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Introduction

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In the field of public understanding of science, the public's understanding of science has been one important line of research (Bauer and Jensen, 2011). The discourses of public understanding of science have moved from people's 'deficit' in scientific knowledge and attitudes to science, to deficit in trust in scientists and institutions (Bauer, 2009). Many policies and activities have been implemented to improve the public's understanding.

At the same time, the increasing development and wide diffusion of social media among the public have provided opportunities for research on people's understanding of science. The exponential growth of social media such as Twitter, Facebook and Sina Weibo has raised the possibility of detecting public opinion on scientific issues. The abundance of data available from social media includes internet users' expressions of feelings and thoughts about a variety of issues and has greatly benefited researchers' social inquiries. Meanwhile, the research community has developed accessible open-source text analysis libraries in R, Python and other programming languages to facilitate analyses of big data (Munzert et al. 2014; Wilkerson and Casas 2017).

In line with such trends, in the past decade we have seen a proliferation of literature on using social media to measure public opinion. In the area of science communication, one of the persistent concerns is always about the public's opinions on science and technology, and specifically on controversial scientific issues. For example, Veltri (2013) investigated public opinion about nanotechnology on Twitter by analysing 24,000 tweets in terms of web metrics, latent semantic and sentiment analysis. In another study on public perception of nuclear power, Kugo et al. (2005) used text mining methods to analyse online public comments regarding high-level radioactive waste disposal. In the public health area, based on the study of tweets, Chew and Eysenbach (2010) investigated public reactions during the 2009 H1N1 pandemic. Drawing on a huge volume of texts posted by the public on social media platforms, these authors found that such texts can be useful data for detecting the public's opinions.

Nevertheless, alongside enthusiasm for understanding public opinion from texts posted on social media, there are challenges in such studies. One of the most important problems is that users on social media do not seem to represent the overall population (Gayo-Avello, 2011; Mislove et al. 2011). Therefore, it is necessary to integrate traditional research methods, such as quantitative

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surveys and qualitative interviews, and data collected from the traditional mass media such as newspapers, to complement web data and thus achieve a more comprehensive understanding of the public.

This special issue of *Cultures of Science* addresses public understanding of controversial scientific issues, in particular genetically modified organisms (GMOs), in the context of China. The papers aim to answer the following questions: What are the Chinese public's perceptions of and attitudes to GMOs? What are the key determinants affecting the public's understanding of this issue? How have GMOs been portrayed in social media, as well as in the mainstream media in China and beyond? The papers examine the relevant societal, organizational and individual factors in identifying the construction of public understanding.

1. The public's perceptions of and attitudes towards GMOs

Since two decades ago, the issue of GMOs has attracted the public's attention in China. People's perceptions of and attitudes to this controversial issue have shifted in those years. The proportion of the public thinking that GMOs are unsafe increased from 13% in 2002 to 45% in 2012 (Huang and Peng, 2015). Therefore, it is imperative for the research community to explore the changing scenario of public perceptions of GMOs in recent years, especially the underlying mentality and mindset of stakeholders in genetic engineering.

In 'Imagining GMOs: the Chinese public's scientific perception in the digital age', Xu and Lu conducted an exploratory study through interviewing both GMO opponents and supporters, aiming to examine the Chinese public's perceptions and attitudes to GMOs from both sides. Drawing on their interview data, they found that the public tended to see GMOs from a risk framework, which consists of panic about scientific uncertainty, concerns about food safety, and conspiracy theories. Moreover, the public's perception of risk seemed to reinforce people's negative attitudes towards GMOs.

2. Factors that affect public understanding of GMOs

Media, as crucial sources of scientific information for the public, have been playing increasingly significant roles in constructing public perceptions of and attitudes towards scientific issues. Disputed issues such as GMOs are no exception.

In 'One issue, different stories: The construction of GMO issues on Chinese, American and British mainstream media portals', Ruan, Yang and Jin employed framing theory and a comparative perspective to investigate the media presentation of GMO issues by examining how those issues were covered on the media. The authors selected influential news media from China (*People's Daily*), the United States (*The New York Times*) and the United Kingdom (*The Guardian*) as sample media outlets and collected 749 pieces of news on GMO issues from 2008 to 2015. Through analysing the underlying sentiments and frames in that coverage, they found that news coverage of GMOs in those three countries seemed to reveal similar frames, including factual, human interest, conflict and regulation frames. Despite those similarities in frames, the sentiments underlying the frames tended to be different among countries.

In addition to finding out how media construct scientific issues, scholars are also curious about the ways in which media usage influences the public's attitudes to and behaviours regarding controversial scientific issues.

In 'How the Chinese public makes decisions about controversial technologies: A case study on GMOs', by surveying 1,235 Chinese residents, You attempted to answer such questions as: How does new media content,

including online news, WeChat information and Sina Weibo posts, influence public attitudes? How does scientific knowledge directly and indirectly affect public attitudes? How do risk perception, institutional trust and trust in scientists influence public attitudes and behaviours? She found that people's scientific literacy had a positive impact on their attitudes to and behaviours regarding GMOs as well as their trust in institutions and scientists. Moreover, she found that new media usage (especially WeChat), which provided channels for acquiring GMO-related information, was significantly related to the public's knowledge of and attitudes to this controversial technology.

At the individual level, it is crucial to investigate what factors affect the public's perception of and attitudes towards GMOs, considering the roles that individual perceptions and attitudes play in affecting the public's behaviours.

In 'Why do intuitions differ? Explaining how individual and scenario features influence disgust and moral judgements on GMOs', Liu, Gao and Zhu attempted to examine the underlying intuitions and emotions of disgust for GMOs from the moral psychology perspective with two interrelated experimental studies. More specifically, they investigated how individual and scenario features influence individuals' disgust and moral judgement about GMOs. Their experiments revealed the dynamics of disgust influencing individuals' moral judgement and demonstrated the role of scenario factors (disgust elicitation types, emotion reappraisal) and individual factors consisting of trait disgust and moral preferences.

3. The diffusion of GMO-related information on social media

Text has always been an important data source in public opinion research. Social media has provided public opinion researchers with more data than their predecessors could have imagined. Meanwhile, there have been increasing numbers of software packages for accessing and processing large-scale data. As a result, research on public opinion by analysing text data extracted from social media such as Facebook, Twitter and Sina Weibo has become increasingly popular among public opinion researchers.

To explore the evolving trajectories of public opinion on GMOs in China, in 'The evolution of online discussion about GMOs in China over the past decade: Changes, causes and characteristics', Li, Luo and Chen chose to analyse texts posted on a popular microblogging platform, Sina Weibo, in China. They wrote their own crawler program to retrieve posts that related to the term 'GM' and collected 886,837 posts produced by Chinese users from 2009 to 2018. After they analysed the texts with descriptive statistics and semantic network analysis, they could reveal and summarise the characteristics and trends of discourses on GMOs. They found that, in line with intuitive observation, dominant public discourses on GMO issues were not static; on the contrary, they have been dynamically changing over time. Moreover, the changes in public opinion seemed to reflect various intertwined factors, such as the public's trust in the government and the role of opinion leaders.

Similarly, in 'Misinformation and disinformation in science: Examining the social diffusion of rumours about GMOs', Jiang and Fang also studied texts posted on Sina Weibo to examine misinformation and disinformation in science. More specifically, they employed the case study method to explore the dynamics of the diffusion of rumours about GM soybeans causing cancer. In addition to demonstrating how rumours were created strategies used to distort information and spread rumours on the social media platform, the authors also found that offline social realities were reflected in the online discussions and at the same time greatly

shaped the focus of those discussions. That is, people's online expressions of panic and anxiety were essentially a reflection of their offline concerns about social injustice and class conflicts, among other things.

In summary, the articles in this issue provide a comprehensive perspective on understanding the public's understanding of GMOs in China. These studies, conducted with multiple methods (including quantitative surveys, qualitative interviews, experiments and text analysis), will shed light on research on the public's understanding of controversial issues such as GMOs, climate change, nuclear power and so on for researchers from other countries. However, we should be cautious when generalizing certain findings of these studies to other types of controversial scientific issues conducted in other countries, given the complexity of some issues and cultural and social differences among different societies.

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Imagining GMOs: The Chinese public's scientific perception in the digital age

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Abstract

This exploratory study, which is based on the basic concepts of science communication, conducted in-depth interviews to examine the Chinese public's perceptions of and attitudes towards genetically modified organisms (GMOs). We found that, while scientific knowledge may to some extent be a differentiating factor in attitudes to GMOs, people are subject to significant influence from other information sources. Besides scientific knowledge and scientific literacy, the perception of risks in three dimensions—scientific uncertainty, food safety and conspiracy theories—forms an individual's affective framework for understanding GMOs. The trust framework, which is the regulating mechanism of perception and attitude, plays different roles through institutional trust and interpersonal trust. These tentative conclusions shed new light on how science communication should build the relationship between science and the public in the age of globalization and digitalization.

Key words

Cognition, attitude, perceived risk, institutional trust, interpersonal trust

1. Research background: How scientific communication creates an informed public

Science communication is broadly defined as the use of appropriate skills, media, activities and dialogue to produce one or more personal responses to science: awareness, enjoyment, interest, opinion-forming and understanding (Burns et al., 2003). The goal of science communication is not just to promote science but also to create an informed public that is aware of the implications, limits and power of science as applied to human affairs (Metcalfe and Gascoigne, 1995). Many believe that social controversies over science are rooted in ignorance, that scientific facts speak for themselves, and that—as long as members of the public are informed of scientific knowledge—they should be able to think about and view scientific issues just as scientists do; if they refuse to accept scientific facts, then scientific journalism, the irrationality of the public, or both, are to blame (Bauer et al., 2007; Nisbet and Goidel, 2007; Bauer, 2008).

However, there is an increasing realization among researchers that scientific literacy

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plays a very limited role in shaping the public's perception of science and influencing its science-related decisions (Allum et al., 2008) and that orientations—including values, ideology, political affiliation and religious faith—play a more important role (Nisbet, 2005; Ho et al., 2008; Scheufele et al., 2009). Therefore, science communication efforts need to be based on a systematic, empirical understanding of an intended audience's values, knowledge and attitudes, its interpersonal and social contexts and its preferred media sources and communication channels (Nisbet and Scheufele, 2009).

Even from the perspective of pure science communication, people vary significantly in their psychological attitudes towards scientific issues (Metag and Schäfer, 2018), and researchers have found that audiences in different groups vary greatly in their access to science communication resources:

- 'Sciencephiles', who have a strong interest in science, an extensive knowledge of it and a pronounced belief in its potential, use a variety of sources intensively.
- 'Critically interested' people, who also have a strong interest in science and tend to support it but place less trust in it, use similar sources but have a more cautious attitude to science.
- 'Passive supporters', who have moderate levels of interest and trust in science and moderate knowledge and tempered perceptions of it, use fewer sources.
- 'Disengaged' people pay little attention to science (Schäfer et al., 2018).

There are also arguments that social reproduction in science communication constructs a narrow public that reflects the shape, values and practices of dominant groups at the expense of the marginalized (Dawson, 2018) and that, in many underdeveloped countries, particularly in rural areas, 'science is everywhere, but no one knows it' (Guenther et al., 2018).

