysis. Therefore, we proceeded with 10-items that met these standards.

Scree plot and parallel analyses showed the CVMS appropriate as one factor. The first item explained 73.04 % of the common variance. Direct oblimin rotated analysis with two principal component factor loadings generated scores underneath 0.20 for the second factor. Forced two factor analyses produced unsatisfactory scores (Dunn et al., 1994; Gibbons et al., 1985). Hence, one factor suited the new COVID-19 vaccine misinformation belief measure.

Over 70 % of participants agreed, each of the ten items to be untrue (see Table 2). This followed a high recommended consensus for continuous true/false scales (Clark and Watson, 1995). The 10-item CVMS was composed of varying misbeliefs about COVID-19 vaccines. For example, there was no evidence microchips are inserted during COVID-19 vaccination despite widely spread U.S. conspiratorial accusations of former CEO of Microsoft, Bill Gates (Gu et al., 2021) (Study 1: $M = 2.06$, $SD = 1.33$; Study 2: $M = 2.44$, $SD = 1.41$). The CVMS encompassed incorrect conspiratorial beliefs and inaccurate health effects propagated at the onset of pandemic when less information was known about COVID-19.

3.3. Convergent and discriminant validity

Correlation analysis of the new scale with existing validated scales examined uniqueness (Maloney et al., 2012; Mathieu and Farr, 1991). Positive correlations indicated degree of convergent validity. Negative correlations indicated a degree of discriminant validity. A correlation

Table 1

Item-factor loadings and item-level descriptive statistics for the 10-item COVID-19 Vaccine Misinformation Scale (CVMS).

Item		Study 1 (N = 508)			Study 2 (N = 572)		
		M	(SD)	Factor loading	M	(SD)	Factor loading
1)	A COVID-19 vaccine will cause someone to be more susceptible to other diseases	2.41	(1.25)	0.867	2.69	(1.32)	0.853
2)	Vitamin and mineral supplements are just as effective as a COVID-19 vaccine	2.41	(1.33)	0.824	2.71	(1.40)	0.851
3)	Microchips are inserted during COVID-19 vaccination	2.06	(1.33)	0.854	2.44	(1.41)	0.840
4)	A COVID-19 vaccine alters someone's DNA	2.33	(1.34)	0.835	2.53	(1.39)	0.849
5)	COVID-19 vaccines cause autism	2.28	(1.31)	0.876	2.48	(1.31)	0.867
6)	Herbs like thyme are a natural COVID-19 vaccine	2.26	(1.30)	0.855	2.54	(1.36)	0.849
7)	COVID-19 vaccines cause neurological damage	2.46	(1.28)	0.859	2.64	(1.31)	0.858
8)	Elderberry is a natural COVID-19 vaccine	2.25	(1.23)	0.822	2.63	(1.34)	0.853
9)	People COVID-19 vaccinated endanger the lives of others	2.20	(1.34)	0.862	2.49	(1.39)	0.856
10)	COVID-19 vaccines will damage someone's spinal cord	2.24	(1.27)	0.843	2.67	(1.29)	0.850

Table 2

Frequency statistics of COVID-19 Vaccine Misinformation Scale items.

	Frequency Believe Not True	Percent Believe Not True
Item 1	794	73.52 %
Item 2	765	70.83 %
Item 3	805	74.54 %
Item 4	796	73.70 %
Item 5	830	76.85 %
Item 6	810	75.00 %
Item 7	788	72.96 %
Item 8	823	76.20 %
Item 9	810	75.00 %
Item 10	800	74.07 %

Notes: Responses 1 – Definitely false, 2 – Probably false, and 3 – Not sure/cannot decide counted as believe as not true. Responses 4 – Probably true and 5 – Definitely true counted as believe as true. Percent out of 1,080 COVID-19 vaccine misinformation item responses. All misinformation statements had responses that ranged from 1 to 5. Each statement was unproven at the time of the study.

was illustrated in Table 3. The CVMS was correlated with the subsequent scales: vaccine conspiracy beliefs (e.g., "Vaccine safety data is often fabricated") (i.e., general mistrust of inoculations) (alpha = 0.94) (Shapiro et al., 2016), locus of control (rational scale) (e.g., "Believe in the power of fate") (i.e., belief in external influences on outcomes) (alpha = 0.61) (Levenson, 1981), peculiarity (e.g., "Am odd") (i.e., belief in being eccentric) (alpha = 0.86) (Simms et al., 2011), emotionally detached (e.g., "Am emotionally reserved") (i.e., expressiveness of emotions) (alpha = 0.82) (Simms et al., 2011), calmness (e.g., "Remain calm under pressure") (i.e., degree of levelheadedness) (alpha = 0.75) (Hogan and Hogan, 1992), extroversion (e.g., "Extraverted, enthusiastic") (i.e., outgoingness) (alpha = 0.77) (Gosling et al., 2003), ability to handle stress (i.e., coping ability) (alpha = 0.77) (Littman et al., 2006), self-esteem (e.g., "I have high self-esteem") (i.e., confidence in oneself) (alpha = 0.64) (Robins et al., 2001), openness (e.g., "Open to new experiences, complex") (i.e., experience seeking) (alpha = 0.62) (Gosling et al., 2003). The tabled results evinced expected relationships between constructs. Two studies enabled analysis on a gamut of varying measures which provided support for convergent and discriminant validity.

