COVID-19 misinformation in Australia: key groups and trends over time in a national longitudinal survey

Kristen Pickles, Erin Cvejic, Brooke Nickel, Tessa Copp, Carissa Bonner, Julie Leask, Julie Ayre, Carys Batcup, Samuel Cornell, Thomas Dakin, Rachael H Dodd, Jennifer MJ Isautier, Kirsten J McCaffery

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Abstract

Background: Misinformation about COVID-19 is common and has spread rapidly across the globe through social media platforms and other information systems. Understanding what the public know about COVID-19 and identifying beliefs based on misinformation can help shape effective public health communications to ensure efforts to reduce viral transmission are not undermined.

Objective: To investigate prevalence and factors associated with COVID-19 misinformation in Australia, and changes over time.

Methods: Adults 18 years and over completed a prospective national longitudinal survey in 2020 (n=4362 April; n=1882 May; n=1369 June).

Results: Stronger agreement with misinformation was associated with younger age, male gender, lower education, and language other than English at home (all p<0.01). After controlling for these variables, misinformation beliefs were significantly associated (p<0.001) with lower digital health literacy, lower perceived threat of COVID-19, lower confidence in government, and lower trust in scientific institutions. Analyses of specific government-identified misinformation revealed 3 clusters: prevention (associated with men and younger age), causation (associated with lower education and greater social disadvantage), and cure (associated with younger age). Lower institutional trust and greater rejection of official government accounts were associated with greater agreement.

Conclusions: These findings highlight important gaps in communication effectiveness, which must be addressed to ensure effective COVID-19 prevention.

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COVID-19 misinformation in Australia: key groups and trends over time in a national longitudinal survey

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Abstract

Background: Misinformation about COVID-19 is common and has spread rapidly across the globe through social media platforms and other information systems. Understanding what the public know about COVID-19 and identifying beliefs based on misinformation can help shape effective public health communications to ensure efforts to reduce viral transmission are not undermined.

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Results: Stronger agreement with misinformation was associated with younger age, male gender, lower education, and language other than English at home (all *P*<.01). After controlling for these variables, misinformation beliefs were significantly associated (*P*<.001) with lower digital health literacy, lower perceived threat of COVID-19, lower confidence in government, and lower trust in scientific institutions. Analyses of specific government-identified misinformation revealed 3 clusters: prevention (associated with men and younger age), causation (associated with lower education and greater social disadvantage), and cure (associated with younger age). Lower institutional trust and greater rejection of official government accounts were associated with greater agreement.

Conclusion: These findings highlight important gaps in communication effectiveness, which must be addressed to ensure effective COVID-19 prevention.

Key words: COVID-19; coronavirus; misinformation; myths; conspiracy; digital health literacy; social media; trust

Introduction

False, misleading or inaccurate health information can pose a serious risk to public health and public action [1]. Misinformation about COVID-19 is common and has spread rapidly across the globe through social media platforms and other information systems [2-5]. In February, the World Health Organisation's Director-General declared the global 'over-abundance' of COVID-19 information an 'infodemic'[6]. The term 'misinfodemic' has since been coined to capture the corresponding rise in misinformation surrounding the virus [7].

Misinformation – which is typically compelling, persuasive, and emotive – spreads significantly farther, faster, deeper, and more broadly than factual information on social media platforms [8]. This is particularly true within tight-knit communities, as has been seen with the spread of vaccine misinformation among some communities in the United States, Sweden, and the Netherlands [9-12]. Common COVID-19 beliefs circulating in mainstream media include framing of the pandemic as a leaked bioweapon, a consequence of 5G wireless technology, a political hoax, and that the COVID-19 pandemic has been made up by governments to control people. Others detail ineffective measures that individuals can take to prevent or treat the virus, such as exposing themselves to sunlight or taking vitamin C [13].

Misinformation can undermine public health efforts through shaping beliefs and attitudes - particularly if encountered within a social network - and by reinforcing pre-existing values and positions [14]. Importantly, lower perceived risk or perceived efficacy of prevention behaviours and altered perception of social norms might influence willingness to follow recommendations, such as voluntary testing, isolation and, potentially, vaccination [15].

Understanding what the public know about COVID-19 and identifying beliefs based on misinformation can help shape effective public health communications to ensure efforts to reduce its impact such as debunking [16].

This paper uses data from a longitudinal cohort study of the Australian public. Our aims were to: a) investigate prevalence of beliefs in COVID-19 misinformation in this sample, b) examine whether any demographic, psychosocial and cognitive factors are associated with these beliefs, and c) investigate how these misinformation beliefs change over time.

