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Understanding health knowledge failures: uncertainty versus misinformation

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Studies of health literacy often employ knowledge measures and typically focus on the correct answers as reflections of the level of (accurate) knowledge and literacy. The wrong answers are treated as failures but usually without further consideration. This paper argues for the importance of distinguishing two forms of knowledge failure—being *uninformed*(uncertain about information) and being *misinformed*(believing objectively wrong information)—because of their differing effects on communication responses and associated judgments and decisions. A measure is developed from the incorrect answers indicating error due to uncertainty versus error due to misinformation. In a survey of a representative sample survey of Swiss adults, the uninformed are more likely than the misinformed to hold positive beliefs and attitudes toward vaccination, recommend them to others, and received more vaccinations themselves. The effects are distinguished from those of objective knowledge and suggest that the misinformed form a distinctive group. The importance of separately measuring and understanding knowledge failures to consumer judgement, decision, and welfare are discussed.

Keywords Health literacy, Misinformation, Vaccination hesitancy

Health literacy—an individual's capacity to access, understand, evaluate, communicate, and apply health information to make decisions beneficial to his or her health[1]–has assumed a dominating role in the health behavior literature as a determinant of a range of health outcomes. Growing out of traditional concepts of literacy as reading and numeracy abilities, early research on health literacy adopted a skills-oriented approach to assessing health literacy—e.g., correctly pronouncing health-related terms or choosing the correct terms to complete a health-related statement[2]. Low levels of such functional literacy predict inferior health knowledge[3–5]. People with limited functional health literacy have problems comprehending healthcare resources, accompanied by lower rates of compliance with medical advice, worse health outcomes, and higher healthcare costs[6]. As research in the area has developed, the concept of health literacy has been enriched to include a range of skills and knowledge involved in making health decisions, but the foundational assumption of literacy as "accurate" has been maintained—that literacy is veridical and enables the person attain accurate and relevant knowledge and use that knowledge to make beneficial health decisions.

In contrast to the objective skills approach, some studies of health literacy have focused on a person's subjective feelings about their ability to execute or the perceived difficulty of health-related tasks[7]. Greater self-perceived ability and ease indicate greater literacy. These subjective measures and skill-based (objective) measures of health literacy are imperfectly related. In a meta-analysis, Carlson et al. found an average correlation of 0.37[8]. This difference suggests that, beyond a single dimension of low vs. high health literacy, people can display either consistent or inconsistent levels of objective and subjective health literacy. A person who has strong knowledge and skills as well as confidence toward health-related tasks is the prototypical highly health literate consumer. Conversely, one who lacks these skills and confidence represents the classic case of low health literacy. The other two cases reflect inconsistency between objective and subjective health literacy. A person might display high objective health literacy yet still lack confidence in their ability with respect to health-related tasks[9]. Conversely, one might have objectively low literacy but feel quite capable[10].

While this distinction between self-perceived and performance-based health literacy measures is well recognized in health literacy research, the assumption of accuracy has limited examination of one aspect of its implications. Assuming accuracy, low literacy is a lack of skill and knowledge that leads to mistakes. However, low literacy can also take the form of misinformation—belief in things that are wrong, and the potentially damaging effect that a high level of confidence in that knowledge can exert on health behavior. The problem of

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health misinformation is both venerable and serious[10]. For example, belief in false informational claims led to higher morbidity and mortality during the recent Covid-19 pandemic. While being misinformed differs from low literacy, it is often conflated in literacy measures, particularly knowledge measures. When a respondent gets an answer wrong in a knowledge battery, it is viewed as a literacy failure but whether the failure is due to uncertainty or misinformation is unclear.

We examine this distinction in the case of vaccination, where this dysfunction could involve two errors: misjudgment of a beneficial health measure as dangerous and/or inefficacious and an inflated belief in one's ability to pass that judgement. If these two errors coincide, it reflects a situation where mistaken information is strongly held, which might explain in part the fierce resistance to vaccination in spite of its obvious successes. Not only do some people misunderstand vaccination, but they are firmly committed to their views and seem willing to publicly advocate for them.

Health literacy in the context of vaccination

Shortcomings in health literacy are an obvious candidate when it comes to finding causes of vaccination hesitancy. However, in studies investigating the association between literacy and vaccination behaviour, the findings are inconsistent[11]. In one systematic review, several studies in the analysis found the expected positive literacy-vaccination relationships but some did not[11]. The review's authors suggest, based on qualitative examination of the studies, that the effect of health literacy on vaccination appears to depend on perceptions of the risk of illness and complications in the short term, with a positive relationship when perceived risk is high and negative or no relationship when risk is low, suggesting a potential disconnect between objective and subjective dimensions of literacy.

