



# The variant of efforts avoiding strain: successful correction of a scientific discourse related to COVID-19

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## Abstract

This study focuses on how scientifically accurate information is disseminated through social media, and how misinformation can be corrected. We have identified examples on Twitter where scientific terms that have been widely misused have been rectified and replaced by scientifically accurate terms through the interaction of users. The results show that the percentage of accurate terms (“variant” or “COVID-19 variant”) being used instead of the inaccurate terms (“strain”) on Twitter has already increased since the end of December 2020. This was about a month before the release of an official statement by the Japanese Association for Infectious Diseases regarding the accurate terminology, and the use of terms on social media was faster than it was in television. Some Twitter users who quickly started using the accurate term were more likely to retweet messages sent by leading influencers on Twitter, rather than messages sent by traditional media or portal sites. However, a few Twitter users continued to use wrong terms even after March 2021, even though the use of the accurate terms was widespread. This study empirically verified that self-correction occurs even on Twitter, and also suggested that influencers with expertise can influence the direction of public opinion on social media.

**Keywords** Dissemination of expertise · Correction of misinformation · COVID-19 variant · Self-correction · Social media influencers

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## Introduction

The disruption of the information ecosystem that has been occurring since the spread of the Internet, especially the advent of social media, is occurring. Among these, social disruption caused by misinformation became a universal problem throughout the COVID-19 pandemic that began in 2020. The dissemination of misinformation can have negative effects on both personal and social levels, especially amid a global pandemic. On a personal level, it has been reported that people face fear, anxiety, and stress when there is a spike in false information related to COVID-19 [1]. The prevalence of misinformation also has a negative impact on society; for example, false information about the relationship between vaccination and autism, and the denial of vaccination as a consequence has caused public health exigencies [2]. Furthermore, some experts have noted that in a democratic society, decisions made by citizens who are not well informed or are misinformed may be detrimental to the community [3].

WHO stated this disturbance of the information at pandemic as the ‘Infodemic,’ and asked for coping for this menace [4]. It has been widely accepted that misinformation and rumors spread more rapidly than factual information on social media [5]. In this regard, social media platforms, such as Facebook, Twitter, and Instagram, have also announced that they will actively deal with false information surrounding COVID-19 [6]. Twitter is often known as an epicenter of misinformation or rumors [7, 8]. Correspondingly, Twitter posted information from the WHO or national health authorities about conspiracy theories and misinformation from sites that disseminate false information and used algorithms to identify and eliminate the circulation of potentially damaging false information [9].

Much research has been accumulated to understand, address, and counteract the current state of this flood of misinformation. Previous studies show that it is not easy to correct misinformation that has been accepted as truth, because it is stored in memory and affects subsequent judgments, characterized as “belief persistence” [10, 11]. In addition, efforts to rectify misinformation may sometimes prove counterproductive, such as making people more dependent on misinformation [12]. For example, in Japan, in March 2020, misinformation that tissue papers are out of stock due to the spread of COVID-19, spread on Twitter. Consequently, many stores sold out of tissue papers. According to a study analyzing related tweets, although the disclaimer spread wider than the misinformation, over-purchase of toilet paper continued [13].

Furthermore, the architecture of Twitter is amplifying such tendencies; retweeting is the key mechanism for information diffusion on Twitter [14]; information is transmitted to other users through retweeting (RT), which has the meaning of social interaction through social media [15]. Users who retweet can be regarded as opinion leaders from the point of view of communication studies that deal with the dissemination of knowledge. Retweeting also serve to disseminate information to many people over a short period. A phenomenon in which messages sent from Twitter spread explosively or rank at the top of portal sites

is called a “Twitter bomb.” [5] Based on these previous studies, retweeting could be interpreted as an act of sharing information in an active sense. In addition, by identifying which users were most retweeted by other users, an axis of information distribution could be determined.

Moreover, in this age of the ‘Hybrid Media Systems,’ [16] which consisted of the entangled information ecosystems of traditional mass-media and social media, prior studies also have addressed ‘cross-media usage and news sharing’. Considering the advancement in media channels, we have used multiple media platforms simultaneously, and the manner in which we used them is also diverse. For example, information is disseminated through traditional media such as newspapers and television, or the news shared on social networking sites such as YouTube or Facebook, and often posted on Twitter or Instagram by sharing personal opinions or impressions, along with the sources of news or captured photos. The use of cross-media on Twitter appears in the form of adding hashtags, post comments and retweeting, as well as by sharing hyperlinks. Hyperlinks are fundamental connective tools that allow users to direct each other in digital spaces while displaying their own interests in specific news and information [17–19]. According to Digital News Report 2021, a comparative analysis of media usage in 46 countries shows that television continues to be a powerful medium in Japan [20]. According to this investigation, when asked what media they used as news sources, 63% of Japanese respondents answered that they used online media (including social media) and 58% chose television. To understand the reality of misinformation, it is necessary to conduct research in the context of this relationship between mass media, particularly television, and social media.

However, the concept of the word “Infodemic” misguides the arguments to tackle this problem. That is, using this word in the circumstance of pandemic motivate to diagnose people those trusting the wrong information as “infected” person and polarize the society. The oblivion of the reflexive function of misinformation is behind the argument; for example, mainstream society believes in *sound science* trying to *enlighten* people with the *right information*, such as the vaccine’s effectiveness. On the other hand, the people believing that vaccines are harmful also have confidence that the wrong information in this Infodemic deceives the majority. At least some part of the current deadlock of the dichotomic dispute about the rightness of the scientific truth would be derived from this kind of mutual pathological stigmatization [21, 22]. The knowledge required to cure this agglutination could be learned from the case study that once a kind of (mis-)information was dominant, but later the trend reversed to the scientifically accurate information, and scrutinize how and why this come-from-behind phenomenon happened.