Methods

The data used in this study are from a prospective longitudinal national survey exploring variation in understanding, attitudes, and uptake of COVID-19 health advice during the 2020 pandemic lockdown [17, 18]. A total of 4362 participants completed the baseline survey (Round 1), recruited in Australia in April 2020 (17-24th). This survey was administered one month after the first measures of physical distancing and quarantine measures were introduced in Australia and when an increasing number of COVID-19 cases were being recorded. A subset (n=3214) of the sample were invited for longitudinal follow-up to assess changes in attitudes, beliefs and behaviour over the course of the pandemic. Round 2 of the study (n=1882 out of 3214 invited, 59% response rate) was administered in May (8-15th), 3 weeks after the baseline (Round 1) survey. Round 3 of the study (n=1369 out of 3214 invited, 43% response rate) was administered in June (5-12th), approximately 6 weeks after the baseline survey, when restrictions in Australia showed signs of easing and new case numbers and reported community transmission had fallen dramatically. Round 3 was administered prior to the resurgence of cases in some areas of Australia.

Recruitment

Participants were recruited via advertisement on social media (i.e. Facebook, Instagram) and by a market research company (Dynata). We used two methods of recruitment with the aim of achieving a more diverse sample. Only those recruited on social media were invited for longitudinal follow-up.

Dynata is a market research company with access to a database of 600,000 members in Australia who are willing to be involved in online research studies. Dynata invites members to participate in research when they meet a study's eligibility criteria. Eligibility criteria included being 18 years or older, currently living in Australia, and able to read and understand English.

Participants recruited via Dynata received points for completing the survey which can be redeemed for gift vouchers, donations to charities, or cash. Participants recruited via social media were given the opportunity to enter into a prize draw for the chance to win one of ten $20 gift cards upon completion of each survey round.

Ethics approval was obtained from the Human Research Ethics Committee of The University of Sydney (2020/212). Participants were informed about the purpose of the study, confidentiality, and risks and benefits to participating at the beginning of the survey. Completion and submission of the online questionnaire was considered evidence of consent.

Measures

The survey was built and administered online using Qualtrics (SAP, Provo, UT) – an online survey platform – and piloted within the health literacy lab. Survey items included in each round were modified from the national longitudinal study [17] to reflect psychological, behavioural, and knowledge factors considered most relevant at that stage of restrictions. Relevant measures for this study are detailed in Table 1. Age, gender, education, language other than English (LOTE) spoken at home, and socioeconomic status (SES) were assessed in Round 1 as detailed in [17].

Table 1. Measures included in this study

Item	Description and reference (if applicable)	April	May	June
Main outcomes				
COVID-19 related misinformation beliefs	4 items, adapted from validated vaccine conspiracy beliefs scale [19] (1=Strongly disagree to 7=Strongly agree)			
	Data about the effectiveness of vaccines is often made up[a]	✓	✓	
	Herd immunity would be beneficial for COVID-19 and this fact is covered up	✓	✓	✓
	The threat of COVID-19 is greatly exaggerated	✓	✓	✓
	The government restrictions are stronger than is needed	✓		
Specific COVID-19 misinformation	10 items, taken from Australian Government Myth busting website [13] (1=Definitely false to 5=Definitely true)			
	5G networks are spreading the virus			✓
	Hot temperatures kill the virus			✓
	Vitamin C is an effective treatment			✓
	Ibuprofen exacerbates COVID-19			✓
	The flu shot provides immunity to COVID-19			✓
	Hydroxychloroquine is an effective treatment			✓
	UV rays kill the virus			✓
	There is a cure/vaccine for COVID-19			✓
	Parcels from China can spread the virus			✓
	The COVID-19 virus was engineered and released from a Chinese laboratory in Wuhan			✓

Explanatory variables				
Digital Health Literacy	Mean of 8 items from the eHealth Literacy Scale (eHeals) [20] (1=Strongly disagree to 5=Strongly agree)			
	I know what health resources are available on the internet	✓		
	I know where to find helpful health resources on the Internet	✓		
	I know how to find helpful health resources on the Internet	✓		
	I know how to use the Internet to answer my questions about health	✓		
	I know how to use the health information I find on the Internet to help me	✓		
	I have the skills I need to evaluate the health resources I find on the Internet	✓		
	I can tell high quality health resources from low quality health resources on the Internet	✓		
	I feel confident in using information from the Internet to make health decisions	✓		
Perceived threat of COVID-19	Two individual items, adapted from [21].			
	Perceived public threat of COVID-19 (1=No threat at all to 10=A very serious public health threat)	✓		✓
	Perceived likelihood of personally getting sick from COVID-19 (1=Not at all to 5=I definitely will)	✓		✓
Confidence in Government	Mean of 4 items, adapted from national Australian survey on vaccination [22] (1=Strongly disagree to 7=Strongly agree)			
	I am confident in information about COVID-19 provided by the government	✓		✓
	I am satisfied with the amount of information about COVID-19 provided by the government	✓		✓
	I follow government advice on social distancing to help protect the wider community	✓		✓
	I am concerned that government recommendations about COVID-19 are not safe, or not enough is being done	✓		✓
Trust in Institutions	Mean of 3 items adapted from [23] (1=Strongly disagree to 7=Strongly agree)			
	Scientists involved in developing and testing new ways to control COVID-19	✓		