3.4. Reliability

The 10-item CVMS demonstrated high reliability (Study 1: alpha = 0.957; Study 2: alpha = 0.958). There was a high level of precision among the items in measuring the construct (Avalos et al., 2005; Kwon et al., 2013; Robbins et al., 2010).

4. Regression analysis

4.1. Predictive validity results

IBM SPSS V26 was used to perform regression analysis (George and Mallery, 2019; Park, 2009). To test the predictive validity hypothesis, we regressed COVID-19 vaccine misinformation beliefs with vaccine hesitancy [$F(6, 1,073) = 69.059$, $R^2 = 0.279$, $p < .001$]. The regression results showed higher COVID-19 vaccine misinformation beliefs was associated with higher vaccine hesitancy ($b = 0.533$, $t = 18.494$, $p < .001$) while holding gender, age, household size, household income, and college degree constant (see Table 4). The model with and without control variables followed the same directional results of statistically significant relationships.

5. Discussion

5.1. General discussion

Results demonstrated the ten-item CVMS to have high reliability across two studies. The CVMS also displayed adequate convergent, discriminant, and predictive validity as a new measure. The CVMS positively correlated with vaccine hesitancy as expected based on misinformation discrediting COVID-19 vaccines. The correlation values did not equal to one, evincing suitable convergent validity. The CVMS demonstrated uniqueness to various constructs and suitable discriminant validity. True/false scale analysis showed between 30 and 20 % of participants believed in each of the COVID-19 vaccine misinformation statements. COVID-19 vaccine misinformation was widespread in the U.S. during the time of the data collection (i.e., during the pandemic) and among the sampled participants.

Public health policies are designed to reduce the spread of diseases and mitigate risks (Bundgaard et al., 2021; Qualls et al., 2017). Predictive validity results found those with higher COVID-19 vaccine misinformation beliefs associated with higher vaccine hesitancy. This contributes to motivated reasoning theory within the context of public health messaging. Misinformation was widely available, shared, and seen by the public. These pieces of misinformation contributed to

value of one would indicate measures as no different and not unique. Correlation results quantified the degree of relatedness and difference between scales (Lucas et al., 1996). Correlations with the 10-item CVMS

Table 3

CVMS bivariate correlations with variables and demographics.

Variables	Study 1				Study 2			
	M	*(SD)*	*r*		*M*	*(SD)*	*r*	
Spontaneous	3.72	(1.21)	-0.430	***	3.61	(1.30)	-0.556	***
Vaccine hesitancy scale (VHS)	2.99	(1.25)	0.556	***	3.01	(1.07)	0.463	***
Vaccine conspiracy belief scale (VCBS)	3.67	(1.85)	0.817	***	4.02	(1.79)	0.825	***
Locus of control	3.93	(1.02)	-0.422	***				
Peculiarity	3.65	(1.43)	0.343	***				
Emotionally detached	3.92	(1.17)	0.284	***				
Calmness	4.62	(0.82)	-0.079					
Extroversion					3.72	(1.34)	0.185	***
Ability to handle stress					4.14	(1.74)	0.284	***
Self-esteem					4.70	(1.66)	0.329	***
Openness					4.61	(1.14)	-0.298	***
Demographic characteristics								
Gender (Female)	1.63	(0.48)	-0.077		1.59	0.492	-0.175	***
Age	40.38	(12.32)	-0.109	*	40.54	12.336	-0.109	**
Household size	3.13	(1.41)	0.342	***	3.30	1.507	0.431	***
Household income	6.00	(2.86)	-0.141	**	5.99	2.755	-0.045	
College Degree	0.92	(0.28)	0.006		0.91	0.284	0.882	

Note: *p <.05, **p <.01, ***p <.001.

COVID-19 vaccine misinformation beliefs was measured using the 10-items to form the COVID-19 Vaccine Misinformation Scale (CVMS). Variables and demographics are correlated with the CVMS. Gender was dummy coded with males as 1 and females as 2. College degree was dummy coded with those with an associate degree or higher as 1 and those without as 0.

Table 4

Regression CVMS effects with vaccine hesitancy.