For the above sake, we found a notable example of scientific facts dispelling wrong information and becoming the dominant term through spontaneous interactions among Twitter users. The COVID-19 variant that originated around December 2020 was initially called the scientifically inaccurate name, “strain (変異種: *hen-i-shu*, which could be directly translated to ‘mutated strain’ in English)” in Japan. However, experts noted that it is appropriate to call it a “variant (変異株: *hen-i-kabu*, ditto ‘mutated variant’)” from a scientific point of view. Accordingly, the Japanese Association for Infectious Diseases officially issued a statement on its website on January 22, 2021, directing the Japanese media to use the accurate

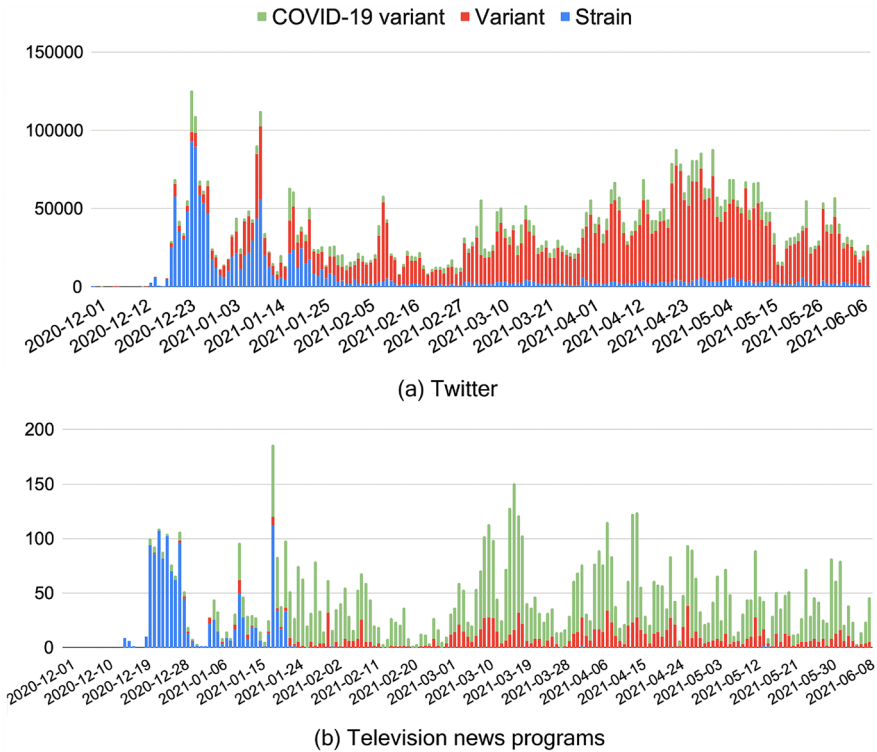
terms “variant” or “COVID-19 variant (変異ウイルス: *hen-i-virus*, ditto ‘mutated virus’).” [23] Meanwhile, even before this statement was released, there were posts on Twitter in December 2020, stating that “variant” was the accurate expression, not “strain.” In a news program aired in December 2020 on television, Japan’s dominant media, both the inaccurate and accurate terms were used, but the usage of the accurate expression seemed to gradually increase. Therefore, we obtained (1) Twitter data and (2) television news programs’ metadata and analyzed them closely.

As a contrasting example, we investigated the Kiev–Kyiv name change, which the government instigated and which rapidly penetrated society. This is related to the fact that governments and media in various countries changed the spelling of the Ukrainian capital from the Russian-derived spelling Kiev to the Ukrainian Cyrillic-based spelling Kyiv. In the case of Japan, the Japanese Ministry of Foreign Affairs announced that it would change the official notation from Kiefu (キエフ) to Kiiu (キーウ). Regarding the strain-variant case, which is the main subject of this study, we focused not on the government but rather on the role of experts who send individual messages via social media. In other words, this additional analysis was performed to compare the government-led top-down method of terminology correction with autonomous expert-driven correction. Through this analysis, we sought to understand the dissemination of scientific expertise on Twitter. Through above premises, following research questions were posed:

- How has the trend in the proportion of scientifically inaccurate and accurate terms used on Twitter changed? How is it different from television news programs?
- Which accounts did users who pioneered the use of accurate terminology trust as sources of information? Specifically, what are the characteristics of the accounts retweeted by those who show changes in behavior?
- What are the characteristics of users who persist in using the wrong term even after the accurate terminology has become prevalent? In particular, what sources of information are they referring to?

## Volume of data

First, we measured the number of tweets on Twitter, including inaccurate and accurate terms, and visualized them as graphs (Fig. 1a). For reference, the total data were 7.1 million cases. As mentioned above, the inaccurate term refers to “strain,” represented in blue in the graph, while the accurate terms include “variant” and “COVID-19 variant,” represented in red and green on the graph, respectively. Tweets that used both accurate and inaccurate terms accounted for only 2% of the total data; thus, no separate processing was performed, such as deletion. Figure 1 shows that the number of users using the inaccurate term on Twitter (blue) has dwindled since mid-December 2020. Although it increased again in mid-January 2021, we can see that there are relatively more users (red and green) who use the accurate term. We performed the same task on television data (Fig. 1b). Furthermore, for the same data, we visualized it with a 100% stacked



**Fig. 1** Comparison of the number of inaccurate terms (blue) and accurate terms (red and green)

bar graph to verify the relative ratio. Figure 2a shows the analysis results of Twitter data, and Fig. 2b shows the television data results.

According to Fig. 2a, in the case of Twitter, the proportion of inaccurate terms started to decrease around December 25, 2020. Specifically, it recorded an 80–90% decrease in mid-December 2020, 74% on December 25, 2020 and 68% from December 29 to 30, 2020. Figure 2b shows the overall similarity in the case of television, but the proportion of inaccurate terms, which accounted for a 90–95% decrease from mid-December, declined throughout January 2021 after hitting 68% on December 30, 2020. In summary, although the decreasing speed is not constant and it is difficult to clearly measure the speed, given the overall tendency, Twitter registered a relatively low rate of usage of the wrong terms in December 2020 compared to television, and the rate at which it was replaced by the accurate term was relatively faster. The proportion of inaccurate terms has decreased dramatically since January 2021. Interestingly, after February 2021, while we could hardly find an inaccurate term on television, there was a group of users who consistently used the misnomer on Twitter.