	Researchers involved in tracking and predicting COVID-19 cases	✓		
	Medical institutions (GPs, hospitals) involved in managing COVID-19 cases	✓		
COVID-19 information sources – social media	Social media reported as being used as a top 3 information source	✓		✓
Rejection of official accounts	Mean of 4 items, adapted from [24] (1=Strongly disagree to 5=Strongly agree)			
	Much of the information we receive is wrong			✓
	I often disagree with commonly held views about the world			✓
	Official government accounts of events cannot be trusted			✓
	Major events are not always what they seem			✓

[a] This question was from a validated scale and referred to vaccines in general, not a COVID-19 vaccine

Statistical Analysis

Analyses were conducted using Stata/IC v16.1 (StataCorp, College Station, TX). The threshold for statistical significance was set at *P*<.05. Descriptive statistics (means and standard deviations for continuous variables, frequency and relative frequency for categorical variables) were calculated for participant characteristics and study outcomes. To reduce the number of outcomes for analysis, misinformation beliefs at baseline were combined into a single measure using principal component analysis (PCA). Associations between the extracted misinformation component and possible explanatory variables were explored using truncated linear regression (with lower-bound truncation based on the minimum numerically possible value of the extracted misinformation component which would result from responding “strongly disagree” to all question items included in the PCA) controlling for sociodemographic factors previously shown to be associated with misinformation beliefs [17].

Changes in misinformation beliefs across study rounds were examined using linear mixed models with random intercepts by participant and robust standard errors. Due to changes in the items included in each round, these items were analysed individually.

Dimension reduction using PCA was applied to the 10 specific COVID-19 myth items (included in Round 3 of the study). Multivariable truncated regression models (with lower-bound truncation as described above) were used to examine associations with the extracted components, using the same explanatory variables as for the analysis of misinformation beliefs from Round 1. Where survey items were repeated in Round 3 (i.e. perceived threat of COVID-19, confidence in government, and use of social media as a "top 3" information source), this version of the variable was included; otherwise the response at baseline was carried forward (i.e. digital health literacy, institutional trust, and sociodemographic variables). An additional explanatory variable added in Round 3 (rejection of official accounts) was also included in these models.

Results

Sample characteristics (Cross-sectional and Longitudinal)

Sample characteristics by each month are summarised in Table 2. When compared to national data, our sample was slightly older, included more females, had higher educational attainment, and less likely to speak a language other than English at home.

Table 2. Sample characteristics by study round (1-3)

		Cross-sectional	Longitudinal		
Sample description		**April: Round 1 (n=4362)**	**April: Round 1 (n=2006)[a]**	**May: Round 2 (n=1882)**	**June: Round 3 (n=1369)**
Age (years), mean (SD)		42.6 (17.4)	43.1 (16.6)	43.0 (16.6)	44.6 (16.7)
Gender, n (%)					
	Male	1698 (39.9%)	635 (31.7%)	589 (31.3%)	433 (31.6%)
	Female	2615 (60.0%)	1338 (66.7%)	1263 (67.1%)	911 (66.5%)
	Not specified / other	49 (1.1%)	33 (1.6%)	30 (1.6%)	25 (1.8%)
Education, n (%)					
	High school or less	934 (21.4%)	317 (15.8%)	302 (16.1%)	198 (14.5%)
	Certificate I-IV[b]	617 (14.1%)	223 (11.1%)	204 (10.8%)	140 (10.2%)
	University education	2811 (64.4%)	1466 (73.1%)	1378 (73.1%)	1031 (75.3%)
Language other than English spoken at home, n (%)		274 (6.3%)	75 (3.7%)	70 (3.7%)	51 (3.7%)
	Cantonese	31 (0.7%)	8 (0.4%)	8 (0.4%)	4 (0.3%)
	Mandarin	28 (0.6%)	12 (0.6%)	11 (0.6%)	2 (0.1%)
	Spanish	19 (0.4%)	6 (0.3%)	6 (0.3%)	2 (0.1%)
	Vietnamese	15 (0.3%)	6 (0.3%)	5 (0.3%)	4 (0.3%)
	Hindi	14 (0.3%)	1 (<0.1%)	1 (0.1%)	1 (0.1%)
	Arabic	11 (0.3%)	1 (<0.1%)	1 (0.1%)	0
	Indonesian	10 (0.2%)	4 (0.2%)	4 (0.2%)	1 (0.1%)
	Urdu	10 (0.2%)	2 (0.1%)	2 (0.1%)	2 (0.1%)
	Other[c]	136 (3.1%)	35 (1.7%)	32 (1.7%)	35 (2.6%)
Socioeconomic status quintile[d], mean (SD)		3.6 (1.4)	3.7 (1.4)	3.7 (1.4)	3.7 (1.4)
Residential location, n (%)					
	New South Wales	2001 (45.9%)	1025 (51.1%)	964 (51.2%)	719 (52.5%)
	Victoria	788 (18.1%)	323 (16.1%)	303 (16.1%)	201 (14.7%)
	Queensland	672 (15.4%)	280 (14.0%)	254 (13.5%)	183 (13.4%)
	Western Australia	371 (8.5%)	138 (6.9%)	133 (7.1%)	91 (6.6%)
	South Australia	238 (5.5%)	93 (4.6%)	89 (4.7%)	64 (4.7%)
	Tasmania	144 (3.3%)	79 (3.9%)	74 (3.9%)	58 (4.2%)
	Australian Capital Territory	120 (2.8%)	62 (3.1%)	59 (3.1%)	49 (3.6%)
	Northern Territory	28 (0.6%)	6 (0.3%)	6 (0.3%)	4 (0.3%)