Another possible contributor to the inconsistent relationship between literacy and vaccination is the nature of the knowledge failure. When objective literacy is high, the expected positive relationship between subjective literacy and healthy behavior should obtain. On the other hand, low objective literacy can take two forms—lack of knowledge and skill versus misinformed knowledge and skill. In the case of Covid-19, for example, major controversies erupted due to misinformation—that vaccination, for example, was more dangerous than the virus itself. Many of those who believed such misinformation developed highly inaccurate but coherent beliefs that led to unhealthy and even dangerous behaviors[10]. These differing knowledge failures would likely have differing effects on responses to vaccination. For those who are misinformed rather than uninformed, the association between subjective competence and positive responses to vaccination would be expected to be weaker or even negative.

In the study reported here, we examine the implications of the difference between uncertainty and misinformation as knowledge limitations. We therefore focus on objective knowledge as a manifestation of health literacy. High levels of objective knowledge should be positively related to positive perceptions, attitude, and behaviors toward vaccination. When objective knowledge is limited, however, we expect those who hold misinformed beliefs about vaccination to act differently from those who recognize they are uninformed. Specifically, those who are uncertain are likely to be guided by their limited objective knowledge so increasing subjective literacy will lead to more positive responses to vaccination. For the misinformed, however, higher subjective literacy should lead to less positive or even negative responses to vaccination. To explain why higher subjective health literacy may be beneficial in certain conditions but problematic in others, we draw on models of literacy that distinguish performance-based from perceived-based health literacy[12,13]. Individuals with high subjective health literacy are more likely to engage in positive health behaviors—but primarily when their actual (objective) literacy is also high. This combination ensures both the skills and self-efficacy needed to interpret and act upon health information effectively. Conversely, individuals with high subjective but low objective literacy may overestimate their competence, which can lead to confident misjudgments or resistance to corrective information[14,15].

Moreover, the psychological distinction between being uninformed and being misinformed is critical. Individuals who are uncertain — that is, aware of what they do not know—are more epistemically open to new information than those who are misinformed, who may hold inaccurate beliefs with unwarranted confidence[16]. As empirical studies on Uncertainty Reduction Theory in the health domain have shown, uncertain individuals are more likely to engage in active information seeking and are more capable of processing health-related content effectively[17]. In contrast, misinformed individuals often engage in motivated reasoning, resisting disconfirming evidence even when they feel confident in their health literacy[10]. Thus, subjective literacy may be especially beneficial for uncertain individuals because it enhances their openness to new knowledge and their capacity to act on it—a dynamic unlikely to hold among the misinformed.

The following hypotheses are advanced:

H0 Consistent with prior research[18], objective vaccination knowledge and subjective vaccination literacy will have interactive effects on responses to vaccination. Higher subjective literacy will amplify the positive effects of objective knowledge.

H1 When health care consumers' objective vaccination knowledge is high, higher subjective knowledge is associated with more favorable beliefs and attitudes toward vaccination and more positive vaccination behaviors regardless of net uncertainty.

H2a When objective knowledge is low and (recognized) lack of knowledge (uncertainty) is high, increasing subjective knowledge is associated with more favorable beliefs and attitudes toward vaccination and more positive vaccination behaviors, albeit less so than for those with high levels of objective knowledge.

H2b When objective knowledge is low and misinformation is high (net uncertainty is low), increasing subjective knowledge is not associated with more favorable beliefs and attitudes toward vaccination or more positive vaccination behaviors.

These hypotheses are examined in a survey study conducted in Switzerland.

Methods

The Institutional Review Board (IRB) of the Università della Svizzera italiana in Lugano has reviewed and approved the research protocol (CE 2023 28). All research activities were conducted in accordance with the ethical guidelines and regulations set forth by the IRB. Participants were provided with an informed consent document, and their voluntary participation was obtained before any data collection activities commenced. All participants were over 18 years of age.

Data sampling

The data are drawn from responses to a survey of residents in Switzerland representative of the population aged 18 or above. The questionnaire was developed by the Institute of Communication and Health (ICH) of the Università della Svizzera italiana in Lugano, in collaboration with the Swiss Federal Office of Public Health. In the last phase of finalizing the questionnaire, ten test interviews were conducted. Data were collected by Polyquest AG, Berne. The contractor selected from an existing representative online panel persons for the survey. Due to a clear underrepresentation of persons with a low level of education, the original sample was completed by an additional 100 persons from the lower education strata, resulting in a final sample size of $N=$ 1,713. Response rate was 35%. Interviews were conducted online. There was an intentional overrepresentation of participants from the French- and Italian-speaking regions of Switzerland to provide a better data basis for separate and comparative analyses of the linguistic regions. Field time was March 8–18, 2018, which preceded the Covid-19 pandemic so the prominence of vaccination and the misinformation associated with that period were not present. It is certainly possible that the number of people displaying high levels of misinformation could have changed, but we believe that the associations examined here will still obtain.