However, it could be argued that the above analysis, which involves duplicated retweets, may not fully capture the changes in the usage of the term by Twitter

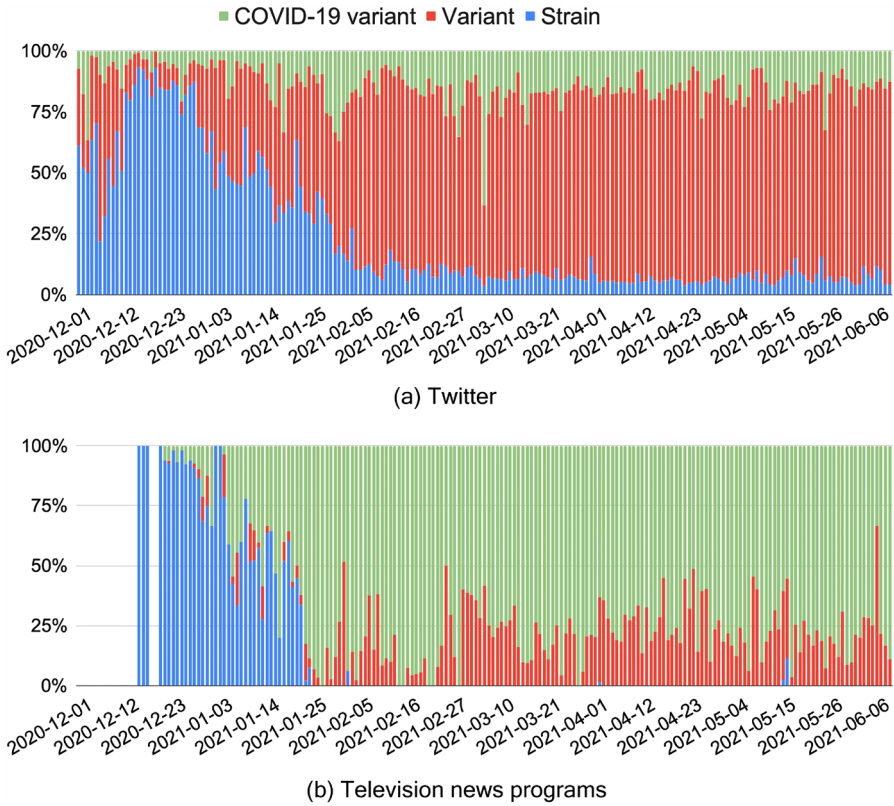


Fig. 2 Relative proportion of the number of inaccurate terms (blue) and accurate terms (red and green)

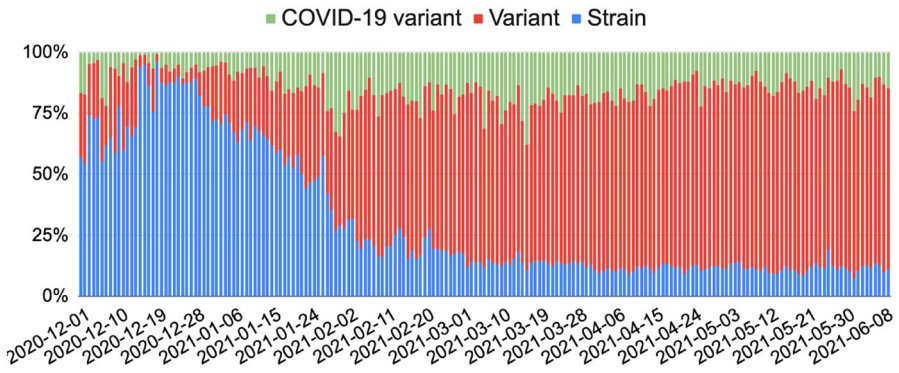


Fig. 3 Relative proportion of the number of inaccurate terms (blue) and accurate terms (red and green) on Japanese original tweets (without retweets)

users. To address this concern, we conducted a similar visualization using original tweets, while excluding retweets, and found that the outcomes were largely consistent. The result is shown in Fig. 3.

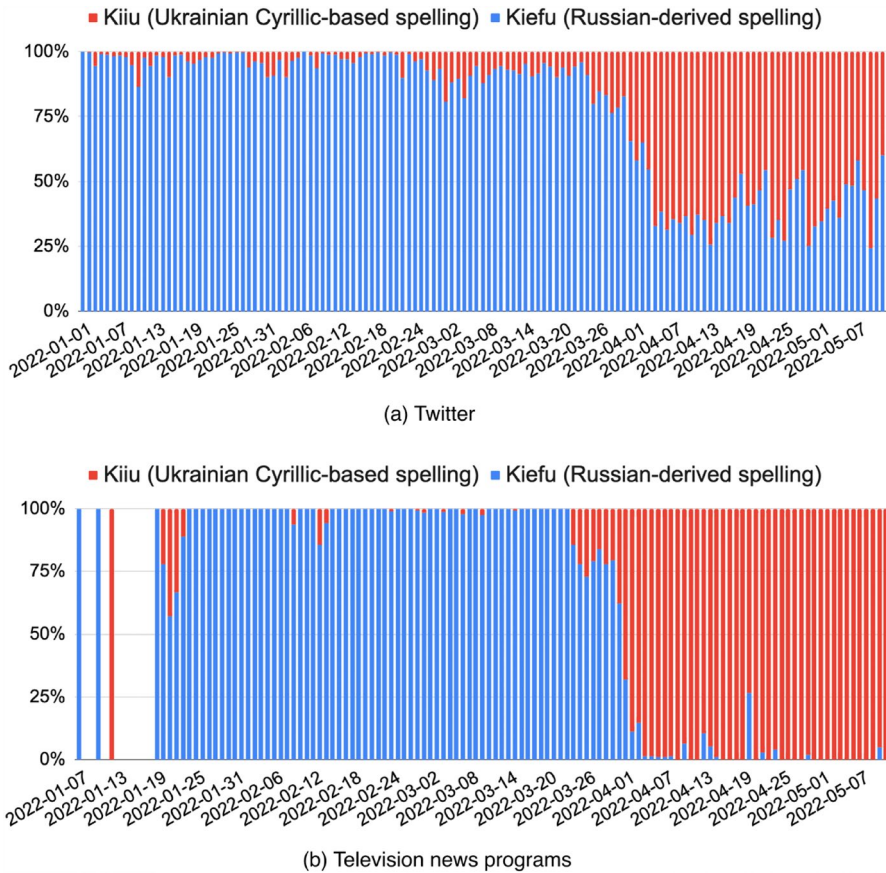
It is important to note that, in our study, we chose to analyze data inclusive of retweets, based on previous research that highlights the significant role of retweeting in disseminating information and shaping public opinion on Twitter [14, 15]. Therefore, we posit that assessing whether tweets that have been frequently retweeted by users employ the appropriate terminology is a crucial component of comprehending the process of term dissemination on Twitter.