[a] Round 1 longitudinal sample is a sub-sample of those included in the cross-sectional Round 1 sample, and who responded to at least one follow-up survey. This group were recruited

through social media only.
[b] Certificates I-IV are tertiary qualifications, see Australian Qualifications Framework.
[c] Languages spoken at home with cell counts < 10 at baseline
[d] SEIFA IRSAD Quintile [1-5] based on residential postcode.

Misinformation beliefs and associations with sociodemographic, cognitive and psychosocial variables (Cross-sectional sample in April)

One month into lockdown in Australia, 753 out of 4362 participants (17.3%) agreed that data about the effectiveness of vaccines is often made up (this question referred to vaccines in general, not a COVID-19 vaccine); 652 out of 4362 (15.0%) agreed that that herd immunity would be beneficial for COVID-19 but this is covered-up; 603 out of 4362 (13.8%) agreed that the threat of COVID-19 is greatly exaggerated; and 595 out of 4362 (13.6%) agreed that the Australian government restrictions are stronger than required. Responses on these items were moderately correlated (pairwise *r*'s between 0.36 and 0.63), with good internal consistency (Cronbach's α= 0.78) and sufficient sampling adequacy (KMO = 0.76). PCA of these items resulted in the extraction of a single component with an eigenvalue greater than 1, accounting for 60.7% of the variance (component loadings provided in Appendix Table 1).

Estimated marginal means from the multivariable regression model of misinformation beliefs at baseline are provided in Table 3. Stronger agreement with misinformation beliefs were significantly associated with younger age, male gender, lower education, and primarily speaking a language other than English at home (all $P<.001$). After controlling for these variables, misinformation beliefs were significantly associated (all $P<.001$) with lower digital health literacy, lower perceived threat of COVID-19, lower confidence in government, and lower trust in scientific institutions.

Table 3: Multivariable truncated linear regression of strength of agreement with misinformation beliefs[a]. Higher values of the outcome indicate greater support for misinformation. Data are presented as estimated marginal mean differences (95% CIs) with corresponding *P*-values.

Explanatory variables			Estimated marginal mean differences (95% confidence interval)	*P*-value
Sociodemographic variables				
Age (/year)			-0.023 (-0.028, -0.018)	<.001
Female gender (vs male)[b]			-0.384 (-0.541, -0.226)	<.001
Education (vs high school or less)				<.001
	Certificate I-IV[c]		0.114 (-0.133, 0.360)	.37
	University education		-0.270 (-0.459, -0.080)	.005
LOTE			0.847 (0.569, 1.126)	<.001
SES (/quintile)			-0.050 (-0.105, 0.005)	.08
Additional explanatory variables		**Sample means**		
Digital health Literacy (1-5)		4.04 (0.74)	-0.250 (-0.356, -0.144)	<.001
Perceived public threat of COVID-19 (1-10)		7.64 (2.17)	-0.336 (-0.372, -0.300)	<.001
Not likely to get sick (n, %)		1091 (25.5%)	0.649 (0.475, 0.823)	<.001
Mean confidence in government (1-7)		5.15 (1.06)	-0.143 (-0.222, -0.063)	<.001
Mean institutional trust (1-7)		5.95 (1.06)	-0.663 (-0.738, -0.587)	<.001
Social media used as a top 3 information source (n, %)		1923 (44.9%)	0.151 (-0.001, 0.307)	.06

[a] analysis sample comprised 4286 complete cases included in analyses; occasional instances of missing data on explanatory variables was not imputed due to the small proportion of missingness (76/4362; 1.8%).