In the age of digital media, science communication faces even more challenges. Driven by new technologies, a new system of science communication has emerged. It has more participants and open interaction, which spreads scientific knowledge as well as information that may be wrong, false or misleading (Lu and Zhou, 2015). The credibility and reliability of information are central to the public understanding of science. In the age of traditional media, the authoritative sources and the credibility of the mass media played a foundational role in the credibility and reliability of scientific information.

However, in today's media environment, which is characterized by the declining authority of scientific culture and the potential risks involved in scientists' direct communication with the public through social media, science communication may be entering a 'post-truth' phase. The greater visibility of scientific results is accompanied by an increasing risk that rushed conclusions and even fraudulent content will be pushed into public discussion (Bucchi, 2017). At the same time, strong differences in perceptions of science between different segments of the public have been shown to relate to demographics, specific scientific knowledge, attention to media, attitudes towards media, and the use of social network platforms (Runge et al., 2018).

Of course, science communication is not concerned solely with the public's science perceptions and literacy. Since the mid-20th century, the public in the 'risk society' (Beck, 2004) has been aware of the potential destructiveness of science. A wide range of concerns has included the threat of nuclear war, the ecological consequences of the misuse of antibiotics and pesticides and the spread of AIDS. This has damaged the public's optimism about science and led to rising distrust of and scepticism about science (Bella et al., 1998). The intertwining of highbrow scientific issues and political, societal, ethical and

risk issues in the age of globalization has given rise to disputes and even social movements, including the 'Not in My Back Yard' movement (Bauer and Bucchi, 2007). The disputes have centred mainly on five major questions: healthcare, public health, food safety, the environment and energy. Among them is the controversy over genetically modified (GM) food.

Genetic modification technology involves multiple fields, including public health, food safety and environmental security. It is intrinsically complex, which creates differences of opinion about its risks and even conflict between the public and the scientific community (Covello and Sandman, 2001). Moreover, its rapid advance from laboratory research to industrial application has been subject to the influence of political and commercial considerations.

Because the dispute about genetic modification has generated heated discussion about things far removed from the scientific issues, misunderstanding of and rumours about it have turned into a 'human panic' (Yuan, 2014). An in-depth exploration of this issue may offer an interesting case study of science communication and shed new light on how science communicators should build the relationship between science and the public in the age of globalization and digitalization.

2. The Chinese public's perception of and attitude towards GMOs: The questions and methodology of an exploratory study

Genetically modified organisms (GMOs) are organisms that have had their genetic material altered using genetic engineering techniques to improve their properties. For some researchers, the primary reason that GMOs have so far been rejected by a significant portion of the public, despite their safety being universally recognized by the scientific community, is a failure of science communication.

According to a previous survey of representative papers on GMOs indexed by Social Sciences Citation Index over the past 20 years, the commercialization of GMOs in the mid-1990s was the key to the intensification of anti-GMO sentiment. A series of factors, including the scientific community's neglect of public concern about the risks of GMOs, negative views in the popular media, the limited role of scientific knowledge in shaping public perceptions and a lack of trust in public institutions, combined to trigger the rapid rise of an anti-GMO movement promoted by diverse groups in Europe (including anti-globalization activists, environmentalists, civic organizations and commercial stakeholders such as organic farmers and organic food retailers). Even in the United States, where neither mainstream environmental organizations nor the media had treated GMOs as a major issue, there was still a remarkably hostile media effect. Therefore, it is difficult to use traditional science communication, which relies on the communication of information, to change the public perception of the GMO dispute, which is stuck in the framework of risk, uncertainty and ethics (Jia and Fan, 2015).

Even though some have reached optimistic conclusions about increasing public knowledge and acceptance of GMOs (Xiong et al., 2014), the promotion of genetic engineering technology and GMO products has always been met with resistance from the public in China. Besides China's traditional cultural emphasis on nature and obsession with traditional agriculture (Fan et al., 2013), the GMO dispute that features prominently in the landscape of science and technology risks (Zeng and Dai, 2015) also relates to uncertainty over new technology and the resulting potential risks.

After safety certificates were issued by China's Ministry of Agriculture for two GM rice varieties developed by Huazhong Agricultural University in 2009, the Chinese public's misgivings about GMOs were

intensified by the proposal of GM staple food in 2010 and the 'golden rice' incident in Hunan in 2012; the dispute was significantly amplified by the debate between internet celebrities Fang Zhouzi and famous former TV host Cui Yongyuan in 2013. A series of factors, including the uneven distribution of topics in popular media, imbalanced discourse on them and the crisis of trust in scientists, fuelled the vicious cycle of the dispute (Chen, 2014).

The decentralization and recentralization of social media, as well as social media's anti-establishment tendency, have facilitated public participation but failed to effectively promote in-depth communication about the underlying scientific issues and the continuous attention required for prudent decision-making, while simultaneously dissolving the elitist authority of science (Jia et al., 2014).

Interpersonal communication has increased the Chinese public's perception of the risks of GMOs, while internet technology not only undermines the effectiveness of science communication in popular media but also becomes a social and technology platform magnifying science risks (Cui and Ma, 2013). One example is the significant overrepresentation of content about the health risks of GMOs in internet videos about them, which substantially undermined the progress framework of science (Wu and Wang, 2017).

The above literature review provides a rough survey of the many factors contributing to the Chinese public's anxiety about GMOs, including irrational, unscientific media reports (Chen, 2014), differences among the scientific community, the media and the public in their understanding of the uncertainty of science (Liu and Qi, 2017), lack of social trust (Zeng and Dai, 2015) and low levels of scientist participation in science popularization (Jin et al., 2018). The existing literature on individual thinking about GMOs showed that scientific uncertainty, if put into the appropriate preventive framework, can play a positive role in reducing misunderstanding (Liu and Qi, 2017), but empirical research on this subject has been very limited.

Therefore, as an exploratory study, we surveyed science communication on mobile internet devices to examine how the Chinese public perceives GMO technology, aiming to not only provide a reference point for the promotion of transgenic technology but also to lay foundations for a new understanding of how science communication builds the relationship between science and the public in the digital age.

Specifically, this study examines how individual members of the public see GMOs in two interrelated dimensions: perception and attitude. Perception is a basic mental process through which a person obtains or employs knowledge. The public perception of GMOs includes how people perceive and understand GMOs and the concepts, judgments and images that appear in people's mind when they process external information about GMOs. People's attitudes towards GMOs encompass their views, opinions and behavioural tendencies based on their perception of GMOs. This involves not only their scientific literacy but also their values and how science communication works in the process. Regarding the GMO dispute, this study attempts to examine the differences between people with a positive attitude towards GMOs ('GMO supporters'), people with a neutral attitude ('GMO neutrals') and people with misgivings about them ('GMO opponents') and the factors that influence their attitudes.

This exploratory research is based on in-depth interviews that we conducted in Shanghai, Xining (Qinghai Province), Jinhua (Zhejiang Province), Nanjing (Jiangsu Province) and Zhanjiang (Guangdong Province) from June to September 2017. Those locations were selected to produce a diverse representation and for convenience. Each interview lasted 50–90 minutes. The interviewees were

acquired through the snowball method, and the interviews were semi-structured. We determined the interview framework and basic questions based on a literature review and focus-group interviews, and interviewers made spontaneous decisions according to their interactions with interviewees.

We collected valid responses from 51 participants (see Table 1), of whom 45% were female and most of whom were fairly young and well educated. GMO supporters (clearly supporting transgenic technology and GM crops and food), GMO neutrals (neither clearly supporting nor expressly opposing and avoiding transgenic technology and GM products) and GMO opponents (expressly opposing, rejecting and avoiding GM crops and food) accounted for approximately 24%, 29% and 47% of respondents, respectively.

Although the sample collected by the snowball method was limited, we still managed to collect fairly rich first-hand material, thereby laying foundations for subsequent research.

3. Imagining GMOs: Research findings on the Chinese public's perceptions of and attitudes toward GMOs

Among the 23 female participants, 15 were GMO opponents and three were supporters; the numbers of male supporters, neutrals and opponents were 9, 10 and 9, respectively. Among the 12 supporters, 10 were under 29 years old, one was between 30 and 50 years old, and one was over 50 years old. The attitudes of respondents with six kinds of academic backgrounds showed certain differences (see Table 2).

3.1 Research finding 1: Perception of GMOs in a motley pool of information

Scholars previously conducted an in-depth investigation into more specific issues under the framework of the risk society theory of Ulrich Beck (2004), reaching the important

Table 1: Summary of semi-structured in-depth interviews

Location	**Shanghai**	**Xining**	**Jinhua**	**Nanjing**	**Zhanjiang**
	27	1	6	7	10
Gender	Female		Male		
	23		28		
Age	10–19	20–29	30–39	40–49	50–59	60–69	Over 70
	1	29	9	8	3	1	0
Educational background	High school	Junior college student or graduate	Bachelor's degree candidate or graduate	Master's degree candidate or graduate	PhD candidate or graduate		
	1	4	16	24	6		
Major[a]	Humanities	Social sciences	Sciences	Engineering	Agricultural science	Medicine	Other
	6	20	1	18	0	5	1
Attitude	GMO supporter		GMO neutral		GMO opponent		
	12		15		24		

a: For bachelor's degree.

Table 2: Profiles of GMO supporters, neutrals, and opponents in the sample

		GMO supporters	GMO neutrals	GMO opponents
Gender	Female	3	5	15
	Male	9	10	9
Age	Below 29	10	8	12
	30–39	1	3	5
	40–49	0	3	5
	Over 50	1	1	2
Major	Humanities	0	1	5
	Social sciences	3	9	8
	Sciences	0	0	1
	Engineering	6	4	8
	Medicine	3	1	1
	Other	0	0	1

conclusion that there is no significant consistency between the actual and perceived risk of an event (Covello and Sandman, 2001). While a technology's actual technical risk is a physical, tangible and measurable risk, people's perception of risk is mentally constructed (Stevens, 2008).

As far as transgenic technology is concerned, although the safety of GMOs is universally recognized in the scientific community from the perspective of technical risk (Jia and Fan, 2015), its perceived risk has long been lodged in people's minds. To investigate the underlying perception of risk, our in-depth interviews started with what the interviewees knew about GMOs and where they acquired such information.