Measures

Objective vaccination knowledge

As an objective, performance-based measure linked with health literacy, the vaccination knowledge test developed by Zingg und Siegrist was used[19]. The recommended version was used with nine knowledge items in the form of assertions that respondents were asked to say were true, false, or "I don't know": Vaccines are superfluous, as diseases can be treated (F); Without broadly applied vaccine programs, smallpox would still exist (T); The efficacy of vaccines has been proven (T); Children would be more resistant if they were not always vaccinated against all diseases (F); Diseases like autism, multiple sclerosis, and diabetes might be triggered through vaccinations (F); The immune system of children is not overloaded through many vaccinations (T); Many vaccinations are administered too early, so that the body's own immune system has no possibility to develop (F); The doses of the chemicals used in vaccines are not dangerous for humans (T); Vaccinations increase the occurrence of allergies (F). The analyses use categorized groups based on the number of correct, incorrect, and "don't know" answers. On average, respondents gave 4.92 (SD = 2.71) correct answers, 2.41 (SD = 2.24) incorrect answers, and 1.67 (SD = 2.06) don't know answers.

A second objective knowledge variable was constructed to distinguish those who are misinformed (gave a wrong answer (answering "false" to a true item or "true" to a false one) from those who were uncertain about knowledge items (answering "I don't know"). The number of wrong answers was subtracted from the number of "I don't know" answers to give a measure labelled "Net Uncertainty". The measure ranged from −9 (highly misinformed) to +9 (highly uncertain) with a mean of 0.73 (SD = 3.34).

Self-perceived or subjective health literacy

Subjective health literacy, or the self-perception of one's ability to find and process vaccination information was measured by three items from the HLS-EU 47 that referred explicitly to vaccination and is interpreted as an indicator of a vaccination-specific measure of health literacy. The items asked about how simple it was to know why one needed vaccination, which vaccinations one needed, and to decide whether to get the flu shot annually as recommended. Scales ran from 1 to 4, with 1 indicating it was very easy, 2 fairly easy, 3 fairly difficult and 4 very difficult, with no option to give a neutral answer. For a composite measure the three scales were reversed (so as to have high values represent high subjective health literacy) and averaged (alpha = 0.69; M = 3.1, SD = 0.67).

Beliefs

Two belief measures were constructed from a 20-item battery of vaccination beliefs to which a participant could agree or disagree on a 5-digit scale. A factor analysis identified three factors, from which two index measures were developed. The first factor, on which 9 items load, describes the historical and universal importance of vaccination—It is irresponsible to others not to be vaccinated; Without vaccination our lives would be shorter; Eradication of infectious diseases is a desirable goal; Carefree world travel is possible because of vaccinations; The discovery of vaccination against infectious disease is a major medical achievement; Eradication of smallpox and polio is a great benefit of vaccinations; Before vaccinations, high infant mortality brought untold suffering to people; There is no need to debate vaccination: its value is clear; It is best to follow the doctor's advice on vaccinations. Agreement with the items reflects greater perceived benefits of vaccination. The second factor relates to individual biomedical aspects of vaccination, especially the risks associated with it. Five items load on this factor—Vaccination is dangerous because one is given a mild form of the disease; Patients are more likely

to be injured by vaccination than other procedures; People are not told how dangerous vaccination is; Because vaccinations are derived from natural pathogens, something can easily go wrong; I trust normal medicines more than vaccines. Here, agreement reflects greater perceived risk associated with vaccination. The items loading on each factor were averaged to form measures of perceived benefits ($\alpha = 0.86$, $M = 2.10$, $SD = 0.69$) and perceived risk ($\alpha = 0.84$, $M = 3.44$, $SD = 0.82$) of vaccination.

Attitudes

The attitude measure was a single item on the balance between advantages and disadvantages, measured with a 9-step scale defined by the endpoints that advantages or disadvantages dominate. High values indicate a dominance of advantages ($M = 6.6$, $SD = 2.12$).

Behavior

Two behavioral measures were constructed as outcome variables. The first measure was the *Number of vaccinations* a respondent self-reported to have had at the time of the survey, among a total of six basic or recommended vaccinations (tetanus, hepatitis B, measles, pertussis, meningitis, and influenza). The mean number of vaccinations received was 2.76 ($SD = 1.82$).

A second behavioral measure was *Willingness to recommend vaccination*, which was measured by asking participants whether they would recommend child vaccination for tetanus, pertussis, measles, hepatitis B, and meningitis. For each disease, a response using a 9-point scale (certainly would not recommend to certainly would recommend) was collected and the responses were averaged. Unidimensionality was assured via principal components ($\alpha = 0.90$, $M = 5.49$, $SD = 1.67$).

Four background demographic variables were included in the study to control for age, educational attainment, gender, and prior professional medical experience (yes/no). The basic characteristics of the data set are shown in Table 1.

Data analysis

To test H0, a set of regression models was constructed to assess the effects of objective and subjective knowledge on perceived benefits, perceived risks, attitude toward vaccination, and the two behavioral measures. The models included objective knowledge, subjective literacy, and their interaction along with the four demographic control variables.

To examine Hypotheses 1 and 2, the focus of the present analysis, net uncertainty was added to objective knowledge and subjective literacy as a predictor. The effects of objective knowledge, subjective literacy, and net uncertainty were examined using linear regressions. The three predictors were mean-centered. All two-way interactions and the three way interaction were included in the analyses. Four demographic control variables—age, education, gender, and prior professional medical experience—were included.