[b] marginal mean differences are not reported for gender = not specified or other due to small sample size but was included in the regression model.

[c] Certificates I-IV are tertiary qualifications, see Australian Qualifications Framework.

Changes in misinformation beliefs over time (Longitudinal sample in April-June)

Prevalence of agreement with misinformation by study month is shown in Figure 1, which appear to be generally consistent over time. Estimated means from the fixed portion of linear mixed models are presented in Table 4. A main effect of time (*P*=.006) was identified for belief that the threat of COVID-19 is greatly exaggerated, with pairwise contrasts showing an increase in this belief between April and May (however, this difference was not maintained in June). There was a decrease in the belief that herd immunity is beneficial for COVID-19, but is covered up, between April and May (*P*<.001). There was no difference across time for the strength of government restrictions item (*P*=.41).

Table 4. Estimated means (95% confidence intervals) of fixed effects from linear mixed models analysis (with random intercepts by participant) of agreement with misinformation beliefs by study month, and estimated mean differences (95% confidence intervals) for pairwise comparisons to Round 1 (April).

Items [scale range 1-7]	**April: Round 1 (n=2006)**	**May: Round 2 (n=1882)**		**June: Round 3 (n=1369)**	
	Mean (95% CI)	Mean (95% CI)	Mean difference[a] (95% CI); *P*-value	Mean (95% CI)	Mean difference[a] (95% CI); *P*-value
Data about the effectiveness of vaccines is often made up	2.37 (2.30, 2.44)				
Herd immunity would be beneficial for COVID-19 and this fact is covered up	2.52 (2.46, 2.59)	2.39 (2.32, 2.46)	-0.13 (-0.19, -0.07); *P*<.001		
The threat of	1.99	2.07	0.08	2.04	0.05

COVID-19 is greatly exaggerated	(1.93, 2.05)	(2.01, 2.14)	(0.03, 0.13); *P*=.002	(1.98, 2.10)	(-0.01, 0.10); *P*=.11
Government restrictions are stronger than is needed	2.14 (2.08, 2.21)	2.16 (2.09, 2.22)	0.01 (-0.04, 0.07); *P*=.67	2.19 (2.12, 2.25)	0.04 (-0.02, 0.11); *P*=.19

[a]Mean difference compared to Round 1: April

Specific misinformation beliefs and associations with sociodemographic, cognitive and psychosocial variables (Longitudinal sample in June)

The level of agreement across the 10 COVID-19 misinformation items from the Australian Government website had moderate internal consistency (Cronbach's α= 0.693), and sufficient sampling adequacy (KMO = 0.761). Application of PCA (with varimax rotation) identified a three-component solution with eigenvalues greater than 1, which cumulatively accounted for 51.15% of the variance (see Appendix Table 2 for component loading and proportion agreeing with each item); examination of the contributing items to each component resulted in the following 3 labels:

1. Symptom management and prevention misinformation (PC1; explaining 18.9% of the total variance)
2. Causes and transmission misinformation (PC2; explaining 16.7% of the total variance); and
3. Immunity and cure misinformation (PC3; explaining 15.6% of the total variance).

Regarding specific misinformation concerning *symptom management and prevention*, 301 out of 1369 (22%) of the sample in June (Round 3) agreed that hot temperatures kill the virus, 295 out of 1369 (21.5%) agreed that UV rays kill the virus, and 179 out of 1369 (13.1%) agreed that Ibuprofen exacerbates COVID-19 (see Appendix Table 2). Greater support for symptom management and prevention misinformation (PC1) was significantly associated with younger age and male gender; and after controlling for demographics (age, gender, education and LOTE) was associated with lower institutional trust and greater rejection of official accounts (PC1; see Table 5).

For misinformation regarding *causes and transmission*, 167 of the sample of 1369 (12.2%) of the sample agreed the COVID-19 virus was engineered and released from a Chinese laboratory in Wuhan, 57 out of 1369 (4.2%) agreed that parcels from China can spread the virus, and only 8 of the 1369 participant (0.6%) agreed that 5G networks are spreading the virus. Causes and transmission misinformation (PC2) was significantly associated with less education and more social disadvantage. Greater belief in these statements was associated with lower digital health literacy, reduced perceived public threat, reduced institutional trust, and greater rejection of official accounts after controlling for sociodemographic variables (PC2; see Table 5).