The interviews showed that, overall, GMO supporters had a certain base of scientific knowledge underlying their support for GMOs. When asked, 'What do you think genetic modification is?', most gave confident answers explaining the underlying scientific specifics:

> Genetic modification is a technique for transferring a piece of DNA from one organism to a different organism. For example, scientists, seeing that cobwebs are adhesive, may try to transfer the corresponding DNA from spiders that contributes to the adhesive property to silkworms, so that they will produce silk with this property. If a laboratory experiment is successful, it can be put into application. (E15, Appendix)

When asked the same question ('What do you think genetic modification is?'), most GMO opponents, while trying to summarize its scientific basis, could not come up with coherent answers and tended to make little or unconfident use of scientific terms:

> Genetic modification is something done to organisms or plants against their natural laws of growth with a view to producing relevant products or food. Literally, it is about transforming DNA, about extracting pieces of DNA from things like molecules of organisms and artificially synthesizing them for cultivation. (C7, Appendix)

Some GMO opponents answered the question without reference to any scientific knowledge and directly showed their attitude:

> What is genetic modification? I think it is nothing good. (C3, Appendix)

> Many things that I grew up with have become very different from how I remember them, with different shapes and tastes. I believe such things have been genetically modified. (E4, Appendix)

To investigate what external information influenced interviewees' answers to this question, they were asked, 'From what sources did you acquire your knowledge about genetic modification?' Most GMO supporters derived their knowledge from school education and other specialized information sources they accessed on their own initiative:

> I learned a little about genetic modification in high school and then became better informed through online media reports and popular science works about the technology. (B3, Appendix)

> I recently read the book *A Rational Look at GMOs*, which was published by the Ministry of Agriculture and is a recommended read for the public. (D13, Appendix)

Among the interviewees, GMO opponents derived their information about GMOs from a wide variety of sources, including celebrities, popular media, mobile social networks, and acquaintances:

> I picked up what I know about GMOs from different sources, including a GMO documentary produced by the former TV host Cui Yongyuan, WeChat articles, discussions on the knowledge-sharing site Zhihu, and discussions with my friends. (C1, Appendix)

> I read articles about GMOs in some magazines, and GMOs were often a dinner table topic with family relatives when I was at home. (D2, Appendix)

> The first time I became aware of GMOs was when I was about to eat cherry tomatoes. I was warned by my classmate not to eat them because, according to her, I would risk becoming infertile. (E4, Appendix)

It can be seen from the GMO supporters' responses that scientific knowledge can help narrow the gap between actual risk and perceived risk. However, GMO opponents often lack scientific knowledge, and their responses show that risk perception based on uncritically accepting false information leads to the social amplification of risk (Kasperson et al., 1988).

Just as previous research has shown, risk perception is a process of the public learning and interpreting risks (Renn et al., 1992). With the wide variety of sources of information in the digital age diluting scientific knowledge, coupled with the point-to-point communication structure of mobile internet, it is possible that some communication nodes will gain a disproportionate influence in shaping people's views. A good example of this is the former CCTV host Cui Yongyuan, who is a vocal opponent of GMOs.

Among the 51 interviewees, 40 mentioned Cui and expressed their opinions about him, and the other 11 did not mention him (see Table 3). Obviously, Cui has been a strong influencer. Whether his views are recognized by the public needs to be examined according to specific situations. Yet it can, at least, be seen that few GMO opponents were critical of Cui, and few GMO supporters spoke positively of him.

3.2 Research finding 2: Three dimensions of imagination of GMO risks

As observed in previous studies, minor risks can trigger massive public attention and lead to major social repercussions by way of the social amplification of risk (Kasperson et al., 1988) due to a combination of many factors,

Table 3: Interviewees' opinions on GMO opponent Cui Yongyuan and his views

	Positive on Cui	Neutral	Negative on Cui	Unmentioned
GMO supporters	1	2	5	4
GMO neutrals	2	6	6	1
GMO opponents	7	9	2	6

including lack of specialized knowledge, conflict of interests, and differences in the frameworks and situations of risk information assessment and interpretation (Edelstein, 1988; Sandman, 2003).

On the issue of GMOs, the social amplification of risk mainly results from the public's imagination of risk. Although research on and industrialization of transgenic technology has made progress in diverse fields, most interviewees, including both GMO supporters and opponents, still focus their attention on GM crops and food, and even equate the technology with GM food.

On the safety of GM crops and food, GMO supporters tended to embrace scientific conclusions rationally based on their scientific knowledge:

> I don't think GMOs are dangerous. . . in the final analysis, DNA and proteins have to be dissolved before being digested. (B3, Appendix)

> As long as the transplanted pieces of DNA are not expressed as proteins harmful to the human body, basically, they will do no harm—you will never become what you eat because what you eat will be digested into simpler substances with no harm at all. (D6, Appendix)

GMO opponents generally share a mental image of GM crops and food as dangerous. This image, which is formed on different dimensions and appeals to emotions, plays a role in shaping GMO perceptions and swaying people's attitudes and behaviour towards GMOs.

The first dimension of the imagination of GMO risks is public panic about scientific uncertainty. Genetic scientists are unanimous in believing that public opposition to GMOs stems from ignorance of biology and the impractical demand for absolutely zero risk (Cook et al., 2004). However, scientists and the public differ greatly in their assessment of risk. While scientists describe risks quantitatively and measurably, the public tends to view them qualitatively (McInerney et al., 2004). This kind of imagination was obvious in this study: besides the lack of scientific knowledge, the more direct reason remains public reluctance to accept scientists' inability to guarantee zero risk and 100% safety of GM crops and food:

> As the saying goes, you are what you eat. If I eat GM food, the existing balance built in my body through the eating of natural food might be disrupted, leading to likely consequences like cancer or sudden blindness. (D9, Appendix)

> Scientists now claim that there is no evidence that GM food causes more harm to the human body than non-GM food. This statement actually has many traps. Sophistically, they might argue that non-GM food may also cause diarrhoea or that, in fact, non-GM food is also harmful to the human body, but that the harm is imperceptible after thousands of years of adaptation. The way they argue in defence of GM food is not very compelling. (D1, Appendix)

Although some interviewees had a certain amount of scientific knowledge and accepted scientists' statements that no GM food safety incidents have occurred since the commercialization of GM crops, they still expressed worry about the uncertainty of science itself:

> We don't have a complete picture of the implications of genetic modification and whether GM food would harm the human body with, say, increased carcinogenicity. (C1, Appendix)

Meanwhile, scientists just saying that GM crops and food do not have short-term risks is not enough for the public, who are also concerned about the long-term impact of those crops and food:

> I fear that the impact might be long term rather than immediate and that it might become apparent only after several years or even decades. . . Due to this factor, there may be a long chain extending across generations. I fear that eating GM food could have an impact on the next generation, even if it does not affect me. (E14, Appendix)

The second dimension of GMO opponents' risk image relates to food safety. They are evidently not concerned about GM crops such as cotton, which are not used for food. Their imagined risk of GMOs, together with the resulting panic, mainly arises from their concern about GM food's impact on health:

> Unlike things such as computers and mobile networks, GM food has a direct bearing on health. (E8, Appendix)

> There are things that, if eaten, could have an irreversible effect on your body. Eating is unlike wearing clothes or using utensils. If bad elements are absorbed by your body, it may be too late to regret eating them. (B8, Appendix)

Another layer of worry about GMOs relates to the shadow left by previous food safety incidents and distrust of the food safety regulator. With reference to previous research on how information processes, social groups' behaviour, individual reactions, and social trust combine to shape the social experience of risks (Renn et al., 1992), public distrust in food safety spreads to GMOs and is further fuelled by distrust of the establishment (Jia and Fan, 2015).

> There have been too many incidents that we should draw lessons from. . . Food safety is a big problem. Even though the government [the Ministry of Agriculture] has approved these [GM] crops, this is no guarantee that you can eat them worry-free. (E11, Appendix)

> Even vaccines can be tampered with, to say nothing of seeds. To maximize profit, those folks can do the same things, if not worse, to GMOs. (E10, Appendix)

The third dimension of GMO opponents' imagination of GMO risks involves so-called conspiracy theories. Very few GMO opponents express this kind of imagination, which implies their worry about the confrontation between the West and China:

> Some people see GMOs as a tool used by Western countries to entrap China. It is not entirely without foundation. If they cannot topple you economically, they could try other methods. Don't you think so? (B2, Appendix)

This kind of imagination also implies misgivings about corporatism:

> GM crops, with their many direct or indirect producers and related enterprises, are certainly a huge industry, and I think they wield huge influence as well. (D2, Appendix)

3.3 Research finding 3: The trust mechanism of GMO perception in digital mobile scenarios

With reference to Luhmann's (1979) classification of trust, this study attempted to examine the roles played by institutional trust and interpersonal trust in shaping perceptions of GMOs by examining interviewees' descriptions of their activities in science communication. Institutional trust refers mainly to trust in public institutions, including government agencies overseeing technologies with potential risks, as well as research institutions, scientific community, and enterprises developing those technologies (Marris, 2001).

We found that, in the point-to-point communication scenarios enabled by mobile internet, it is difficult to establish public trust in the government, the scientific community, institutional media and the popular science community on the specific issue of GMOs. Moreover, negative sentiments towards GMOs are further magnified by the rapid spread of rumours. For example, GMO opponents overall think that institutional media and relevant government watchdogs have failed to provide authoritative information:

> Our state media, like CCTV-1, haven't told us clearly what GMOs are. (B8, Appendix)

> No national authority, such as the food administration, has ever issued an official statement on this thing. (B2, Appendix)

The scientific community, given its vested interests, is not seen as entirely trustworthy, either:

> I used to place a lot of trust and faith in scientists and academics, believing that they know things best and are the most socially responsible. But I have changed my mind and found that they are no different from those money-obsessed celebrities. (D10, Appendix)

Some internet rumours also aggravated public distrust:

> A notice issued by a kindergarten affiliated with the Ministry of Agriculture was circulated on the internet, claiming that GM food was prohibited for children. (C4, Appendix)

In contrast to the difficulty of developing institutional trust, it is much easier for GMO opponents to develop or demonstrate interpersonal trust on social platforms with point-to-point communication, which has become an important factor in influencing their perception of GMOs:

> From time to time, I would receive articles about GMOs forwarded by my family members or friends, like '100 GM foods', which I certainly take as being well-intended advice on health. (B6, Appendix)

> I was in China, and my mother was overseas. One day she sent a link to me, and I was instantly convinced by the linked article. (E1, Appendix)

> My former classmates are well educated and well informed, and even they spoke with fear about GMOs. (E4, Appendix)

4. Discussion and conclusions

Scientific knowledge and literacy are undoubtedly important factors influencing the perception of and attitudes towards GMOs. However, there is also the public's imagination of GMO risks, due to their distrust of emerging biotechnology, which significantly shapes their emotional framework in perceiving and understanding what GMOs are. This encompasses three dimensions: panic about scientific uncertainty, worry about food safety, and (to a small degree) conspiracy theories. When people are mentally processing various pieces of information, their imagination of GMO risks strengthens their negative judgments of GMOs, and thus some individuals become GMO opponents.

The trust mechanism is a useful regulatory function of the mental processes that shape perceptions and attitudes; however, trust in government, institutional media, the scientific community and the popular science community has been dissolved by a combination of factors, including the wide variety of information sources, experience of previous public health and food safety incidents, vested commercial interests, and the declining reputation of professionals.

We found that good institutional media platforms such as *Caixin Weekly* and *Sanlian Lifeweek Magazine* have published high-quality reports on GMOs, and there are also online platforms such as Guokr.com and its column 'Rumour Crusher' that have debunked and clarified many rumours about GMOs. However, those examples of high-quality scientific content are just a drop in the ocean of online information, with its myriad point-to-point communications.