Results

According to H0, subjective literacy should amplify the positive effects of objective knowledge. The regression results are summarized in Table 2.

		Subjective Literacy	Objective Knowledge	Net Uncertainty	Perceived Benefits	Perceived Risk	Attitude	Willingness to Recommend	Vaccinations Received	Age	Education	Gender	Medical Experience
Mean		3.06	4.92	0.733	3.93	2.5	6.55	5.49	2.76	48.5	2.27	0.519	0.132
Std. Deviation		0.658	2.71	3.34	0.681	0.83	2.18	1.17	1.82	16.7	0.89	0.5	0.339
Correlation Matrix													
Objective Knowledge	r	0.315	–										
	p	< .001	–										
Net Uncertainty	r	-0.084	-0.084	–									
	p	< .001	< .001	–									
Perceived Benefits	r	0.284	0.634	0.181	–								
	p	< .001	< .001	< .001	–								
Perceived Risk	r	-0.280	-0.623	-0.188	-0.547	–							
	p	< .001	< .001	< .001	< .001	–							
Attitude	r	0.236	0.564	0.190	0.629	-0.588	–						
	p	< .001	< .001	< .001	< .001	< .001	–						
Willingness to Recommend	r	0.171	0.473	0.175	0.547	-0.427	0.461	–					
	p	< .001	< .001	< .001	< .001	< .001	< .001	–					
Vaccinations Received	r	0.207	0.382	0.023	0.315	-0.294	0.291	0.399	–				
	p	< .001	< .001	0.335	< .001	< .001	< .001	< .001	–				
Age	r	0.067	0.015	0.034	0.128	-0.017	0.106	-0.039	-0.204	–			
	p	<.01	>.10	>.10	< .001	>.10	< .001	<.10	< .001	–			
Education	r	0.019	0.070	-0.028	0.067	-0.137	0.025	0.043	0.100	0.011	–		
	p	>.10	<.01	>.10	<.01	< .001	>.10	<.10	< .001	>.10	–		
Gender	r	0.057	-0.029	-0.031	-0.056	0.078	-0.085	0.005	0.050	-0.201	-0.017	–	
	p	<.05	>.10	>.10	<.05	<.01	< .001	>.10	<.05	< .001	>.10	–	
Medical Experience	r	-0.109	-0.062	0.084	0.007	0.033	-0.026	-0.065	-0.143	0.085	-0.030	-0.198	–
	p	< .001	<.05	< .001	>.10	>.10	>.10	<.01	< .001	< .001	>.10	< .001	–

Table 1. Basic variable characteristics.

	Dependent variable									
	Perceived vaccination benefits		Perceived vaccination risk		Attitude toward vaccination		Number of vaccinations received		Willingness to Recommend Vaccination	
Predictor Variable	b	p	b	p	b	p	b	p	b	p
Subjective Literacy	0.0044	> 0.10	−0.0559	> 0.10	0.0921	> 0.10	0.0324	> 0.10	−0.1192	< 0.10
Obj. Know. × Subj. Lit.	0.0202	< 0.005	−0.0170	< 0.10	0.0275	> 0.10	0.0583	< 0.01	0.0395	< 0.01
Age	0.0043	< 0.001	0.0007	> 0.10	0.0108	< 0.001	−0.0225	< 0.001	−0.0031	< 0.05
Education	0.0162	> 0.10	−0.0859	< 0.001	−0.0404	> 0.10	0.1437	< 0.001	0.0104	> 0.10
Gender	−0.0181	> 0.10	0.1118	< 0.001	−0.2525	< 0.01	−0.0330	> 0.10	0.0088	> 0.10
Medical experience	−0.0992	< 0.01	0.0092	> 0.10	0.0353	> 0.10	0.6233	< 0.001	0.0640	> 0.10
Intercept	2.9447		3.6626		3.8074		1.2170		4.9807	
R^2	0.43		0.41		0.34		0.23		0.23	

Table 2. Initial regression models for beliefs, attitude, and behavior.