Regarding misinformation about *immunity and cure*, 62 of the 1369 participants in the sample (4.5%) agreed Vitamin C is an effective treatment, 55 out of 1369 (4.0%) agreed there is a cure/vaccine for COVID-19, 32 out of 1369 (2.3%) agreed Hydroxychloroquine is an effective treatment, and 15 of the 1369 participants (1.1%) agreed the flu shot provides immunity. Greater support for immunity and cure misinformation (PC3) was significantly associated with younger age. After controlling for sociodemographic factors, lower digital health literacy, reduced perceived public threat, reduced institutional trust, and greater rejection of official accounts were associated with greater belief in these statements (PC3; see Table 5).

Table 5: Multivariable truncated linear regression of the misinformation beliefs in June[a]. Higher values of the outcome indicate greater support for these beliefs. Data are presented as estimated marginal mean differences (95% confidence intervals) and *P*-values.

		Estimated marginal mean difference (95% confidence interval); *P*-value		
Sociodemographic variables[b]		**Symptom management & prevention (PC1)**	**Causes & transmission (PC2)**	**Immunity & cure (PC3)**
Age (/year)		-0.007 (-0.014, -0.001); *P*=.03	0.005 (-0.003, 0.014); *P*=.23	-0.021 (-0.029, -0.013); *P*<.001
Female gender (vs male)[c]		-0.397 (-0.610, -0.184); *P*<.001	0.222 (-0.087, 0.530); *P*=.16	-0.088 (-0.341, 0.165); *P*=.49
Education (vs high school or less)		*P*=.51	*P*<.001	*P*=.25
Certificate I-IV[d]		0.155 (-0.245, 0.556); *P*=.45	0.401 (-0.109, 0.912); *P*=.13	0.266 (-0.185, 0.716); *P*=.25
University education		0.173 (-0.121, 0.467); *P*=.25	-0.498 (-0.899, -0.096); *P*=.02	-0.051 (-0.388, 0.285); *P*=.77
LOTE		-0.298 (-0.827, 0.230); *P*=.27	0.463 (-0.254, 1.18); *P*=.21	0.212 (-0.375, 0.799); *P*=.48
SES (/quintile)		-0.032 (-0.104, 0.040); *P*=.01	-0.212 (-0.313, -0.111); *P*<.001	-0.007 (-0.092, 0.079); *P*=.88
Additional explanatory variables	**Sample means**			
Digital health Literacy (1-5)[b]	4.18 (0.67)	0.105 (-0.046, 0.255); *P*=.17	-0.304 (-0.512, -0.097); *P*=.004	-0.444 (-0.618, -0.270); *P*<.001
Perceived public threat of COVID-19 (1-10)	7.33 (2.44)	-0.027 (-0.069, 0.016); *P*=.22	-0.074 (-0.133, -0.015); *P*=.01	-0.057 (-0.107, -0.007); *P*=.03
Not likely to get sick (n, %)	123 (9.0%)	0.083 (-0.264, 0.429); *P*=.64	-0.285 (-0.781, 0.211); *P*=.26	0.133 (-0.267, 0.535); *P*=.52
Mean confidence in government (1-7)	5.52 (0.94)	0.028 (-0.094, 0.149); *P*=.67	0.117 (-0.054, 0.288); *P*=.18	0.051 (-0.093, 0.194); *P*=.49
Mean institutional trust (1-7)[b]	6.15 (0.95)	-0.229 (-0.339, -0.119); *P*<.001	-0.599 (-0.750, -0.448); *P*<.001	-0.226 (-0.353, -0.099); *P*<.001
Social media used as a top 3 information source (n, %)	680 (49.8%)	0.107 (-0.094, 0.307); *P*=.30	0.200 (-0.087, 0.486); *P*=.17	0.177 (-0.063, 0.417); *P*=.15
Rejection of official accounts (1-5)	2.36 (0.83)	0.172 (0.031, 0.313); *P*=.02	0.451 (0.245, 0.657); *P*<.001	0.337 (0.169, 0.506); *P*<.001

[a] Analysis sample n=1366; occasional cases of missing data in explanatory variables were not imputed due to small proportion of missingness (3/1369; 0.2%).

[b] indicates values that were obtained at baseline (Round 1) and carried forward

[c] marginal mean differences are not reported for gender = not specified or other due to small sample size but were included in the regression model.

[d] Certificates I-IV are tertiary qualifications, see Australian Qualifications Framework

Discussion

Our analysis showed lower institutional trust, lower digital health literacy, and greater rejection of official accounts were associated with stronger agreement with COVID-19 misinformation. Misinformation was also more common among those who primarily spoke a language other than English at home, in younger age groups, and in males. The most commonly held misinformation beliefs in this study concerned symptom management and prevention. We found small changes between April and May on two of the misinformation items: an increase in agreement with 'COVID-19 is greatly exaggerated' and a decrease in agreement that 'herd immunity is beneficial for COVID-19 but is covered up'. Despite these differences being statistically significant, they likely have little to no practical importance (i.e., only a 0.08 and 0.12 unit change respectively on a 7-point scale). Notably, the proportion of participants agreeing with each item remained generally consistent over time during and after lockdown restrictions were in place.