Moreover, with connected presence strengthened by digital mobile technologies (Licoppe, 2004), interpersonal trust is another important factor influencing perceptions of and attitudes towards GMOs in science communication. Digital mobile platforms such as WeChat, which enable networks of close relationships among family members and friends, and interactions based on knowledge background and personal attitudes, have significantly shaped individuals' cognitive framework for understanding transgenic technology. Moreover, influential personalities such as Cui Yongyuan, who are both traditional and internet influencers, also play an important role in the interpersonal trust mechanism.

How to express and face scientific uncertainty is an important subject in understanding the relationship between the scientific

community and the public, advancing science communication, promoting social participation, and improving the public's quality of life. The complexity and sensitivity of the GMO issue have increased the difficulty of research. Moreover, the imagination of the risks of emerging science and technology, institutional trust and personal trust are all very complicated 'umbrella' concepts. Therefore, this exploratory study can provide only a limited empirical explanation of the subject matter. The concepts used in the study and their significance for science communication in mobile digital scenarios deserve further examination under a more operational and rigorous framework of empirical research. Due to space constraints, this study did not examine discussions with GMO neutrals. This unfinished work will be investigated in subsequent research.

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Appendix:

Personal information of interviewees in this study

No.	Gender	Age	Education	Major	Attitude to GMOs
B2	Male	67	Bachelor's	Economic management	GMO opponent
B3	Male	22	Bachelor's	Materials science and engineering	GMO supporter
B6	Female	46	Bachelor's	Fine art	GMO opponent
B8	Female	45	High school	–	GMO opponent
C1	Male	24	Master's candidate	Information science	GMO opponent
C3	Female	39	Associate degree	Engineering science	GMO opponent
C4	Female	44	Master's	Economics	GMO opponent
C7	Male	46	Master's	History	GMO opponent
D1	Female	25	Master's candidate	Philosophy of science and technology	GMO opponent
D2	Male	23	Master's candidate	Philosophy of science and technology	GMO opponent
D6	Female	23	Master's candidate	Engineering, information science	GMO supporter
D9	Female	27	Bachelor's	Journalism	GMO opponent
D10	Male	25	Bachelor's	Chinese language and culture	GMO opponent
D13	Male	23	Master's candidate	Life science, education	GMO supporter
E1	Female	33	PhD	Mathematics, economics	GMO opponent
E4	Female	41	Bachelor's	Environmental protection	GMO opponent
E8	Female	27	Master's	Transportation	GMO opponent
E10	Female	35	Bachelor's	Accounting	GMO opponent
E11	Female	30	Master's	Editing and publishing	GMO opponent
E14	Female	25	Master's	Environmental engineering	GMO opponent
E15	Male	19	Bachelor's candidate	Clinical medicine	GMO supporter

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One issue, different stories: The construction of GMO issues on Chinese, American and British mainstream media portals

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Abstract

Biotechnology, as an emerging technology, has drawn much attention from the public and elicited hot debates in countries around the world and among various stakeholders. Due to the public's limited access to front-line scientific information and scientists, as well as the difficulty of processing complex scientific knowledge, the media have become one of the most important channels for the public to get news about scientific issues such as genetically modified organisms (GMOs). According to framing theory, how the media portray GMO issues may influence audiences' perceptions of those issues. Moreover, different countries and societies have various GMO regulations, policies and public opinion, which also affect the way media cover GMO issues. Thus, it is necessary to investigate how GMO issues are covered in different media outlets across different countries. We conducted a comparative content analysis of media coverage of GMO issues in China, the US and the UK. One mainstream news portal in each of the three countries was chosen (*People's Daily* for China, *The New York Times* for the US, and *The Guardian* for the UK). We collected coverage over eight years, from 2008 to 2015, which yielded 749 pieces of news in total. We examined the sentiments expressed and the generic frames used in coverage of GMO issues. We found that the factual, human interest, conflict and regulation frames were the most common frames used on the three portals, while the sentiments expressed under those frames varied across the media outlets, indicating differences in the state of GMO development, promotion and regulation among the three countries.

Key words

GMO, genetic engineering, framing analysis, media outlets, risk communication

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1. Introduction

In the late 20th century, the world became fascinated by the promise that biotechnology held for dealing with medical, environmental and agricultural challenges (Cao, 2018). Those technological advances have been applied to various scenarios, such as disease diagnosis and immunization in medical treatment and healthcare and the cultivation of crops with specific traits such as resistance to pests or tolerance of herbicides in agriculture. However, unlike applications in the biomedical field, which are seen as less controversial, the application of agricultural biotechnology (agritech), especially genetically modified organisms (GMOs), has always been met with public doubt and strong opposition because of its 'unnaturalness' and possible consequences for people's health and the environment (Cao, 2018).

Concern over GMOs has not been limited to certain countries but has swept across the globe, thus deepening the public's fear about modern science and technology. Understanding modern sciences and technologies, such as biotechnology, nanotechnology and climatology, has become an increasingly complex task, as these disciplines have both high levels of uncertainty and risk and the potential to benefit society greatly. These characteristics of modern science and technology make it harder for laypeople to comprehend (Yeo and Brossard, 2017). Moreover, these technologies have become integrated into daily life in a highly sophisticated and unprecedented manner (Yeo and Brossard, 2017); it is therefore important that discussions of these issues take account of their social, ethical and cultural aspects, rather than only the scientific ones. In the case of GMOs, for example, although for the mainstream academic community there is no difference between consuming genetically modified (GM) crops and those cultivated more traditionally, there is a great deal of public concern about the safety of GM crops and their possible adverse impact on health (Lull and Scheufele, 2017).

However, the public rarely has direct access to GMO-related studies or scientists in this discipline (Scheufele, 2007); besides, without relevant professional training, it is almost impossible to process such sophisticated scientific information. Thus, the media, especially the legacy media, play an essential role in the transmission and interpretation of GMO-related knowledge and information (Listerman, 2010; McCluskey et al., 2016), affecting the public's opinions and attitudes towards GMOs (Clark and Illman, 2006) as well as the policymaking process concerning biotechnology (Lundy and Irani, 2004; Maeseele and Schuurman, 2008; Pollock et al., 2017). Media may influence people's understanding and perception of scientific issues through agenda setting and framing (Lundy and Irani, 2004; Meraz, 2009). When delivering scientific messages, news media tend to select issues to cover and make certain aspects of an issue salient and then emphasize the importance and value of the selected aspects over others, thus providing the public with a lens through which to look at and consider the issue (Entman, 1991; McCombs and Shaw, 1993; Nisbet and Scheufele, 2009; Scheufele, 2000). Even in the face of the impact of social media, mainstream media have retained their agenda-setting influence, which operates through both print and online channels (Ceron et al., 2016; Harder et al., 2017).

Several factors affect the way that GMO issues are covered, such as the news system, GMO policy, economic and agricultural development, the overall scientific atmosphere, and values in various regions and countries (Nisbet and Lewenstein, 2002; Pollock et al., 2017). For example, during the period examined in this study, China was actively carrying out research and development (R&D) work, while the commercialization process was slow, as experts in China were watching for any change in attitudes towards GMOs in

other countries (Williams, 2003). Meanwhile, in the US, GM crops and foods were not regarded as different from their non-GM equivalents; there is thus no law or institution established in the country specifically for the regulation of GM products (Cao, 2018). The UK follows the regulatory framework of the European Union, which requires applications for permission to use GM products to be decided on a case-by-case basis (European Commission, 2000). These factors may further influence the choice of frames through which information about GMOs is presented and the sentiments conveyed under those frames in different social contexts.

Hence, our study sought to understand the differences in news framing—and the differences in the sentiments expressed behind the various news frames—of GMO issues among mainstream news portals in China, the US and the UK. This study should serve as a useful tool to understand how GMO issues were constructed in different societies and to observe public attitudes towards them, allowing us a glimpse of the interwoven conditions among scientific innovations, political and economic considerations, and public opinion. The three countries were chosen mainly due to differences in their GMO policies and GMO-related R&D. Moreover, public opinion towards GMO issues also varies among the three countries.

2. Literature review

This section considers GMO issues, risk communication and framing theory.

2.1 GMO issues and risk communication

Agricultural biotechnology is an emerging technology: its R&D is still in progress, and the further commercialization of its products is still under heated discussion among the various stakeholders in society (Pidgeon et al., 2017). Despite overwhelming academic consensus on the safety of GM crops and foods, the public expresses its concerns about consuming such products out of consideration of issues such as their potentially harmful impact on health and the environment and the violation of the laws of nature and ethics. This reflects Akin and Scheufele's (2017) view that the public does not perceive scientific issues from a purely scientific perspective; instead, social, cultural and ethical dimensions are all included in people's assessments of these emerging technologies. This may also reveal the complexity of communicating modern science to the public, as these topics have become deeply embedded in society and can strongly affect people's lives.

One of the critical factors that make communicating GMO issues challenging is that modern science has developed so rapidly that laypeople cannot process or understand it (Jamieson et al., 2017). Under these circumstances, scandals relating to food safety and biotechnology that have taken place in different countries may make people's impressions of biotechnology and genetic modification even worse. For example, in 2002, the international non-governmental organization Greenpeace revealed that several food products, including baby formula, that contained GM ingredients were being sold in Chinese supermarkets without the public being aware of those ingredients (Cao, 2018). Since then, Chinese consumers' demand for GMO labelling and insistence on people's 'right to know' has begun. Several subsequent food safety scandals, such as those involving melamine-contaminated baby formula and clenbuterol-contaminated meat, have further heightened public concern over and opposition to GM foods and weakened public trust in the government (Cao, 2018).

In the US and the UK, the findings of several published studies have sparked heated public debates about the possible adverse impacts of GM crops and foods on animals or the environment. For example, a study

conducted by researchers at Cornell University, stating that Bt corn pollen might harm monarch caterpillars, was published in *Nature* in 1999 (as cited in Cao, 2018). This elicited the public's worry about GM crops' detrimental effects on the environment. In 1998, Árpád Pusztai of the Rowett Institute in the UK declared that eating GM potatoes was related to the thickening of stomach mucosa and suppression of the immune system in rats, and that finding was published in the medical journal *The Lancet* in 1999 (as cited in Cao, 2018). These concerns are manifestations of what Beck (1992) called the 'risk society', in which the risks that arise from modern technologies go far beyond the comprehension or perception of human beings.

In this situation, in which most members of the public cannot learn about scientific progress directly from scientists, the media play a vital role in building a channel between scientific advancements and the public (Jamieson et al., 2017; Schäfer, 2012), as well as in the construction of risks and uncertainty. Consequently, the public's perception of GMOs—both their benefits and their risks—is primarily based on messages provided by the media.

2.2 Biotechnology coverage and framing theory

How the news media influence the public's attitudes, opinions and choices has always been one of the concerns of political science and communications. McCombs and Shaw (1972) found that, although coverage in newspapers cannot determine how people think about different issues, it can affect what people think. In the case of scientific issues such as biotechnology, nuclear technology, nanotechnology and climate change, which the public has little direct access to or cognitive experience of, people rely heavily on news media (McCluskey et al., 2016; Scheufele, 2007). The public's reliance on media for information about biotechnology, in particular, has been shown by several studies (Marks et al., 2003; Marks et al., 2007; Priest, 1994). Therefore, the influence of the media's agenda setting and framing on the public's attitudes to scientific issues, particularly biotechnology issues, is evident (Meraz, 2009). In other words, the public's ideas about and attitudes towards emerging technologies such as biotechnology can be seen as a reflection of how those issues are covered in the media (Marks et al., 2007).