To learn more about changes in the use of the terms on Twitter and TV news programs, we analyzed another case for control. This case concerns the pronunciation and spelling of Kyiv, the capital of Ukraine. On March 31, 2022, the Ministry of Foreign Affairs of Japan announced that the name of the capital of Ukraine would be changed from Kieff (キエフ), a Russian-derived spelling, to Kiiu (キーウ), a Ukrainian Cyrillic-based spelling [24]. We collected about 3.5 million Japanese tweets containing Kieff or Kiiu posted between January 1, 2022 and May 11, 2022 and analyzed using the same method used to produce the results shown in Fig. 2. The result is shown in Fig. 4.

Blue indicates the number of tweets featuring the Russian spelling, Kieff, and red indicates the number of tweets featuring the Ukrainian spelling, Kiiu. Sharp changes were observed in both Twitter and TV news programs as of April 1, the day after the Japanese government's announcement. On the other hand, according to Fig. 4a, in the case of Twitter, even before April, there were some users who used Kiiu, the Ukrainian spelling. According to our additional calculations, from January 1 to March 30, 1 day before the Japanese government's announcement, the number of tweets referring to Kiiu accounted for 25.4% of all tweets that referred to the capital city posted over the entire period.

In the case of TV programs, as shown in Fig. 4b, it was found that usage of the Ukrainian pronunciation increased rapidly after the government's announcement. Specifically, on March 30, the day before the announcement, the usage rate of Kieff, the Russian spelling, was 79.4%, but it fell sharply to 62.3% by March 31 and dropped further to 32.0% by April 1 and 11.1% by April 2. As of April 3, TV news programs have used Kiiu, the Ukrainian spelling, almost universally. This phenomenon differs from the trend observed on Twitter. As can be seen in Fig. 4a, in the case of Twitter, between 25 and 50% of users were still using the Russian spelling, even after April.

Admittedly, the Kyiv case is technically different from the strain-variant case. Specifically, there was a difference regarding the subjects who assumed an active role in explaining why the terminology needed to be corrected and presenting the accurate term. In the case of the strain-variant, a group of experts played this role, and in the case of Kyiv, it was a government agency. This difference seems to have also affected the speed at which the terms were corrected on Twitter and in the mass media. In the strain-variant case, the shift toward using the new term occurred earlier on Twitter than in the mass media. On the other hand, in the case of Kyiv, given the government's proposal of a new term, the corresponding change occurred in the mass media immediately after the announcement. This is presumably because

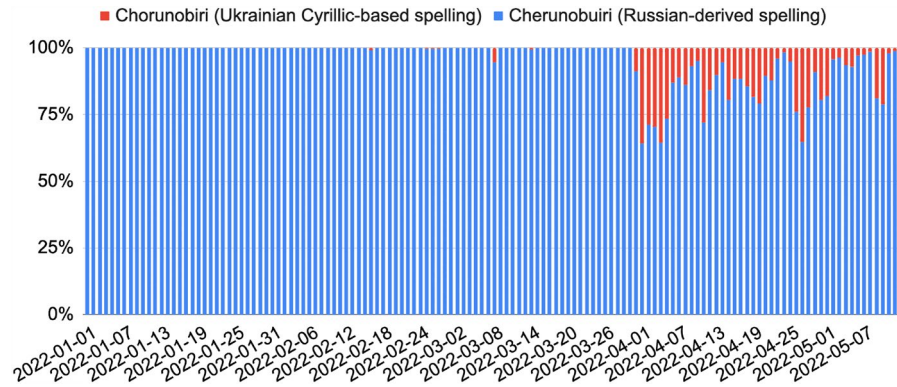


**Fig. 4** Relative proportion of the number of instances of the Russian spelling (blue) and the Ukrainian spelling (red) of Kyiv

in Japan, the staff of the broadcasting stations that produce TV news are very conscious of the government's official announcements.

However, these features will not always be observed. It sometimes takes a long time for a new term to become common. In this regard, we investigated one more case concerning the name of a region in Ukraine called Chornobyl. On March 31, the date of the Japanese government's announcement regarding Kyiv, the government also announced that it would change the Japanese spelling of Chornobyl; that is, the government decided to use the Ukrainian pronunciation, "Chorunobiri (Chornobyl)," instead of the Russian pronunciation, "Cherunobuiri (Chernobyl)." Figure 5 shows the speed at which the old term, the Russian term, Cherunobuiri, is being replaced by the new term, the Ukrainian term, Chorunobiri, on Twitter in Japan. This is the result of analyzing more than 790,000 Japanese tweets, including those featuring Cherunobuiri and Chorunobiri, between January 1, 2022 and May 13, 2022. According to our analysis, the new term is still not widely used. In





**Fig. 5** Relative proportion of the usage frequency of the Russian spelling (blue) and the Ukrainian spelling (red) of Chernobyl on Japanese Twitter

other words, the usage rate of Chorunobiri, a new term based on Ukrainian spelling, was found to still be much lower than that of Cherunobuiri, which is based on the Russian spelling and was previously widely used. This slow terminology correction speed may be attributed to the fact that Chernobyl has received little attention compared to Kyiv. Moreover, the noun Chernobyl has been frequently mentioned, and it took root in press coverage after the Fukushima nuclear accident in 2011. Compared to other cases, there seem to be two reasons the change occurred faster on Twitter than in the mass media in the strain-variant case. The first reason is that an expert group, not a government agency, actively led correction of the term, and the second was that many users were exposed to and interested in the new term. This suggests that experts' opinions are likely to reach social media faster than news from the mass media.