Variables	*b*	*SE*	*p*
Independent variable			
CVMS	0.533	0.029	<0.001
Control variables			
Gender	0.065	0.062	<0.05
Age	−0.042	0.002	0.113
Household size	−0.065	0.023	<0.05
Household income	−0.019	0.011	0.473
College degree	−0.111	0.109	<0.001

Notes: COVID-19 vaccine misinformation beliefs was measured using the 10-items COVID-19 vaccine misinformation scale (CVMS). Gender was dummy coded with males as 1 and females as 2. College degree was dummy coded with those with an associate degree or higher as 1 and those without as 0.

distrust in vaccines, highlighted by the public institutions as a main way to combat the COVID-19 pandemic. Addressing negative and unfounded claims spread online has become a necessary part of disease prevention because it can impede cooperation to scientifically supported preventative measures. The CVMS provides healthcare professionals a tool to identify misbelievers and opportunity to present convincing fact-based educational materials to dispel false beliefs. Reaching those with vaccine misbeliefs is crucial to reduce the spread of COVID-19 and future disease outbreaks.

5.2. Limitations

Major events will remain in the collective memory of those alive at the time (Zelizer, 1995). However, as with most major events (e.g., Sino–Japanese conflicts), societal memory will fade with time (Gustafsson, 2020). Memory recall can reconstruct understanding of the past (Mena et al., 2016). COVID-19 vaccine misinformation beliefs took hold during the pandemic. While false COVID-19 vaccine narratives spread during the pandemic, the strength of false beliefs may decrease overtime. For example, the vaccine microchip narrative may grow more preposterous as people learn about the enormous amounts of data smartphone devices track from users. Technology advancements may change how society perceives the world and grow more skeptical of opinion shared on social media. Reconstruction of COVID-19 memories may focus on facts and fiction may fade with time.

With incentives to gain followers and views on social media,

misinformation will continue to grow online. The human imagination can take wild ideas like 5G network towers and connect them to unfounded COVID-19 transmission (Gu et al., 2021). With the COVID-19 virus mutating, vaccine misinformation can also change with new events. New false claims could gain traction since most have been debunked (Caulfield, 2020; Hakim, 2021; Khalid et al., 2020). Therefore, changes in time and new outbreaks could add to the list of COVID-19 vaccine misconceptions. The CVMS demonstrated reliability and validity in the recent years after the initial outbreak. However, with time and new variants, it is likely new misbeliefs will spawn and create new public concerns. For example, previous vaccine false narratives transferred to COVID-19 vaccines like unfounded changes to someone's DNA (Center for Disease Control and Prevention, 2022). People with these false beliefs are likely to evaluate new information through this motivated reasoning lens.

5.3. Future research

Mandates are a consequential form of initiating behaviors. Governments and private businesses implemented vaccine mandates for the safety of employees and operations to continue with fewer COVID-19 related complications (Leask et al., 2021). Kaiser Family Foundation conducted found in November 2021 that 14 % of U.S. participants indicated they will definitely not get the COVID-19 vaccine (Kirzinger et al., 2021). This was a one percent decrease from December 2020 from their first vaccine monitor surveys. This polling found uninsured persons under 65 years old (25 %), Evangelical White Christians (25 %), and Republicans (26 %), the three highest groups to indicate they will definitely not get the COVID-19 vaccine. Three percent of the participants indicated they would vaccinate if it was required. This suggests mandates may not reach those ardently vaccine resistant, especially when multiple vaccine injections are recommended. Future research can explore underlying reasons for COVID-19 vaccine resistance. Research suggests isolation, cohesion, and conformity as factors to groupthink (Forsyth, 2020). Belonging to a group may supersede any one COVID-19 vaccine misconception stated as a reason to not vaccinate.

6. Conclusion

The CVMS demonstrated suitable psychometric properties to measure a unique construct among large U.S. samples. Higher CVMS scores related to greater vaccine hesitancy, where immunization became a key

preventive health care action to reduce COVID-19 infections. These findings advance our understanding of how quickly misinformation can be spread and acquired by the public about a disease. Health care providers can utilize the brief measure to identify the strength and specificity of misbeliefs to better address patient concerns.

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8. Ethics statement

The project was reviewed and approved by the California State University, East Bay Institutional Review Board (CSUEB-IRB-2020-176).

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CRediT authorship contribution statement

Stephen Bok: Conceptualization, Software, Data curation, Methodology, Validation, Writing – original draft, Supervision. **Daniel Martin:** Methodology, Validation, Writing – original draft. **Erik Acosta:** Conceptualization, Methodology, Writing – original draft. **James Shum:** Conceptualization, Writing – original draft, Validation. **Jason Harvie:** Writing – original draft, Writing – review & editing. **Maria Lee:** Conceptualization, Visualization, Writing – review & editing.

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.

Data availability

The data that has been used is confidential.

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