Notably, media agencies also influence one another's agenda setting in a phenomenon called 'intermedia agenda setting' (Heim, 2013; McCombs, 2004). It has been argued that legacy media or traditional mainstream media influence less elite traditional media outlets (Lim, 2006; Meraz, 2009). However, given the rise of newer forms of media and of more channels for the public to use to access information, the number of agenda-setters will also increase, which may contribute to weakening the influence of the traditional media's agenda setting (Ceron et al., 2016; Sayre et al., 2010). Nevertheless, several studies have shown that, even in the context of the internet, the public still turns to traditional media sites such as *The New York Times* for information (McCombs, 2005) and that legacy media still influence the agendas and coverage of other media outlets, including social media (Ceron et al., 2016; Sayre et al., 2010). Thus, taking this situation and the accessibility of research materials into account, we chose as our subjects one elite traditional media website in each of China, the US and the UK. Each website can be regarded as an agenda-setter on the national level.

Agenda-setting theory has different levels of application, such as issue agenda-setting and attribute agenda-setting (McCombs and Ghanem, 2001; Meraz, 2009). The former is concerned with the media's role in choosing specific topics or issues to transmit to the

public, while the latter focuses on highlighting certain features and aspects of a topic for the public (Boydstun et al., 2013)—an idea that overlaps with framing theory. Some communications scholars equate framing with attribute agenda-setting, as both work to make the selected attributes of an issue salient (Boydstun et al., 2013; Park et al., 2012; Scheufele, 2000). Although some voices disagree that framing is identical to attribute agenda-setting (Song, 2007), this is not the focus of the current study, which follows the former vein.

Entman (1991) describes framing as a process of selecting and presenting specific aspects of an issue or event and further illustrating and interpreting those aspects, such as highlighting specific considerations regarding an issue over others. Frames are the angles for media to interpret an issue, as well as the lens through which the public can understand it (Nisbet and Scheufele, 2009). Using frames can simplify complex issues to a certain extent and can also provide a common ground for dialogue between scientists and the public on scientific issues (Nisbet and Scheufele, 2009). Concerning science communication, in which the news media are an essential source from which the public obtains information, the frames used may play an important role, as they are very likely to affect public opinion on the issue.

Moreover, framing theory argues that news frames reflect the cognitive and discursive norms agreed on and followed by individuals and organizations in a given society and historical period, which are influenced by factors such as the nature of news organizations, the process of newsmaking, the ideologies of journalists and the characteristics of information providers (Pan and Kosicki, 1993). Thus, the use of frames may change across time and space and be sensitive to related events and policies. For example, in a study of biotechnology coverage in three regions/countries between 1992 and 1996 and between 1997 and 1999, researchers found that the medical frame was the most salient in US coverage, while food and related frames were prominent in the European elite press (Bauer et al., 1996). In addition, Botelho and Kurtz (2008) revealed that major GMO-related events also influenced the use of frames in biotechnology coverage.

Given that news coverage emphasizes certain aspects of GMO issues over others by using frames, different sentiments may follow. For example, when focusing on the potential hazards of GMOs, the sentiment of the coverage is likely to be negative, whereas the sentiment is likely to be positive when GMOs' economic benefits are salient in the coverage (Marks et al., 2007). Moreover, the sentiment expressed in news coverage affects public attitudes to the issues. For example, Nisbet and Lewenstein (2001) found that when biotechnology coverage became negative, the public's attitudes towards biotechnology would, in turn, become negative.

As the R&D status of GMOs in China, the US and the UK is different, one would expect differences in their GMO regulations and in public opinion towards GMO-related issues. The consequential differences in the coverage of GMO issues in the three countries are worth investigating.

In an earlier study of GMO coverage in China, Li (2007) showed that the primary frames used were progress and economic prospects and that, as the international debate on the safety of GMO technologies became increasingly heated, the *People's Daily* started to emphasize legal regulation. Regarding the US news media, Nisbet and Lewenstein (2002) analysed reports on biotechnology in *The New York Times* and *Newsweek* between 1970 and 1999 and found that scientific progress and economic prospects were the main frames employed. In the UK, Clayton et al. (1993) found no significant difference in topic selection in the coverage of sci-tech issues between *The Times* and *The Guardian*; however, the latter focused more on the negative impacts of science and technology.

Overall, very few studies have compared GMO coverage in these three countries; the current study is intended to fill that research gap.

In the studies mentioned above, and using De Vreese's (2005) typology, it was apparent that the media tended to use both generic frames and issue-specific frames when reporting on biotechnology issues. Issue-specific frames, such as scientific progress, economic prospects, ethics, Pandora's Box, runaway, nature/nurture, public accountability and globalization (Bonfadelli, 2017; Eyck and Williment, 2003; Nisbet and Lewenstein, 2002; Schäfer, 2009), are used in covering specific issues, such as healthcare and biotechnology (De Vreese and Lecheler, 2012). Although it is indeed a strength to use issue-specific frames in the coverage of particular issues, as they can deepen the discussion and provide readers with more detail about the issue, it can sometimes become a disadvantage in situations in which, for example, people want to make comparisons of different themes across time in various cultures (Lecheler and De Vreese, 2019; Semetko and Valkenburg, 2000), and that is when generic frames have the advantage.

As our study sought to compare the coverage of GMO issues in three countries, we used generic frames for our analysis. There are seven commonly identified generic frames: factual, conflict, human interest, responsibility attribution, morality, economic consequences and leadership (De Vreese et al., 2001; Zillmann et al., 2004). However, unlike sudden events that require clarity about the responsible parties, the coverage of GMO issues places more emphasis on the responsibility for regulation. Thus, in this study, the responsibility attribution frame was changed to the regulation frame.

Based on the factors discussed above, we aimed to identify the differences in GMO coverage, particularly in the use of frames, among three legacy news media portals in China, the US and the UK. We also intended to explore various sentiments expressed by those media outlets under different frames when reporting on GMO-related issues. To examine the differences in the use of news frames and in the sentiments behind the various frames, the following research questions were put forward:

RQ1: What are the most prominent frames for GMO coverage in mainstream media portals in China, the US and the UK?

RQ2: What are the differences in the framing of GMO issues among mainstream media portals in the three countries?

RQ3: What are the most prominent sentiments expressed in GMO coverage under different frames by mainstream media portals in the three countries?

RQ4: What are the differences in the association of particular sentiments with particular frames for GMO coverage among mainstream media portals in the three countries?

3. Methods

This section describes our approach to sampling and measurement, including our coding scheme.

3.1 Sampling

We chose as subjects for this study articles that covered GMO issues on the websites of the *People's Daily* (*People.cn*, http://people.cn), *The New York Times* (https://www.nytimes.com) and *The Guardian* (https://www.theguardian.com) between 2008 and 2015. Because China launched a major project to cultivate new varieties of GMOs in 2008, which received considerable attention and thus contributed to the increasing coverage of GMO issues (Cao, 2018), that year was selected as the start of the study period.

We sought Chinese news articles covering GMO issues using the combination of keywords '转基因' (genetically modified) and '人民网' (*People's Daily* website: *People.cn*), yielding 317 articles from 1 January 2008 to 31 December 2015. We searched *The New York Times* using the keywords 'genetically modified', 'genetically engineered' and 'GMO' to collect articles. As an additional consideration, only those articles that mentioned GMO-related keywords three or more times were chosen, ultimately yielding 144 articles from *The New York Times* website. For *The Guardian*, we gathered articles directly from the integrated GMO-themed webpage on the publication's website, yielding 288 articles. In total, 749 eligible articles (in Chinese and English) were collected. Table 1 shows the number of articles covering GMOs across the three countries.

3.2 Measurement

Content analysis was used to analyse all news articles selected (n = 749), and the individual article was the unit of analysis.

3.2.1 Coding scheme

For basic information about the news, we coded the sentiment of the coverage. As for the frames, we took a deductive approach (Graham and Wright, 2015). Since one of the study's aims was to use generic frames instead of issue-specific frames to analyse the coverage of GMO issues, the generic frames used in previous studies were adopted (De Vreese et al., 2001; Zillmann et al., 2004), with a slight change to convert the responsibility attribution frame into the regulation frame, so the final frame list comprised factual, conflict, human interest, regulation, morality, economic consequences and leadership (see Table 2). It should be noted that the codes for sentiment and generic frames were mutually exclusive; that is, only one frame and one indicator of sentiment were coded for each article.

3.2.2 Reliability

To ensure confidence in the coding scheme, we conducted an inter-coder reliability test.

Table 1: Number of GMO-related articles on three mainstream media websites

	People.cn	***The New York Times***	***The Guardian***	**Total**
2008	11	9	40	60
2009	10	11	20	41
2010	34	26	33	93
2011	8	5	21	34
2012	20	12	32	64
2013	119	34	61	214
2014	84	14	41	139
2015	31	33	40	104
Total	**317**	**144**	**288**	**749**

Table 2: Coding scheme

Variables	**Codes**
Sentiment	1= positive; 2= negative; 3= both positive and negative; 4= no sentiment expressed
Generic frames	1= factual; 2= human interest; 3= conflict; 4= regulation; 5= morality; 6= economic consequences; 7= leadership

Table 3: Inter-coder reliability (n = 749)

	Cronbach's alpha
Sentiment	0.819
Generic frames	0.889
Mean	0.854

The coder in the current study invited another coder to code 60 randomly selected articles together but independently (20 from *the People's Daily*, 20 from *The New York Times* and 20 from *The Guardian*). The reliability of the coding scheme was relatively high, with an average Cronbach's alpha of 0.854 on inter-coder agreement. One researcher, who had participated in the inter-coder reliability test, then coded the 749 articles independently.

4. Results

In this section, we present the results of our analysis of framing and the relative weights of frames and sentiments.

4.1 Preliminary analysis: Volume of GMO coverage

Before analysing the frames used in coverage, this section first examines descriptive statistics about the articles analysed and briefly describes some findings and trends. Figure 1 depicts the changes in the number of articles covering GMO controversies on the three websites over time.