	Dependent variable									
	Perceived vaccination benefits		Perceived vaccination risk		Attitude toward vaccination		Number of vaccinations received		Willingness to Recommend Vaccination	
Predictor variable	b	p	b	p	b	p	b	p	b	p
Subjective literacy	0.1191	< 0.001	−0.1508	< 0.001	0.2584	< 0.001	0.3291	< 0.001	0.0866	< 0.05
Objective knowledge	0.1502	< 0.001	−0.186	< 0.001	0.4410	< 0.001	0.2224	< 0.001	0.1945	< 0.001
Net uncertainty	0.0340	< 0.001	−0.0799	< 0.001	0.1466	< 0.001	0.0348	< 0.10	0.0503	< 0.001
Obj. Know. × Subj. Lit.	0.0128	< 0.10	−0.0166	< 0.05	0.0099	> 0.10	0.0463	< 0.05	0.0233	< 0.10
Subj. Lit. × Net Uncert.	−0.0057	< 0.005	0.0203	< 0.10	−0.0282	> 0.10	−0.0063	> 0.10.	−0.0169	> 0.10
Obj. Know. × Net Uncert.	−0.0147	< 0.10	−0.0077	< 0.001	−0.0063	> 0.10	−0.0066	> 0.10	−0.0131	< 0.001
Subj. Lit. × Obj. Know. × Net Uncert.	−0.0082	< 0.001	0.0029	> 0.10	−0.0149	< 0.10	−0.0134	< 0.108	−0.0120	< 0.05
Age	0.0040	< 0.001	0.0012	> 0.10	0.0098	< 0.001	−0.0229	< 0.001	−0.0035	< 0.05
Education	0.0208	> 0.10	−0.0891	< 0.001	−0.0272	> 0.10	0.1475	< 0.001	0.0190	> 0.10
Gender	−0.0096	> 0.10	0.1176	< 0.001	−0.2374	< 0.01	−0.0270	> 0.10	0.0280	> 0.10
Medical experience	−0.0771	< 0.05	−0.0436	> 0.10	0.1294	> 0.10	0.6370	< 0.001	0.0952	> 0.10
Intercept	3.696		2.602		6.230		3.436		5.570	
R^2	0.489		0.476		0.393		0.232		0.286	

Table 3. Regression analyses of responses to vaccination.

A significant interaction effect is found for perceived benefits, perceived risk (marginal), number of vaccinations received, and willingness to recommend vaccination. For attitude, objective knowledge is associated with more positive attitude but the interaction with subjective literacy is not significant. Thus, for beliefs and behaviors, Hypothesis 0 is supported, consistent with prior research[18].

The results of the regression models examining Hypotheses 1 and 2 are summarized in Table 3.

Beliefs: perceived benefits and risk

In the analysis of perceived benefits, objective knowledge, subjective literacy, and net uncertainty all have strong direct effects. These effects are moderated by interactions including the 3-way interaction of the knowledge variables. In order to characterize this interaction pattern, responses with the knowledge variables either 1 standard deviation below (low) or above (high) 0 were are shown in Fig. 1. For those with higher objective knowledge, net uncertainty has limited effect. Regardless of net uncertainty, these respondents report greater benefits of vaccination. Higher subjective literacy further increases perceived benefits. For those with lower objective knowledge, those who are more uncertain report less perceived benefits of vaccination but, as for those with greater objective knowledge, higher subjective literacy is associated with greater perceived benefits. Those with lower objective knowledge who are also more misinformed reflect a different pattern of responses. They report still less benefits of vaccination than other respondents, and increasing subjective literacy doesn't affect these perceptions. The results are consistent with Hypothesis 1 and 2a. As proposed in Hypothesis 2b, subjective knowledge is not associated with higher perceived benefits for the low knowledge, misinformed respondents, differing from the respondents.

In the analysis of perceived risk, main effects of objective knowledge, net uncertainty, and subjective literacy are again significant, as is the interaction of objective knowledge and net uncertainly. Greater objective knowledge, greater subjective literacy, and less misinformation all decrease perceived risk. Notably, the effect of misinformation is greater for those with lower objective knowledge than for those with greater objective