## Retweet ranking

As demonstrated above, the behavior of Twitter users changed faster to a certain extent than television users. Therefore, what is the information that influences them to change their behavior? To understand this, we analyzed the retweeting behavior of users. We set the analysis period as of December 25–31, 2020 as demonstrated above, during which period the rate of misuse of the term began to decrease significantly. Table 1 shows a list of the ten most retweeted tweets during this period and the users (accounts) who sent those tweets.

To elucidate this result, some media and influencers within the top 10 were observed to be employing scientifically inaccurate terms (1st, 5th, 7th, 8th, 10th positions), whereas others were utilizing scientifically accurate terminology (3rd, 6th, and 9th positions) or actively advocating for its usage (2nd and 4th positions). In particular, the breaking news reports from traditional media outlets that ranked 1st, 5th, and 10th were found to be using scientifically inaccurate terms. Regarding the 10th ranked position, the tweet in question was disseminated by an influencer;

**Table 1** Top 10 most retweeted tweets from December 25–31, 2020

Rank	Tweet (translated to English)	Account	Remarks
1	[Breaking News] People infected with a strain (...)	@tbs_news	Traditional media (TV)
2	That's right. It's a ``variant'', not a ``strain'' (...)	@YamabukiOrea	Influencer (doctor)
3	[Breaking News JUST IN] COVID-19 variant (...)	@nhk_news	Traditional media (TV)
4	The word ``strain'' is frequently used, but it is not a new ``species'' (...)	@masahirono	Influencer (doctor)
5	[Breaking News] Infection by a strain spreads in Britain and other countries (...)	@tbs_news	Traditional media (TV)
6	[Breaking News] First confirmation in Japan of COVID-19 variant (...)	@livedoornews	Portal site
7	The situation regarding a strain of COVID-19 is dizzying (...)	@kutsunatasoshi	Influencer (doctor)
8	Confirmed infection of a man in his thirties who returned from the United Kingdom (...)	@ojimakohei	Influencer (politician)
9	Locked down in the UK, some areas work and some don't (...)	@shinkai35	Influencer
10	[Asahi Shimbun extra edition] Extra: Strain of COVID-19 (...)	@UN_NERV	Influencer
11	It has been confirmed that the mutant COVID-19 has entered Japan (...)	@katsusyatakasu	Influencer (doctor)
12	Five men and women infected with mutated strains at Haneda and (...)	@YahooNewsTopics	Portal site

however, the substance of the message was sourced from traditional media. The 7th ranking user, a doctor, utilized scientifically inaccurate terminology while explaining the seriousness and context of the situation, while in the case of the 8th ranking tweet, information regarding a patient who was a politician was disseminated, also utilizing scientifically inaccurate language.

Conversely, there were instances where the appropriate terminology was employed, such as the tweets occupying the 3rd, 6th, and 9th positions, all of which relayed breaking news sourced from traditional media. Additionally, both the 6th ranked portal site and the 9th ranked influencer were disseminating news from traditional media, accurately employing the scientific terminology. Furthermore, in the case of the 2nd and 4th ranked influencers who are professionals in the medical field, they not only utilized the accurate terminology but also actively promoted its usage.

On the other hand, instances where the accurate terminology was employed include the tweets that correspond to ranks 3, 6, and 9, all of which were breaking news reports from traditional media outlets. Furthermore, the 6th ranking portal site delivered traditional media news, while the 9th ranking influencer was found to be quoting and disseminating traditional media news. In the cases of the 2nd and 4th rankings, doctors serving as influencers went beyond simply utilizing the accurate terminology and actively encouraged its use.

In summary, a number of breaking news reports from traditional media outlets were featured prominently in the rankings, with a combination of both accurate and inaccurate terminology being used among the media and influencers included. While certain portals and influencers presented the news without comment, others with specialized expertise took steps to actively rectify the use of scientifically accurate terminology. To add, it is noteworthy that certain portal sites and influencers were reporting on breaking news from traditional media sources, while others with specialized knowledge were taking proactive measures to correct the usage of terminology.

According to the analysis results, the accounts ranked at the top can be categorized into (1) traditional media, (2) portal sites, and (3) influencers, including doctors and politicians. Accounts operated by television and portal sites, which have a strong influence on Japan's media environment, also had a significant impact on Twitter. Influencers, particularly doctors, were ranked at the top. This could be attributed to the characteristics of the analysis target, which is terminology related to COVID-19. Based on these results, we predicted that there could be a difference in behavior among users who retweeted information from each of these three groups (traditional media, portal sites, and influencers). To verify this, we analyzed whether there were any changes in behavior before and after the analysis period set in Table 1 (December 25–31, 2020, hereinafter “period B”). Specifically, we investigated the percentage of inaccurate terminology used in the week before (December 18–24, 2020, hereinafter “period A”) and the week after (January 1–7, 2021, hereinafter “period C”). Based on the Retweet Top 10 analysis results (Table 1), accounts of the top two traditional media (@tbs\_news and @nhk\_news), the top two portal site (@livedoornews and @YahooNewsTopic), and the top two influencers (@YamabukiOrca and @masahirono) were selected as representatives for each group.

Although not included in the table, @YahooNewsTopic, the most influential portal site in Japan, ranked 12th.