Figure 1 reveals very similar trends in the number of articles covering GMO controversies on the three websites. For example, from 2009 to 2010 and from 2011 to 2013 all three websites showed an upward trend, while from 2010 to 2011 and from 2013 to 2014 they all showed a declining trend. Put alternatively, over the eight years examined, there were five years during which the trend in the number of articles covering GMO issues was similar across the three websites. There is obviously an association between the occurrence of newsworthy GMO-related events and trends in coverage: for example, in 2010, the controversy about GM salmon and changes to policies on

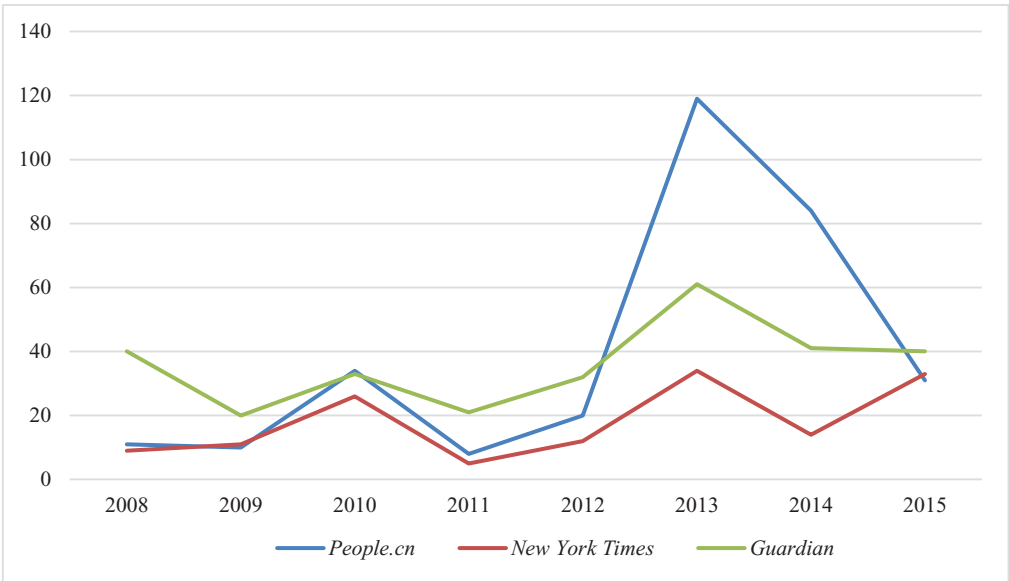

Figure 1: Number of articles covering GMO controversies on the websites, 2008 to 2015

GMOs in the UK and the European Union were issues that drew attention from all three websites, indicating that events in other countries may have a strong agenda-setting function for domestic reports. It can thus be argued that the GMO issue is international.

When the situation in each country is examined closely, it becomes evident that changes in the number of articles covering GMOs may be related to GMO incidents that occurred at that time. In China, the 'golden rice' controversy in 2012 was a significant turning point in the GMO discourse, after which the GMO agenda entered the *People's Daily*, marked by the first wave in its trend line. In 2013, China approved the importation of three types of GM soybean from Monsanto and BASF (Cao, 2018) along with other GM crops, which raised concerns about the examination and approval system and the safety of GMOs in China. Subsequently, in 2014, a year of several GMO-related scandals and topical events, the *People's Daily* carried 84 reports on GMO issues. For example, in 2014, a GM rice that was still at the experimental stage was found to have been released into the environment illegally in Hainan (Cao, 2018) and illegal planting of GM rice was discovered in Hunan.

The amount of coverage in *The New York Times* was limited and fluctuating. It peaked in 2010, 2013 and 2015. In 2010, reports focused on events such as the approval of GM beets and alfalfa (lucerne) in the US, the assessment of the safety of GM salmon as food, and Europe's loosening policy on GMOs (Kanter, 2010; Pollack, 2010a, 2010b). From 2012 to 2013, two major GMO events drew the media's attention. First, several US states voted on whether to label GMOs (Harmon and Pollack, 2012). Second, GM wheat was found among farmers' crops in Oregon (Wines, 2013). When GM salmon was approved for commercial production in 2015, the media's attention to GM animals peaked (Pollack, 2015).

Overall, of the three mainstream media websites, *The Guardian* had the most stable coverage of GMOs, with peaks in 2008, 2010 and 2013. In 2008, Prince Charles made negative comments on genetic modification (Collier, 2008). In 2010, two critical incidents may have contributed to an increase in the amount of coverage: the UK was pressing the European Union to let in more GM products (Lucas, 2010), while the GM salmon experiment was ongoing in the US (Doward, 2010; Kennedy, 2010). In 2012, the destruction of GM fields in the UK gave rise to critical public discussion of anti-GMO activists (Atkinson, 2012). In 2013, the UK's new environment minister, Owen Paterson, who supported GMOs, eased the restrictions on GMOs in the UK (Vidal, 2013a, 2013b).

4.2 Framing analysis

By examining the frames adopted in news coverage, it is possible to learn how the media choose certain aspects of GMO issues to articulate and present to the public. Therefore, the ideas that the media have tried to convey can be deduced via the salient attributes of GMO issues highlighted by media frames. Using generic frames modified explicitly for this study, we sought to determine how the focal mainstream media websites presented GMO issues and changes in the frames used from 2008 to 2015. Figures 2, 3 and 4 show the frames that appeared on the three websites.

4.2.1 Frames used on the People's Daily website

As shown in Figure 2, the *People's Daily* website generally gave priority to the factual frame. A total of 132 articles used that frame to cover GMO issues (accounting for 41.64% of all coverage collected from the website), followed by the regulation (22.40%) and human interest (14.83%) frames. The website's

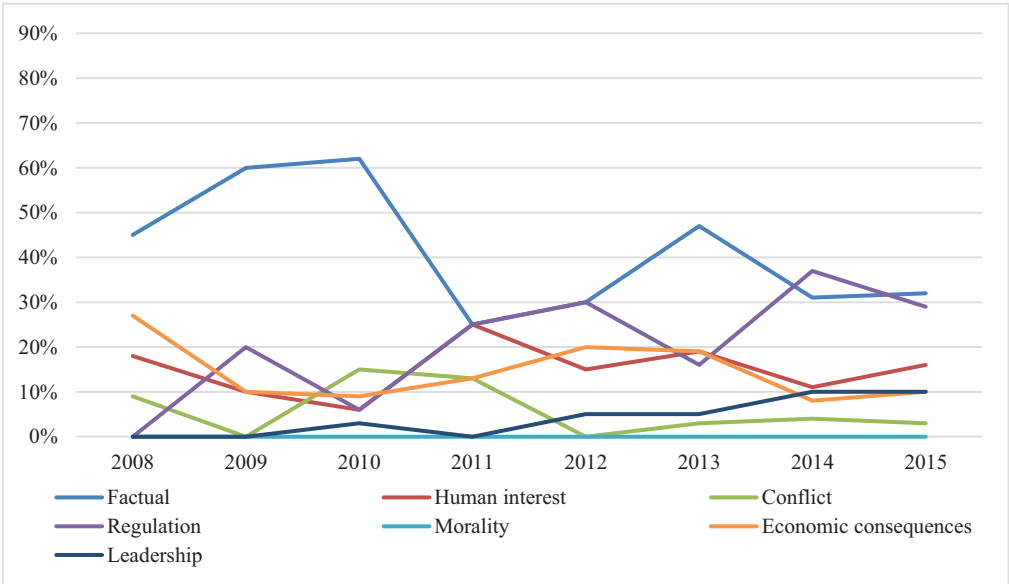

Figure 2: Occurrence of frames on the *People's Daily* website, 2008 to 2015 (%)

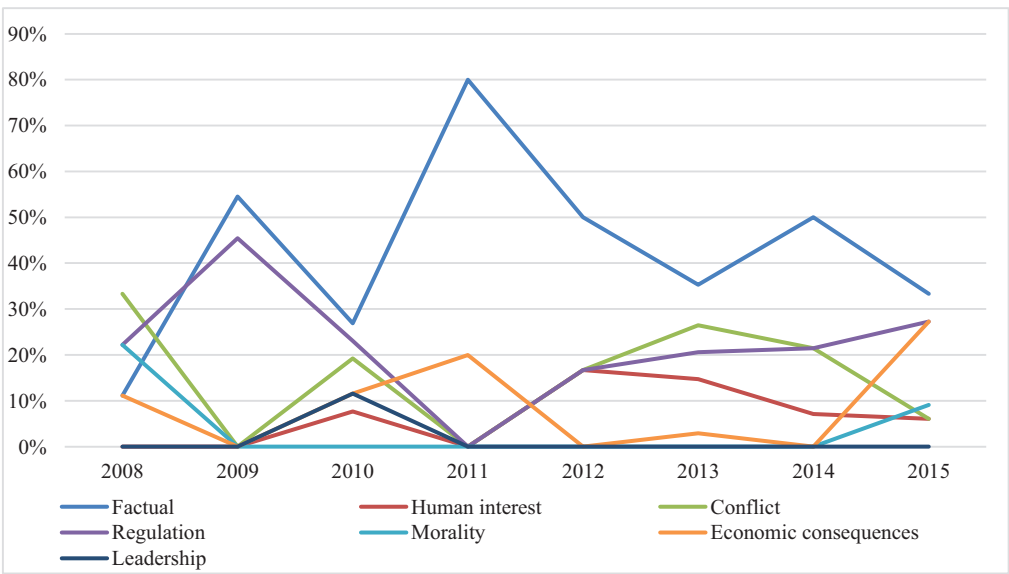

Figure 3: Occurrence of frames on *The New York Times* website, 2008 to 2015 (%)

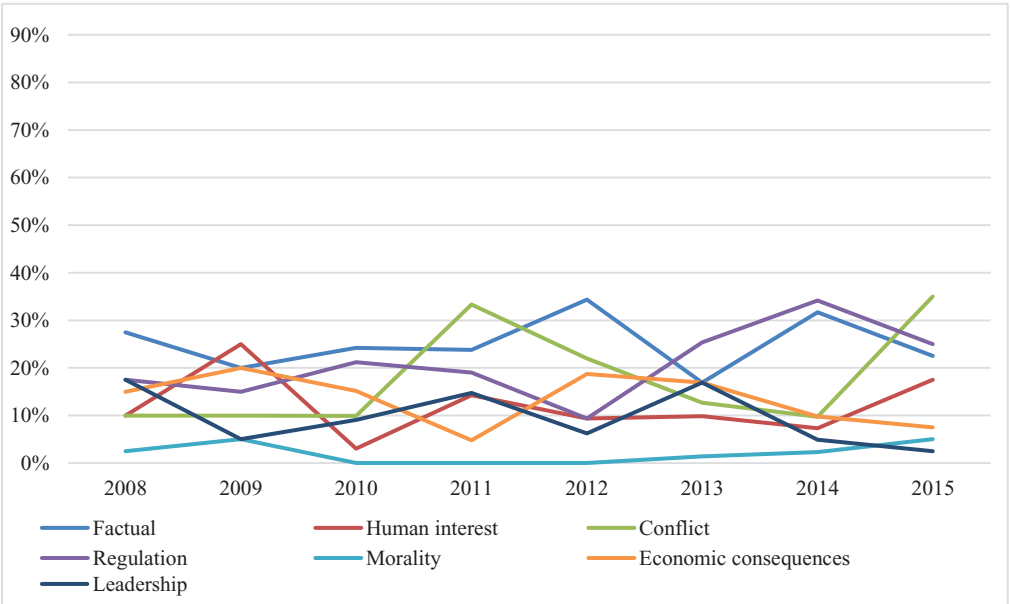

Figure 4: Occurrence of frames on *The Guardian* website, 2008 to 2015 (%)

emphasis on the factual frame may reflect the newspaper's belief that GMO was not a clear concept for the public; rather, it was an unfamiliar concept and it was very challenging, if not impossible, for ordinary people to understand. Therefore, the *People's Daily* paid more attention to the facts related to GMOs, perhaps indicating that it sees itself as a provider of essential information.