Our rates of COVID-19 misinformation beliefs were lower compared to other countries [22,23] but we note that our study was not sampled as to be representative of the Australian population. An Australian poll conducted in May 2020 found relatively high support (12-77%) for misinformation beliefs relating to the creation, spread, and prevention of the virus [27]. Interestingly, we saw a much lower prevalence of people agreeing that 5G networks are spreading the virus when compared with this poll. The poll found similar demographic patterns to our findings, where men and younger people agreed with a range of COVID-19 misinformation more than other groups. In the US and UK, younger people are more likely to hold conspiracy beliefs about COVID-19 [28,29]. Studies have also reported that American men are more likely to agree with COVID-19 conspiracy theories than women [30].

The association between misinformation beliefs and lower education, language other than English, younger age and male gender point to important gaps in public health messaging to these groups. We previously highlighted similar disparities in knowledge and behavior in April [17], and issues with the complexity of government health information about COVID-19. People with less education and language other than English had poorer understanding of COVID-19 symptoms and were less able to identify behaviors to prevent infection. Recent attention has focused on the importance of reaching people who do not speak English as a first language [31]. Our study further highlights the need for health information to be written to meet diverse health literacy requirements and targeted to specific groups. For instance, young people and CALD group representatives should be involved in the design of COVID-19 messages to get the tone and delivery right. This can be done by testing communications with these groups, running consumer focus groups before releasing messages to the public, and ensuring representation on public health communication teams [32]. Ideally, a co-production approach should be used to ensure targeted community messages about COVID-19 prevention are relevant and effective.

Provision of quality information online is unlikely to be a sufficient strategy to counter the influence of misinformation if digital health literacy is not accounted for. Messaging and debunking must be delivered on multiple trusted channels [33], consistent in content and style, and conveyed in local languages to ensure engagement with all communities [34]. Emerging evidence supports the idea that psychological inoculation – pre-emptively exposing people to small doses of misinformation techniques - can build resistance to false information across cultures [35]. Going forward, it will be important to invest in programs teaching digital health literacy and healthy scepticism of health news, including interventions nudging people to consider the accuracy of COVID-19 -related news content before sharing [36]. Finally, partnerships between public health authorities and trusted organisations to deliver information and correct misinformation should be utilised where possible [37]. Corrective messages are most successful when they offer a coherent explanation for how and why a belief based on misinformation is incorrect [38]. Research shows that corrective information can counter misperceptions and improve belief accuracy after a person's exposure to misinformation [39].

Timely, accurate and transparent messaging is vitally important to gaining public trust in messaging from authorities ahead of other less credible sources [40]. While there is now intense global interest aimed at limiting the spread of misinformation in the first place,[2, 35, 41] it will require 'a sustained and coordinated effort by independent fact checkers, independent news media, platform companies, trusted spokespeople and public authorities to help the public understand and navigate the pandemic'[42].

Around the world and in Australia, anti-lockdown protests have taken place in capital cities, with protesters voicing opposition to vaccination, telecommunication towers, and the COVID 'hoax'. Researchers have recently investigated the degree to which misinformation about COVID-19 is associated with people's willingness to adhere to public health recommendations and government enforced measures and found that willingness decreases significantly as the strength of misbeliefs increases [43,44], including decreased COVID-19 vaccination intentions [45]. In some cases, misinformation has led to serious harm, such as the Iranian methanol poisoning experience [46]. The spread of misinformation is an ongoing area of concern as Australia and the world continue to live with the fluctuating realities of a global pandemic. Correcting misinformation should be viewed as a vitally important science and health policy activity [47]. Importantly, the more extreme conspiracy beliefs were rare, for example fewer than 1% in our sample endorsed the 5G conspiracy. However other beliefs were held by over 20% in certain demographics, indicating widespread confusion or simply outdated information, such as regarding the use of Ibuprofen.

Strengths & limitations

The study was large and diverse but not representative of the national population. Given this, caution is needed in generalising from the prevalence findings. The sample was recruited via an online panel and social media, the majority were well educated, with a low proportion of culturally and linguistically diverse participants, and thus may not represent the demographic of all people concerned by COVID-19 and vulnerable to misinformation, including the elderly. Participants recruited via Dynata were not included in the follow up (i.e. rounds 2 and 3) due to funding constraints. The specific social media platform/s used by respondents such as YouTube, Twitter, or Facebook was not captured in our survey, but it is important to note that both good and poor quality information may be obtained through these channels. (Mis)information can come from a variety of other sources such as family and friends, television, radio, print media, or misinformed healthcare providers (including primary, allied, alternative and complementary health sectors). The use of social media as a "top 3" information source was comparable across education categories (45% for all 3 categories) – but as per the limitation mentioned above, it is unclear which platform is being used by whom.