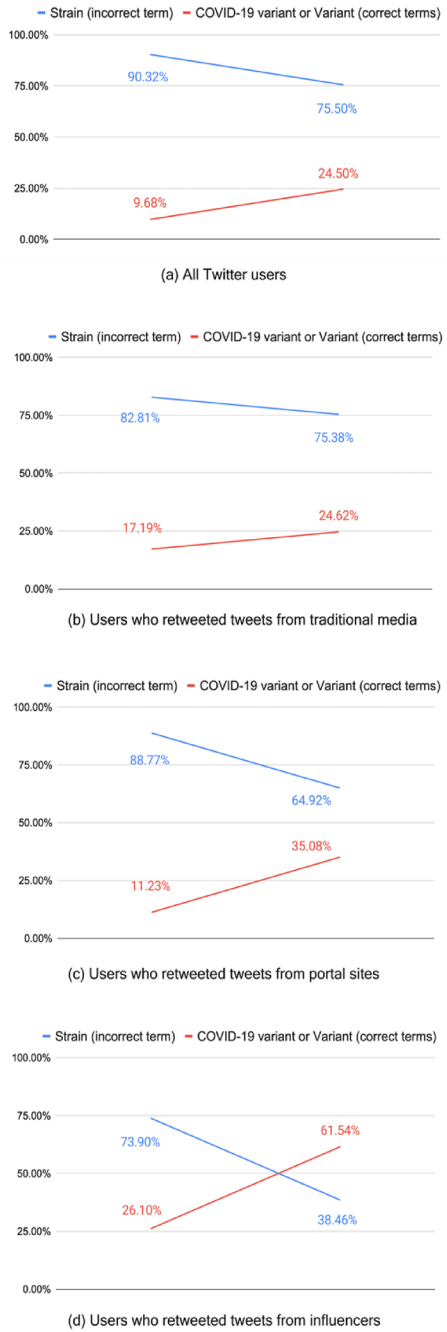
To be more concise, we conducted an analysis of users who (1) directly posted tweets containing ‘strain’ or ‘variant’ more than once, or (2) retweeted other users’ tweets more than once, during the period. Regarding Fig. 6a, the analysis identified a total of 17,019 users during Period A and 12,076 users during Period C who either directly posted tweets containing strains or mutants more than once or retweeted such tweets more than once. Concerning the traditional media group presented in Fig. 6b, there were 954 individuals during Period A and 666 individuals during Period C who met the aforementioned criteria. In the case of the portal media group depicted in Fig. 6c, the corresponding figures were 721 users during Period A and 573 users during Period C. Finally, the influencer group illustrated in Fig. 6d had 705 users during Period A and 754 users during Period C. It should be noted that there may be users who cited multiple media sources, resulting in overlapping in each group.

Figure 6a is a control group for comparison, which is the result of an analysis of all users regardless of the retweeted media. Although the proportion of users using the accurate term increased to 24.5% in period C, 75.5% continued to use the inaccurate term. Figure 6b shows that, in the case of users who retweeted traditional media tweets during period B, 75.38% used the inaccurate term and 24.62% used the accurate terminology during period C. In the group of users who retweeted tweets from the portal sites shown in Fig. 6c, 64.92% used the inaccurate term and 35.08% used the accurate expression during period C. Finally, Fig. 6d shows that for users who retweeted tweets from influencers, the proportion of those who used the accurate term in period C increased to 61.54%. In addition, the percentage of users who used the inaccurate term was 38.46%. This was the only case in which the accurate terms were used more than 50% of the time.

## People who continued to use the inaccurate term

As confirmed in the figures above, the proportion of users using the wrong term on Twitter has declined sharply since January and February 2021, and they have become a minority. However, even after March 2021, when the accurate terminology was widely used, around 5% of users consistently used the inaccurate term. In order to learn more about those who “resist change” or “still have not accepted new information”, we focused on the sharing of hyperlinks, given that the posting of hyperlinks, unlike retweets and comments, is a common practice without users having to follow one another. Holton et al. [19] revealed a central social role for hyperlinks, indicating their use in seeking information by soliciting reciprocal links from other users. Sharing this point of view, we extracted and analyzed URLs inserted in the form of hyperlinks in the body of the tweets they sent or retweeted. We expected that this analysis would allow us to learn what media they are referring to other than Twitter. In addition, owing to the limitations of the analysis tool, 5000 cases were randomly extracted and analyzed from each set.

**Fig. 6** Changes in the percentage of inaccurate terminology



**Table 2** Top 10 sites cited by Twitter users who continued to use the accurate term after March 2021

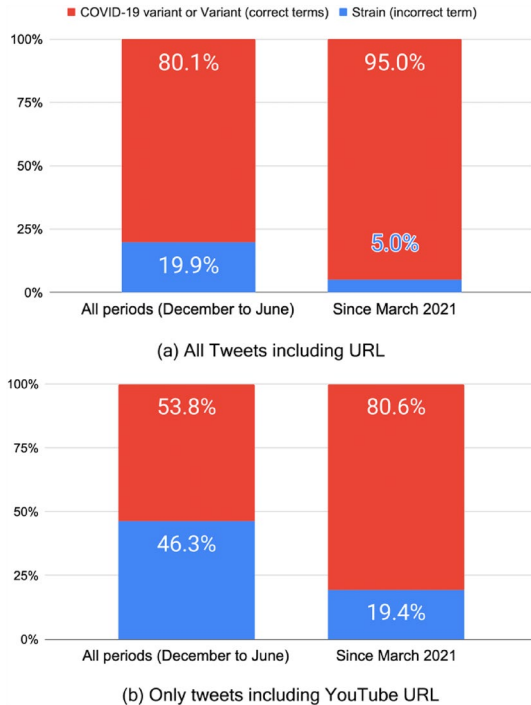
Rank	Sites	Remarks
1	<a href="http://news.yahoo.co.jp">http://news.yahoo.co.jp</a>	Portal site
2	<a href="http://mainichi.jp">http://mainichi.jp</a>	Traditional media
3	<a href="http://www.tokyo-np.co.jp">www.tokyo-np.co.jp</a>	Traditional media
4	<a href="http://www.jiji.com">www.jiji.com</a>	Traditional media
5	<a href="http://www.youtube.com">www.youtube.com</a>	Social media
6	nordot.app	Traditional media
7	<a href="http://www.nikkei.com">www.nikkei.com</a>	Traditional media
8	<a href="http://jp.reuters.com">http://jp.reuters.com</a>	Traditional media
9	<a href="http://www.newsweekjapan.jp">www.newsweekjapan.jp</a>	Traditional media
10	<a href="http://www.nikkan-gendai.com">www.nikkan-gendai.com</a>	Traditional media