In 2010, the Chinese Government proposed to accelerate the commercialization of GMOs (Cao, 2018: 67), indicating that its emphasis had changed from research into GMOs to practical applications. In effect, GMOs are no longer just scientific issues, but have entered the public domain. The policy change has affected the use of frames in the *People's Daily*'s coverage of GMO issues. Since then, the overall proportion of the factual frame used has declined slightly, and the use of the regulation and human interest frames has increased.

The regulation frame focuses on the management and regulation of GMO technologies in China; hence, emphasizing the regulation frame indicates that the *People's Daily* had moved the framing of risk from science and technology *per se* to related regulatory aspects. This shift echoed a change in the Chinese public's imagination of risk following various food safety scandals in China, which gave rise to a negative impression of food safety regulation that, in turn, spilled over into GMO issues. The human interest frame used anecdotes from ordinary people to convey attitudes to GMOs. The stories were based mainly on GMO scholars and government officials (Lin, 2013).

Human interest is a frame that contains sentiment. Resorting to feelings and emotions, in most cases, is more likely to impress readers. The *People's Daily* might use that frame as a way to persuade the public or change people's attitudes to GMOs.

4.2.2 Frames used on The New York Times website

As shown in Figure 3, coverage of GMO issues on *The New York Times* website was

also dominated by the factual frame, although its proportion of 37.50% was slightly lower than on the *People's Daily* website. The regulation and conflict frames were in second and third places, accounting for 23.61% and 16.6%, respectively. The proportion of the regulation frame used in GMO coverage on *The New York Times* website increased after 2012, when a referendum on GM food labelling was held in California. Since then, debates about GMO labelling have appeared frequently on the website. While presenting opinions from different sides, *The New York Times* emphasized the public's 'right to know' and assumed the role of the public's spokesperson. By 2015, the proportion of the regulation frame used on the website had increased to 27.27%. This trend partially reflected the fact that *The New York Times* had been following GMO regulatory issues, such as the policy debate over GMO labelling.[1]

However, in contrast to previous studies (such as Nisbet and Lewenstein, 2002), the data in our study did not reflect the tendentious use of the economic consequences frame in *The New York Times*' coverage of GMO issues, which accounted for less than 10% of overall coverage. One possible explanation may be that there is usually more than one frame present in an article, and the economic consequences frame might not necessarily be the most prominent; thus, it could have been replaced by other frames during the coding process. The same situation may exist in the construction of the conflict frame. Even though multiple, even conflicting, sentiments were presented in an article, those conflicts were based on regulation topics, such as GMO labelling. Thus, the regulation frame took the place of the conflict frame. During the period examined in this study, coverage in *The New York Times* highlighted the regulation frame, which may be associated with the events that were taking place at that time. In other words, the construction of frames in news coverage is influenced by related events.

4.2.3 Frames used on The Guardian website

As shown in Figure 4, coverage on *The Guardian* website was dominated by the factual (25.35%) and regulation (20.83%) frames. The conflict frame came next, at 19.44%. In 2013, the regulation frame began to appear at about the time of discussions about the 'right to know' about GMOs in the UK and the US. However, because the UK adopted a clear policy that GM foods had to be labelled, the situation in the UK was quite different from that in the US. In this scenario, *The Guardian*'s coverage might have been influenced by the agenda of the media in other countries. The conflict frame was used mainly in discussing whether the UK needed to accept GMOs and whether GMOs could bring benefits.

It is noticeable that the leadership frame was particularly prominent in 2008 (Percival, 2008), when the British Government believed that the UK ought to adopt a different perspective on GMOs. Such remarks recurred over the following years (Carrington, 2014; Quinn, 2012; Stirling, 2013). It could be said that the British Government's attitude to GMOs was generally positive. However, the use of the leadership frame on *The Guardian*'s website decreased after 2008.

4.2.4 Comparison of the frames used by the three media websites on GMO issues

The use of frames by the websites of *The New York Times* and *The Guardian* was somewhat similar, suggesting that the two media outlets have similarities in content when covering GMO issues, whereas frames were used differently on the *People's Daily* website. Our analysis revealed that some GMO issues were highlighted over time while some were gradually ignored, accounting for the use of corresponding frames. There is thus competition between the frames used in GMO coverage.

All three websites highlighted the regulation frame, indicating that the regulatory issue of GMOs was a common concern for people in many regions and reflecting the consensus that GMOs need to be regulated. However, in the coverage using this frame, attribution of responsibility varied. For example, in coverage on the *People's Daily* website, the Chinese Government was mainly represented as being responsible for GMO regulation. Therefore, many articles that used the regulation frame were related to government supervision and regulation policies in China. By contrast, coverage on *The New York Times* website suggested that the industry had primary responsibility and that GMO enterprises should promote the establishment of a GMO labelling system. Meanwhile, coverage on *The Guardian* website attributed responsibility to the European Union and the British Government.

The conflict frame was prominent in coverage by *The New York Times* and *The Guardian*. This frame reflected the fact that GMO issues are controversial, magnifying the uncertainty of genetic modification. Under the conflict frame, the media presented the different views of various stakeholders, thus implying the conflicts among them. This practice of balancing the views of various stakeholders is in line with the principle of news neutrality. It also reflected the differentiation of attitudes towards GMOs among different actors in the US and the UK. However, the *People's Daily* website rarely used the conflict frame, which accounted for only 4.73% of articles. This ratio has continually declined in recent years, which indicates that the *People's Daily* website might have reduced its coverage of uncertainties and controversies related to GMOs. The human interest frame differentiated the *People's Daily* website from the other two newspaper websites, transmitting the voices and stories of GMO scholars and government officials who support GMOs, thus making GMOs more familiar to the public in a positive way.

The use of the leadership frame was proportionally similar in GMO coverage on the *People's Daily* and *The Guardian* websites. Figure 2 shows that the use of the leadership frame in the *People's Daily*'s GMO coverage has increased steadily since 2012. Government officials, especially Ministry of Agriculture officials, have begun to use the media to spread information about China's strict administration of genetic modification. By contrast, although the proportion of the leadership frame was still high in *The Guardian*'s GMO coverage, it was characterized by a general declining trend during the study period, indicating that the leadership frame became less popular in *The Guardian*'s portrayal of GMO's image.

Through the use of news frames, the *People's Daily* website has constructed GMOs as an important but less controversial sci-tech issue that needs government regulation. *The New York Times* portal has presented GMOs as a rapidly growing, well-known, highly controversial issue that calls for stronger regulation. Somewhat similarly, *The Guardian* has presented GMOs as a well-known but controversial issue with high levels of associated uncertainty that also needs regulatory action.

4.3 Cross comparison: frames versus sentiments

The sentiments of all the collected articles were coded to find the overall sentiment expressed in GMO coverage in different countries (see Table 4) and to discuss the possible factors associated with this. Additionally, we sought to investigate whether different sentiments were expressed under different news frames. This section briefly describes the pattern and changes of sentiment in GMO coverage on the three websites. It then cross-analyses between sentiment and news frames in GMO coverage.

Table 4: Sentiment of GM coverage on the three websites

Sentiment (%)	2008	2009	2010	2011	2012	2013	2014	2015
People.cn								
Positive	81.2	80	47.6	50	25	39.5	27.38	67.74
Negative	0	10	20.59	50	45	19.33	22.62	3.23
Both positive and negative	18.18	0	8.82	0	10	15.13	15.14	0
No sentiment expressed	0	10	24.53	0	20	26.05	34.52	29.03
The New York Times								
Positive	33.33	36.36	42.31	80	0	29.41	42.86	36.36
Negative	22.22	54.55	23.08	0	58.33	38.24	14.29	36.36
Both positive and negative	44.44	9.09	30.77	20	41.67	32.35	35.71	21.21
No sentiment expressed	0	0	3.85	0	0	0	7.14	6.06
The Guardian								
Positive	55	50	30.3	33.33	50	14.75	43.90	27.5
Negative	25	30	21.21	23.81	15.63	44.26	31.71	40
Both positive and negative	7.5	15	39.39	33.33	28.13	36.07	24.39	30
No sentiment expressed	12.5	5	9.09	9.52	6.25	4.92	0	2.5

The results of a chi-square test ($P < 0.001$) indicated a statistically significant difference among sentiments expressed on the three websites. The sentiment in coverage by the *People's Daily* was the most positive. Although GMO coverage sentiment in *The New York Times* and *The Guardian* was slightly positive, more coverage expressed negative sentiments, as well as both positive and negative sentiments. Therefore, the image of GMOs may seem somewhat contradictory on the two English-language websites. There is far more coverage lacking expression of any sentiment on the *People's Daily* website than on those of *The New York Times* and *The Guardian*. Articles that did not express any sentiment basically covered the simple facts about GMO issues. At one stage, *The New York Times* had a large proportion of GMO coverage expressing no sentiment (Priest and Ten Eyck, 2004), but that proportion has been decreasing, indicating that with the gradual maturity of GMO development the media will shift from chasing facts to critiquing GMO issues.

We then explored the differences in sentiment under different frames on the three websites. We performed a cross-comparison of the sentiments expressed in the three portals under the three most prominent frames they used. This left four media frames with which to make cross-comparisons of sentiment among the three portals: factual, human interest, conflict and regulation (see Table 5).

Coverage using the factual frame on the *People's Daily* website tended to express no sentiment but gave a simple description of the facts, whereas in GMO coverage on the websites of *The New York Times* and *The Guardian* this frame was used more often in expressing positive sentiment. As for the human interest frame, GMO coverage on the *People's Daily* website expressed the opposite sentiment to that of *The New York Times* and *The Guardian*: when using the human interest frame, they tended to cover GMO issues negatively. This maybe partly because *The New York Times* and *The Guardian* were more inclined to report stories about individuals who oppose GMOs. In contrast, the *People's Daily* website tended to report stories about government officials and scientists who support GMOs.

As the word 'conflict' indicates, the coverage usually contained ideas on opposite sides when using the conflict frame. Correspondingly, the sentiment expressed under this news frame contained both positive and

Table 5: Cross-comparison between prominent frames and sentiment in GMO coverage on the three websites

	Factual			**Human interest**			**Conflict**			**Regulation**		
	People.cn	***The New York Times***	***The Guardian***	***People.cn***	***The New York Times***	***The Guardian***	***People.cn***	***The New York Times***	***The Guardian***	***People.cn***	***The New York Times***	***The Guardian***
Positive	37.88%	57.41%	49.32%	74.47%	33.33%	45.45%	20.00%	4.17%	0.00%	15.49%	11.76%	20.00%
Negative	14.39%	24.07%	28.77%	14.89%	50.00%	48.48%	20.00%	8.33%	12.50%	38.03%	58.82%	50.00%
Both positive and negative	6.06%	11.11%	9.59%	10.64%	16.67%	6.06%	60.0%	87.50%	85.71%	12.68%	29.41%	20.00%
No sentiment expressed	41.67%	7.41%	12.33%	0.00%	0.00%	0.00%	0.00%	0.00%	1.77%	33.80%	0.00%	10.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

negative sentiments. Although all three websites used the conflict frame in covering GMO issues, they used it in different ways. Unlike *The New York Times* or *The Guardian*, which presented confronting ideas to draw out the controversial nature of GMO issues, the *People's Daily* website focused more on describing conflicts. However, by presenting both positive and negative sentiments in a balanced way, *The New York Times* and *The Guardian* made the content more readable and dramatic, regardless of the scientific nature of the GMO issues. This choice may be associated with the pursuit of economic interests by attracting readers' attention, as these publications differ in that *The New York Times* and *The Guardian* are more market-oriented than the *People's Daily*. In this situation, it may seem inevitable that those newspapers will amplify the uncertainty and risk of GMO issues to draw the public's attention.