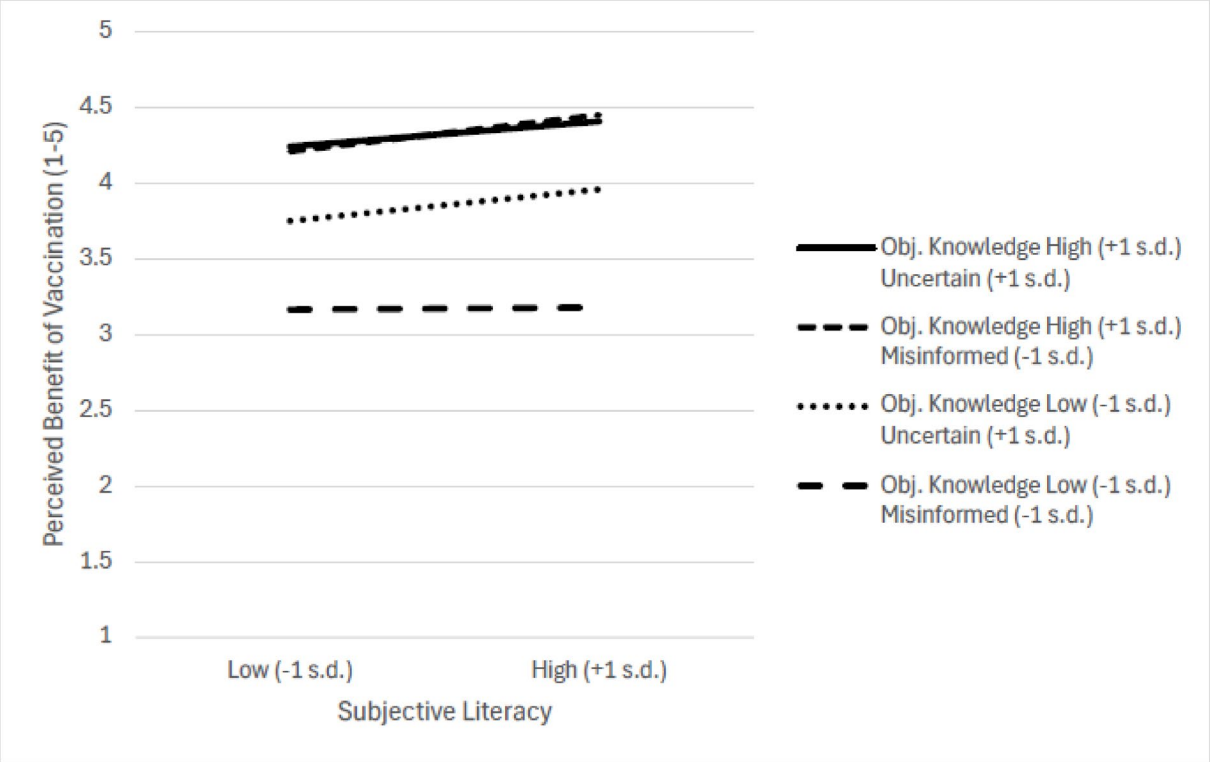


Fig. 1. Objective knowledge/uncertainty and subjective literacy effects on perceived benefits of vaccination.

	Perceived vaccination benefits		perceived vaccination risk		Attitude toward vaccination		Number of vaccinations received		Willingness to recommend vaccination	
Subjective literacy	−1 s.d.	+ 1 s.d.	−1 s.d.	+ 1 s.d.	−1 s.d.	+ 1 s.d.	−1 s.d.	+ 1 s.d.	−1 s.d.	+ 1 s.d.
High knowledge-uncertain	4.24	4.41	2.02	1.80	7.72	8.00	3.08	3.62	5.94	6.08
High knowledge-misinformed	4.21	4.45	2.25	1.96	7.37	7.84	2.99	3.64	5.85	6.11
Low knowledge-uncertain	3.75	3.96	2.78	2.72	5.88	6.26	2.14	2.58	5.26	5.39
Low knowledge-misiniformed	3.17	3.18	3.38	3.17	4.50	4.73	1.85	1.94	4.59	4.53

Table 4. Characterization of interaction patterns.

knowledge (Table 4). The interactions of subjective literacy and objective knowledge and subjective literacy and net uncertainty are marginally significant, but the 3-way interaction is not significant (Table 3). This pattern is again consistent with Hypotheses 1 and 2a but not with Hypothesis 2b.

Attitude

The analysis of attitude reveals significant main effects of objective knowledge, subjective literacy, and net uncertainty. None of the 2-way interactions is significant but the 3-way interaction is marginally significant (Table 3). The three main effects reflect the positive effect on attitude of increased knowledge, subjective literacy, and net uncertainty. The marginally significant interaction primarily reflects a greater effect of net uncertainty on those with low objective knowledge, further moderated by smaller differences in the effect of subjective literacy (Table 4). As hypothesized, when respondents have low objective knowledge, the effect of subjective literacy is greater for those with high net uncertainty than those with higher levels of misinformation. However, for those with high objective knowledge, higher subjective literacy has a smaller effect for respondents with higher net uncertainty compared to those with low net uncertainty, contrary to Hypothesis 2b.

Behavioral outcome variables

Two behavioral variables were included—the number of vaccinations received and willingness to recommend vaccination. Willingness to recommend vaccination was associated with significant effects of objective knowledge, subjective literacy, and net uncertainty. Significant interactions were seen of objective knowledge and subjective literacy (marginal), objective knowledge and net uncertainty, and the 3-way interaction of objective knowledge, subjective literacy, and net uncertainty (Table 3). For those with high objective knowledge, regardless of net uncertainty, higher subjective literacy led to greater willingness to recommend. This was also the case for