**Table 3** Top 10 sites cited by Twitter users who continued to use the inaccurate term after March 2021

Rank	Sites	Remarks
1	<a href="http://www.youtube.com">www.youtube.com</a>	Social media
2	<a href="http://news.yahoo.co.jp">http://news.yahoo.co.jp</a>	Portal site
3	<a href="http://www.nikkei.com">www.nikkei.com</a>	Traditional media
4	ameblo.jp	Blog site
5	<a href="http://www.abc.net.au">www.abc.net.au</a>	Traditional media
6	<a href="http://www.yomiuri.co.jp">www.yomiuri.co.jp</a>	Traditional media
7	<a href="http://jp.reuters.com">http://jp.reuters.com</a>	Traditional media
8	<a href="http://www.tokyo-sports.co.jp">www.tokyo-sports.co.jp</a>	Traditional media
9	<a href="http://www.nikkansports.com">www.nikkansports.com</a>	Traditional media
10	indeep.jp	Conspiracy theory-related site

Table 2 shows the analysis results of the groups using the accurate term after March 2021. Among the accounts corresponding to the Top 10, eight are traditional media; one is a portal site; and YouTube holds the fifth place. Table 3 shows the media mainly cited by users who continued to use the inaccurate term after March 2021; it is worth noting that YouTube, notorious for being a provider of conspiracy theories [25, 26] or misinformation is ranked first. It is also interesting that sports newspapers are in the eighth and ninth places, and a conspiracy theory-related site is in tenth place.

In addition, based on the results shown in Tables 2 and 3, we analyzed whether there is a difference in the percentage of accurate term usage depending on the referenced URL, that is, the referenced media. In this analysis, 10,000 cases were randomly extracted and set as the target for analysis. Figure 7a shows the analysis of the control group, which targeted all tweets with URLs attached in the form of hyperlinks. When analyzing tweets over all periods (December 2020–June 2021), 19.9% of tweets used the wrong terminology, and after March 2021, it fell to 5%. However, the analysis results of the tweets citing YouTube are shown in Fig. 7b. It showed

**Fig. 7** Percentage of inaccurate terms

46.3% for all periods and 19.4% since March 2021, indicating that there are far more users who use the inaccurate term than the control group.

## Discussion

In this study, we analyzed how scientifically accurate information is disseminated on Twitter. We determined the process of accurate terms replacing wrong expressions by analyzing 7.1 million Twitter data. We also analyzed more than 7600 television metadata for comparison. Accordingly, our answers to each of the three main points presented in the introduction are as follows:

- The rate of the use of a scientifically inaccurate term “strain” on Twitter began to decline in late December 2020 and continued to decline in January 2021, with more than 90% being replaced by the accurate terms in February 2021. The changes began to occur slightly earlier than they did for television.
- When users were grouped according to the account from which they retweeted, the rate at which they started using the accurate term differed. Users who retweeted tweets from traditional media and portal sites began to use the accurate term faster than the overall average, but more than half continued to use the inaccurate term. In contrast, for users who retweeted influencers on Twit-

ter, the accurate term usage rate was 61.5%, exceeding the inaccurate term usage rate of 38.5%.

- Even after March 2021, when most users were using the accurate term, some users continued to tweet the wrong term; YouTube was the most cited media by such users. This was markedly different from other groups, which tended to mainly cite portal sites and traditional media. In addition, when we extracted tweets citing YouTube and analyzed the percentage of inaccurate terms used, it was higher than that shown in tweets citing the portal site Yahoo! JAPAN.

Regarding the first result, we assume that, to some extent, self-corrections have occurred on Twitter. This is because the inaccurate term was already being rectified before January 22, 2021 when the Japanese Association for Infectious Diseases officially issued a statement on the accurate term. It was even a little ahead of television, a major media outlet with a strong influence in Japan. This was a case in contrast to the failure to correct misinformation, such as the toilet paper rumor in Japan in March 2020. Furthermore, it is in stark contrast to the case of Kiev–Kyiv, where the government, rather than private experts, actively took steps to accurate terminology. This can be attributed to the fact that most users were not strongly opposed to the corrected information because the subject of this analysis was a matter of terminology that had nothing to do with individual beliefs. The fact that users who are persistent in using the wrong term after March 2021 are still active on Twitter reportedly highlights the limitations of self-correction on social media or the existence of the motivated reasoned people who tenaciously use the word “strain” those fit for their conspiratory worldview: the Japanese word “(mutated) strain” has a representative tone of an enigmatic creature. The fact they are frequently quoting conspiratory Youtube channels support this possibility as described below.

In the second result, the fact that three of the top five accounts that sent the most retweeted tweets related to traditional media (especially television) and portal sites seems to reflect Japan’s unique media environment. Given that portal sites generally serve as a conduit for the collection and provision of articles originating from traditional media, the influence of traditional media, especially television, is quite strong.

Among the accounts of influencers on Twitter, which accounted for the remaining 6 of the top 10 list, 3 accounts supposed that they were doctors. This seems to be related to the fact that the subject of this study was a medical term related to COVID-19. It makes sense to trust a medical expert’s message regarding medical jargon. However, it is also worth noting that there was a difference in behavior between users who retweeted tweets from traditional media or portal sites and those who retweeted tweets from influencers. This could be attributed to differences in the content of the message. Specifically, tweets from traditional media or portal sites were mainly breaking news, while some influencers graciously explained the accurate use of terminology, such as “it is right to use the term variant rather than strain.” Specifically, tweets by influencers containing the accurate term ranked second and fourth in the top 10 list. This period was immediately after the outbreak of the variant, and there was still no clear guidance from authorities on the specific terminology, unlike the Kiev case where the government took the initiative and provided a



direction. Therefore, it can be inferred that influencers with expertise may have had a significant impact on Twitter users' use of jargon.