The longitudinal design enabled us to look at whether misinformation beliefs changed over the course of the pandemic. By design, the survey items changed across time, however this prevented us from being able to calculate longitudinal changes in the principal component derived at baseline. Lastly, some of the misinformation items are likely contextual and subjective (e.g. ‘the government restrictions are stronger than is needed’), which may have influenced the interpretation and responses of some participants.

Incorrect information about COVID-19 – whether labelled as misinformation, myth, conspiracy theory, or rumour – circulates every day and our knowledge regarding the value of various preventive interventions has progressed with the pandemic. While we acknowledge that some of the misinformation items included in this survey were subject to legitimate inquiry (e.g. advice recommending against the use of Ibuprofen was issued by the World Health Organisation early in the pandemic but then retracted), they have since been demonstrated to be scientifically incorrect, classified as misinformation, and included on myth busting lists of leading public health institutions. The broader implication being that the groups identified in this study as being more likely to agree with misinformation – younger age, males, lower education, lower health literacy, and LOTE - may not be getting up-to-date, evidence-based advice.

Conclusion

Misinformation can undermine public health efforts. These findings highlight important gaps in communication effectiveness. In efforts to pre and debunk misinformation, public health authorities must urgently build new partnerships with trusted, influential stakeholders and social media companies to reach the groups identified in this study. Communicators must pay close attention to ensuring that all communities can access, understand, and act on reliable COVID-19 advice.

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Abbreviations:

ABS: Australian Bureau of Statistics

CALD: Culturally and linguistically diverse

LOTE: Language other than English

PCA: Principal component analysis

SEIFA: Socioeconomic indexes for areas

SES: Socioeconomic status

Appendix

Table 1: Misinformation beliefs at baseline (Round 1) PC loading

Item	Component Loading
Data about the effectiveness of vaccines is	0.429

often made up	
The threat of COVID-19 is greatly exaggerated	0.546
Herd immunity would be beneficial for COVID-19 and this fact is covered up	0.497
Australian government restrictions are stronger than is needed	0.521

Table 2. Agreement^ and summary statistics for COVID-19 misinformation items (selected from the Australian Government COVID-19 Mythbusting website) at Round 3 (n=1369); and descriptive statistics and component loadings% from Principal Component Analysis]

Items [1 to 5]	Disagree, n (%)	Unsure, n (%)	Agree, n (%)	Mean (SD)	Component loadings		
					PC1	PC2	PC3
5G networks are spreading the virus	1328 (96.9%)	356 (2.5%)	8 (0.6%)	1.10 (0.43)		0.590	
Hot temperatures kill the virus	808 (58.9%)	262 (19.1%)	301 (22.0%)	2.30 (1.28)	0.596		
Vitamin C is an effective treatment	1128 (82.3%)	181 (13.2%)	62 (4.5%)	1.62 (0.90)			
Ibuprofen exacerbates COVID-19	746 (54.4%)	446 (32.5%)	179 (13.1%)	2.33 (1.07)	0.351		
The flu shot provides immunity to COVID-19	1317 (96.1%)	39 (2.8%)	15 (1.1%)	1.17 (0.51)			0.658
Hydroxychloroquine is an effective treatment	1008 (73.5%)	331 (24.1%)	32 (2.3%)	1.85 (0.87)			
UV rays kill the virus	734 (53.5%)	342 (25.0%)	295 (21.5%)	2.39 (1.25)	0.618		
There is a cure/vaccine for COVID-19	1218 (88.8%)	98 (7.2%)	55 (4.0%)	1.37 (0.81)			0.629
Parcels from China can spread the virus	1179 (86.0%)	135 (9.8%)	57 (4.2%)	1.66 (0.82)		0.460	
The COVID-19 virus was engineered and released from a Chinese laboratory in Wuhan	1008 (73.5%)	196 (14.3%)	167 (12.2%)	1.95 (1.09)		0.620	

^ Items were recoded to disagree [1-2], neutral/unknown [3], agree [4-5]. % Component loadings less than |0.3| have been omitted.

Multimedia Appendix 1: Prevalence of agreement (i.e., responding as somewhat agree (5) to strongly agree (7) on the 1 to 7 Likert scale) with misinformation beliefs by study month. Error bars indicate 95% confidence intervals.

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Supplementary Files

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Multimedia Appendixes

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