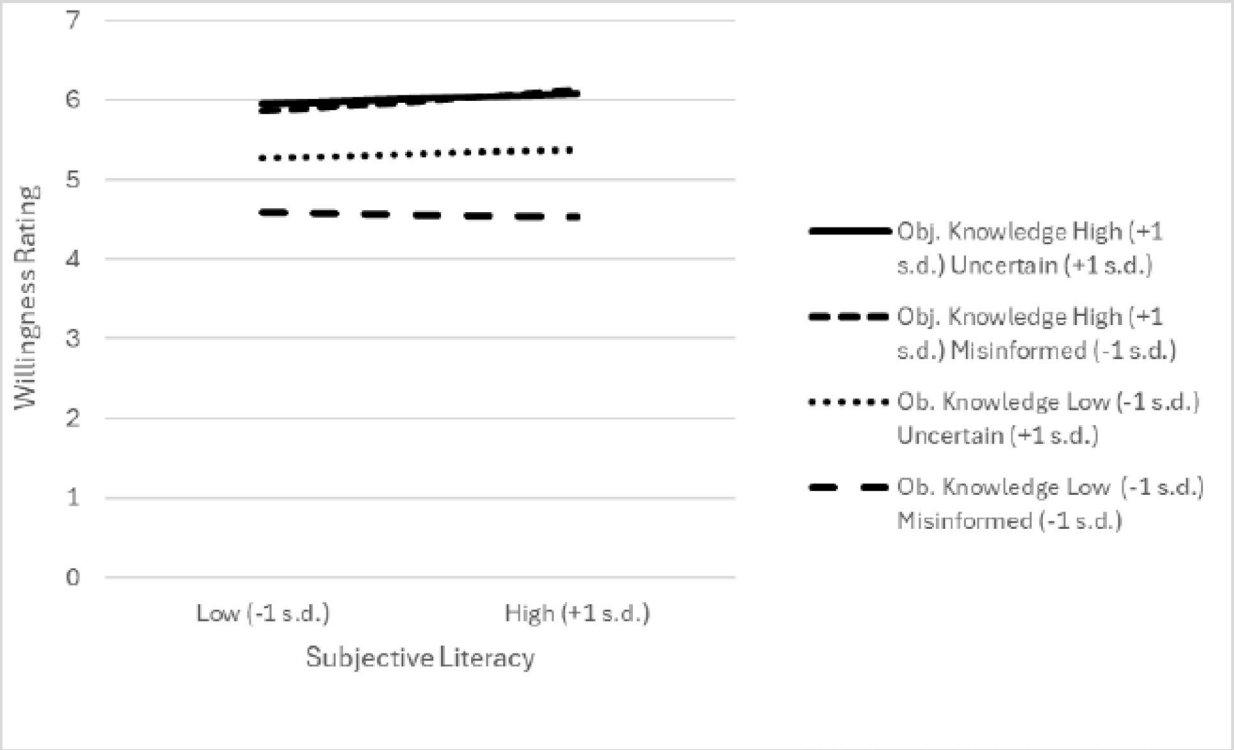


Fig. 2. Objective knowledge/uncertainty and subjective literacy effects on willingness to recommend vaccination.

those with low objective knowledge and high net uncertainty. For those with low objective knowledge and low net uncertainty (i.e., misinformed), higher subjective literacy did not increase willingness to recommend and actually decreased it slightly (see Fig. 2). These results are consistent with both Hypotheses 1 and 2.

The pattern is similar for number of vaccinations received. Significant main effects of objective knowledge and subjective literacy, and a marginally significant effect of net uncertainty were seen. The interaction of objective knowledge and subjective literacy was significant, and the 3-way interaction approached significance. As was the case for willingness to recommend, higher subjective literacy had a much smaller effect for those with low objective knowledge and low net uncertainty (i.e., misinformed) than for those with high objective knowledge or low objective knowledge and high net uncertainty.

Discussion

As has been the case in prior studies, measures of objective and subjective literacy are related but only to a limited extent. The correlation of objective knowledge and subjective literacy in this study was 0.315, in line with the review by Carlson et al.[8] As such, separate effects of these variables on responses to vaccination were expected. In particular, the effect of subjective literacy was expected to be contingent on the level of objective knowledge. This was shown in the preliminary analysis in which objective knowledge and subjective literacy were regressed on the five outcome variables was consistent with prior research (H0[18]). A positive interaction was found for perceived benefits and risks of vaccination as well as the two behavioral outcomes—number of vaccinations received and willingness to recommend vaccination. Higher subjective literacy amplified the positive effects of objective knowledge. Objective knowledge also predicted positive attitude, but subjective literacy had no effect.

Of focal interest in this study was failure of objective knowledge. Two types of knowledge failure were distinguished—uncertainty and misinformation. Uncertainty corresponds to the usual vision of lower literacy—lack of knowledge. Misinformation, on the other hand, constitutes belief in incorrect or untrue information. Misinformed beliefs were expected to weaken positive attitudes and behaviors toward vaccination more than uncertainty. Moreover, if higher subjective literacy amplifies the positive effects of (correct) objective knowledge, we hypothesized that it would likewise amplify the effects of misinformed beliefs and further weaken vaccination attitudes and behavior. In this study, increased misinformation relative to uncertainty did indeed weaken positive beliefs, attitude, and behaviors toward vaccination.

When objective knowledge was high, changes in subjective literacy were expected to be driven primarily by accurate knowledge so reactions to vaccination were expected to be more positive, and the results were consistent with this. Respondents with high objective knowledge were more likely to respond positively to all of the outcome variables than those with low objective knowledge and, as can be seen in Figs. 1 and 2, higher subjective literacy increased positive vaccination responses regardless of the mix of uncertain and misinformed responses (net uncertainty). There is a strong influence of objective knowledge on the complete battery of outcome variables.