The third result is an intensive analysis of users who resisted change and continued to use the inaccurate term, even after the accurate terminology was widely prevalent. Admittedly, we have not been able to clearly determine whether they are deliberately using the inaccurate term, or whether they continue to use it due to a lack of information. However, through URL analysis, it was possible to determine what media they primarily cited. Compared with the results of analyzing the control group and users using the accurate term, users of the inaccurate term cited YouTube more frequently. In addition, the fact that sites mainly dealing with conspiracy theories were ranked in the 10th place was also a characteristic phenomenon not found in other groups. It was also found that the proportion containing inaccurate terms was significantly higher than those containing other URLs. It can be inferred that there may be a relationship between users who cite YouTube and those who use inaccurate terminology. Arguably, these people may be concerned with inaccuracies in order to express that they hold ideas that differ from mainstream science.

This study has several limitations. First, one might question the external validity of this research in that it is a case study. Furthermore, since it is a special case in which influencers, experts on terminology, have had a significant impact and have succeeded in rectifying misinformation, it is highly likely that the same result will not be obtained in other cases. This study analyzed two types of data, Twitter and television metadata, but it is regrettable that better insights could have been obtained if Internet news and newspaper articles, which wield considerable influence in Japan, were also included in the analysis. Furthermore, another limitation of this paper is its narrow focus on the side of information dissemination, namely the influencers who exert influence. However, we acknowledge that a comprehensive understanding requires an analysis of the influencers who receive the information and are affected by it. This is because the acceptance of information may vary depending on the characteristics of the influencees. Hence, we believe that future follow-up studies that focus on the influencees will be necessary.

The implications of this study should also be carefully considered. In other words, this study is a dogmatic case study in which academic terminology, which is considered orthodox, has displaced the general vocabulary. The selected case study ignores the question of whether academia can and should guarantee the correctness of words in society in the first place. Such an assumption neglects the modern knowledge of science communication studies that confirmed during the COVID-19 pandemic that anxiety and partisan motivated reasoning matter in scientific disputes in society [27]. Moreover, if we take the study's findings as they are as an alarmist statement, it would mean that scientific experts should contribute more actively to enlightenment activities on social media. This would encourage the organizational promotion of science, or "medialization of science," which Peter Weingart has repeatedly and skeptically warned against, and would cause new problems that could harm trust in science [28, 29]. These aspects remain issues for further epistemological investigation.

Nevertheless, this study empirically confirms the process by which inaccurate information on Twitter can be successfully rectified through interaction within Twitter. This

also allowed us to understand the influence of experts on the dissemination of scientific facts in contrast to top-down correction of the spelling of the Ukrainian capital city. Even on Twitter, which has been recognized as a “hotbed of rumors and fake news propagation,” we could see that self-corrections centered on influencers with expertise occurred. Furthermore, we confirmed that users who use the accurate term and those who persistently use inaccurate terminology differ in the media they cite. This suggests that the type of media one refers to can also affect individual attitude changes. Also, the importance of the collective movement of experts can be a harbinger of the scientific correction of the technical term. This case study shows merely an example of the successful correction of the scientific term but would provide a clue for better deliberation in the circumstances of the Hybrid Media Systems.

## Methods

This study draws on two datasets: Twitter data collected by the authors, and television-related metadata compiled by a Japanese company, “M Data Co., Ltd.” specializing in collecting metadata related to television. For the Twitter data, 7.1 million cases were collected between December 1, 2020, and June 22, 2021, with the inaccurate term “変異種 (strain)” and the accurate terms “変異株 (variant)” or “変異ウイルス (COVID-19 variant).” In some analyses, 5000 or 10,000 cases, not all data, were randomly extracted and analyzed.

Television data were acquired through a system called “i-Catch” provided by VLe Linac, Inc. This study analyzed metadata from news programs aired on six major broadcasting stations, including the date, time, headline, and content summary. The news programs included breaking news segments that could last as short as 40 min or longer, and headlines typically consisted of about 50 characters, while memos ranged from 300 to 1000 words in length. The analysis focused on news items that contained the words “strain” or “variant” in either the headline or the memo. Through this system, we extracted information about 7600 news items broadcast from December 1, 2020, to June 9, 2021, that contained the term “変異” in headlines or memos.

We utilized Google Colab to analyze data, and mainly used libraries like MeCab and urllib. Google Spreadsheet and Overleaf were employed to visualize figures and tables. In general, URLs shared on Twitter are shortened, therefore, we used a library called “urllib” to revert URLs back to their full form before it was shortened. In addition, in consideration of realistic conditions such as hardware and time required for analyses, in some analysis, 5000 or 10,000 samples were randomly sampled and analyzed.

## Supplementary information

Supplementary material regarding the statistical validation of the data used in this paper is available in the GitHub repository (<https://github.com/dongwoolim-tokyo/JCSS>).

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**Author contributions** DL, FT and MY designed the model and the computational framework, carried out the implementation, and analyzed the data. MY and FT collected and stored data for the research. DL, FT and MT wrote the manuscript with input from all authors. KY provided invaluable guidance on statistical hypothesis testing and offered practical support in its execution. All authors verified the analytical methods, discussed the results, and contributed to the final manuscript.

**Data availability** The datasets and script for analysis for the current study are available in the GitHub repository (<https://github.com/dongwoolim-tokyo/JCSS>) and according to Twitter's company regulations, only tweet id will be shared. The authors used the Twitter API for Academic Research that authorizes non-commercial use to collect data for the current study.

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

**Human and animal rights** All methods were carried out in accordance with relevant guidelines and regulations. Human participants have not been involved in the current study.

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