Moreover, subjective literacy, or confidence in one's knowledge, enhances the effects of accurate information. In short, the results highlight the importance of objective knowledge in making healthy vaccination decisions. If information has such broad favorable consequences, information campaigns cannot be easily dismissed as superfluous. However, such implications have to be understood as interpretative as we have no longitudinal data in this study so support for causal inferences is limited.

It is in the case of low objective knowledge that different outcomes were expected for uncertain and misinformed respondents. When objective knowledge is low and uncertainty is high, less objective knowledge is available so positive reactions to vaccination would be expected to weaken. However, since the available objective knowledge is generally accurate, increasing subjective literacy should still bolster positive reactions. This pattern was found for all of the reaction variables—perceived benefits and risk, attitude, and the two behavioral measures as shown in Figs. 1 and 2, and Table 3.

When objective knowledge was low and misinformation high, the results were different from those of the other three groups. For all the outcome variables, this group displayed the least positive responses to vaccination. In addition, increasing subjective literacy had different effects. For positive beliefs and the two behavioral measures, higher subjective literacy had either little effect or a slightly negative one. It seems that the doubt injected by misinformation was sufficient to weaken support for vaccination even if subjective literacy (thus confidence in misinformation) was not strong. This raises the question of the quality of health decisions they would make.

The results of this study highlight the importance of distinguishing the type of knowledge failure—uncertainty or ignorance versus misinformation. We constructed a measure to distinguish those knowledge errors expressed as uncertainty from those expressed as erroneous belief, which in turn allowed us to differentiate people whose errors were predominantly uncertain from those whose errors were predominantly misinformed. Hypothesis 2 suggested that these groups of people would hold differing beliefs and attitudes about vaccination and would make different decisions about vaccination behaviors. Compared to the well-informed, these differences were observed. Of particular interest are the results pertaining to behavioral outcomes. Contrary to the main effect findings of positive effects of literacy on vaccination beliefs, attitudes, and behavior, when objective knowledge is predominantly inaccurate, higher subjective competence negates the positive effects of knowledge and perceived competence. The group of particular interest—those with low objective knowledge and high subjective literacy—form what we have called dangerous self-managers[20]. These are people who objectively lack the skills and knowledge to make healthy choices but have no clue for their own ineptitude and feel capable of making health decisions. The risk with these people of course is that they risk harming themselves when they make poorly informed decisions. In this study, this group was relatively small, amounting to about 5% of the sample. However, the phenomenon is common across a range of domains. Dunning has examined this condition and argues that it arises because people lacking skill are often unaware of this fact[15]. The same skills that enable people to perform well on a task are the ones that would enable them to realize they are performing badly and, lacking that insight, they overstate their abilities. From the standpoint of vaccination advocates, the challenge presented by this group is that changing their stance is likely to be difficult. Moreover, as has been seen in the debates over vaccination in recent years, outspoken people with misinformed skepticism of vaccination have had an outsize impact on public discussion.

Finally, from a theoretical standpoint, these findings argue that, unlike traditional literacy (reading and numeracy) skills, health literacy cannot be viewed simply as "more is better". Low literacy can take the form of a lack of skills and knowledge but it is also possible to possess misinformed knowledge and skill and be confident about them. These two types of literacy failure differ profoundly in their behavior and policy implications[10].

Conclusion

As the concept of health literacy has grown richer, it has subsumed both objective and subjective dimensions. While the two are related, they are distinct in their effects on health behavior. Moreover, objective literacy failure can come in two forms—being uninformed and being misinformed. In the face of these two failures, subjective literacy can be low but it can also be high. People who are misinformed but confident in their skills present potential problems for medical care providers and health policy makers. As such, it is critical to distinguish objective and subjective literacy dimensions and also being uninformed versus misinformed as types of literacy failure.

Practice implications

For research practice, our findings point to the problem of increasing health literacy without ensuring that a knowledge basis exists, and to the problem of measuring health literacy merely by perception-based self-rating item batteries. These might more or less overlook the more complex relationsships that hide in the maze of health literacies, their dimensions and their functions.

The distinction drawn between knowledge failures driven by lack of information versus misinformation has implications for public health practice. It helps to clarify the audiences for whom informational campaigns are likely to be effective—not all who display limited objective knowledge but those whose knowledge failures reflect primarily recognized uncertainty, i.e., lack of knowledge. Informational campaigns are also likely to be useful in bolstering the confidence of more knowledgeable people. The most problematic audience will be those with limited objective knowledge whose knowledge failures are driven primarily by misinformation and who are confident of their literacy. Studies have shown that misinformation is difficult to dislodge so that for this audience informational campaigns are unlikely to be effective, at least by themselves. In the case of vaccination, it may be more beneficial to the public to focus on herd immunity among the knowledgeable and uncertain to protect them from infectious disease harbored by vaccine skeptics.

Data availability

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

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Author contributions

PJS and KN designed the studies, analyzed and interpreted the data, and wrote the main manuscript text, including tables and figures. Both authors reviewed the manuscript and approved the submitted version.

Additional information

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