In terms of the regulation frame, although the sentiment of coverage on the three media portals was mostly negative, 33.8% of the *People's Daily*'s coverage exhibited no sentiment. In these non-sentiment articles, only the importance of GMO regulation and the government's responsibility for it were mentioned; specifically, many national policies were introduced via the regulation frame. However, coverage in *The New York Times* and *The Guardian* attributed responsibility more clearly and directly expressed discontent over inadequate GMO regulation from the government and enterprises.

5. Discussion and conclusions

This section summarizes some key points from the discussion in the previous sections and discusses the differences in covering GMO issues among Chinese, American and British mainstream media portals.

Generally, GMO coverage in Chinese media, of which the *People's Daily* website was used as an example, was more likely to be susceptible to national policies and key opinion leaders. The preference for using the regulation and factual frames shows that Chinese media tend to set agendas aligned with official voices, and GMO messages were more likely to be transmitted in plain language that was not intended to provoke a public reaction. The US media, represented by *The New York Times*, tended to report GMO stories from the industry's perspective, emphasizing domestic GMO incidents and policy development. The British media, represented by *The Guardian*, were inclined to strike a balance between coverage of the benefits and uncertainties of GMOs.

5.1 Characteristics of GMO reports on the three media websites

Based on our findings, we summarize the characteristics of GMO reports on the three mainstream media websites in this section.

5.1.1 People's Daily: A tendency to endorse policies

GMO coverage on the *People's Daily* website showed a sudden increase in 2012, suggesting that national policies and opinion leaders strongly influenced how the *People's Daily* covered GMO issues. The factual, human interest and regulation frames were the news frames used most frequently on the *People's Daily* website, and the proportion of human interest and regulation frames exhibited an increasing trend. Moreover, positive coverage was particularly prominent under the human interest and leadership frames. Even under the human interest frame, the individuals covered were mostly scientists and government officials. The articles all reflected, to some extent, the *People's Daily* website's emphasis on the nation's capabilities in GMO regulation. This characteristic of GMO coverage reflects the *People's Daily*'s tendency to engage in policy endorsement.

5.1.2 The New York Times: A tendency to reflect domestic GMO development

On *The New York Times* website, scientific progress and national regulatory events were more likely to cause fluctuations in the amount of GMO coverage. This website's GMO coverage heavily used the factual, regulation and conflict frames, and the proportion of the regulation frame increased after 2013, reflecting changes in domestic public opinion and policies on GMO issues. Over the period examined, GMO coverage on *The New York Times* website that was either positive or expressed no sentiment decreased, while negative sentiment reports increased. GMO coverage in *The New York Times* focused more on domestic GMO development. This is also consistent with the leading status of GMO companies in the US. Moreover, heavy use of the regulation and conflict frames in GMO coverage was in line with the highly controversial issue of GMO labelling at that time.

5.1.3 The Guardian: A tendency to provide balanced coverage

The Guardian has always paid a high level of attention to GMO issues. Over the study period, its use of the conflict frame increased, containing both positive and negative sentiment. This could partially reflect the UK pausing to ponder the benefits and risks of GMOs, as well as the media's contradictions in covering this issue. By using a relatively neutral sentiment, *The Guardian*'s GMO coverage was balanced, highlighting both the advantages and risks of GMOs. This kind of approach to reporting was affected by the reality of political and scientific development regarding GMOs in the UK. Due to the UK's lagging scientific progress in GMO areas and unsound GMO policies, the content of GMO coverage sometimes needed to be introduced from other countries, presenting different attitudes from the outside world; therefore, UK media may have had little choice on what to cover in GMO news. Over the years, they have been trying to maintain a kind of delicate balance in their coverage of GMO issues.

5.2 Reasons for differences among GMO reports on the three media websites

Cultural differences, the current status of GMO R&D and the public's science literacy may all contribute to differences in the construction of GMO issues by the three media outlets. In his work *Culture's Consequences*, Hofstede (2001) proposed five dimensions for understanding cultural differences, two of which may provide explanations for the differences in the media's construction of GMOs in this study: *uncertainty avoidance* and *individualism versus collectivism*.

5.2.1 Uncertainty avoidance

Uncertainty avoidance is the extent to which members of a certain culture feel comfortable (or uncomfortable) about novel and unknown subjects such as GMOs. Those cultures with substantial uncertainty avoidance tend to focus on reducing uncertainty through various means and measures, whereas cultures with low uncertainty avoidance tend to embrace risks and challenges (Hofstede, 2001). In Hofstede's research, among China, the UK and the US, China has the most avoidant attitude towards uncertainty, followed by the UK and then the US. This is consistent with the findings of the current study, in which the *People's Daily* website was found to be least likely to report on the scientific progress of GMOs, while *The New York Times* showed interest in the development of GMOs in various fields, exhibiting its confidence in scientific advances.

5.2.2 Individualism versus collectivism

The opposition between 'individualism' and 'collectivism' concerns the degree to which

individuals maintain their individual independence or integrate into groups (Hofstede, 2001). The Chinese and Western cultures differ sharply in this respect. Under the influence of China's collectivist culture, the nation tends to be the priority of the Chinese news media, while the US media's deference to the government's voice is less frequent. Therefore, in GMO coverage, the *People's Daily* website focused on propagating related policies and educating the public. Furthermore, in the construction of GMO issues, the *People's Daily* website stuck closely to aspects such as national strategy and national food security, trying to persuade the public through emphasizing community good over the individual.

Additionally, the state of GMO R&D in different countries may also affect how GMO issues are constructed. Although China is accelerating scientific research on GMOs and may commercialize them in the future, the US is currently more advanced in such research. Therefore, the *People's Daily* GMO reports contained more basic information, such as popular science content, whereas *The New York Times* published more coverage of new GMO scientific research results.

6. Limitations and future directions

This study compared the use of news frames in GMO coverage in the mainstream media of China, the UK and the US over an eight-year period. Using framing analysis, we identified the prominent frames used by different media outlets and the changes in their use over time. This may reveal the deeper-level contest over GMO issues among various stakeholders of different societies.

Moreover, this study made innovative use of generic frames, instead of issue-specific frames, to compare media portals across different cultures. This strategy could be used in the future to compare coverage regarding other issues and media forms. However, in this study of the mainstream media in three countries, only one representative media outlet was selected in each country due to limited time and human resources. This is far from enough to understand how GMO issues are constructed by the media in a given country.

Future research could choose more than one media outlet in a country to derive a more comprehensive view. In addition, with the rise of newer forms of media, increasing numbers of people tend to source scientific information from social media. Future studies could also investigate the association between GMO coverage on social media and mainstream media websites and the mutual agenda-setting effects among them.

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Note

[1] On 14 July 2016, the US House of Representatives passed the bill on GMO labelling (Cao, 2018: 21).

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How the Chinese public makes decisions about controversial technologies: A case study on GMOs

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Abstract

A number of events in China in recent years have been characterized by tensions or controversies between scientists and the public, such as the p-Xylene chemical project in Xiamen, nuclear energy projects, and genetic engineering. Scientists tend to attribute such conflict to inadequate public knowledge of science, leading to misunderstandings about it. However, that view ignores the influence on public perceptions of news reports and online discussions about controversial technologies in new media. Social media reporting affects the audience's perception of the risks posed by controversial technologies and can cause people to lose confidence in the scientific community and damage their trust in government. Thus, the public opposes these technologies. In this context, this study explores the relationship between the public's trust in the scientific community and the government on the one hand and its attitude towards controversial technologies on the other. I surveyed 1,235 people using a national online probability sampling strategy. I found that people's use of new media was significantly related to the extent of their knowledge of specific controversial technologies and was associated with other people's opinions about those technologies. The more attention people paid to WeChat coverage of genetically modified organisms (GMOs), the more supportive they were of them. Thus, the public's use of new media is a key factor in predicting its positive attitude to GMOs. Scientific literacy also significantly affects public attitudes to GMOs, directly as well as indirectly.

Key words

New media use, scientific knowledge, risk perception, trust, attitude to science

1. Introduction

The internet has promoted formal and informal communication about science that allows the public to directly discuss the development of new technologies. However, such controversial issues in China in recent years as a planned p-Xylene plant in Xiamen, nuclear power and waste incineration have led to conflicts between science and public opinion.

This exemplifies the idea of the 'science literacy/knowledge deficit model' in science

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communication, which involves enhancing the public's understanding and acceptance of science by improving its scientific literacy. China's efforts to promote knowledge of science and technology have intensified in recent years. According to the 2015 *National Science Popularization Statistics of China*, more than two million people have been engaged in activities to promote scientific knowledge nationwide. A total of 161,100 science and technology exhibitions have attracted more than 249 million visitors (Ministry of Science and Technology, 2015).

China's 13th Five-Year Plan notes the need to promote scientific knowledge and includes an annually increasing budget for improving overall national scientific literacy. Specifically, for example, in 2016, the *Action Plan for the Outline of the National Scheme for Scientific Literacy (2016–2020)* was launched.

Although large investments have already been made to promote science popularization in China, it is difficult to see the effects in the short term. Even if the number of annual activities to promote scientific knowledge increases drastically, the public's acceptance of new technologies will not increase at a corresponding rate. Of all public debates related to new technologies, the controversy on genetically modified organisms (GMOs) has been the most intense. Although many measures have been taken to increase the public's knowledge of GMOs, the impact of those measures in improving public attitudes cannot offset the negative impact of rumours and stigma. In recent years, a growing volume of fake news and information about GMOs has appeared on the internet.

The public's understanding of scientific knowledge affects its attitudes to science (Brossard and Nisbet, 2007). However, few studies have analysed differences in scientific knowledge among members of the public. Perceptions and understanding of GMO technology differ among groups, such as doctoral students, middle school students, art students, science students, and rural and urban residents. The factors influencing public support for controversial technologies are diverse and complex. Therefore, personalized methods for the popularization of science should be used to target different segments of the population.

In addition, the following three questions should be answered before planning activities to promote scientific knowledge on GMO technology:

- How do social media influence public scientific knowledge of controversial technologies?
- How do different segments of the population differ in their understanding of science?
- How do psychographic variables affect the public's attitudes?

By answering these questions, we can understand how the public forms opinions in the Information Age to construct its own understanding of GMOs.

2. An integrated model: How the public makes decisions about controversial technologies

Public science policy is complex and difficult for non-scientists to grasp. Understanding it requires time and close attention, so it is nearly impossible for the public to be well informed about all issues related to scientific policy; therefore, people need to find shortcuts to process this information and make judgments about complex controversies in scientific policy (Popkin, 1991; Brossard and Nisbet, 2007). The fact that the public may be relatively ignorant of controversial technological discussions does not mean that it cannot make judgements about controversial technologies (Scheufele and Lewenstein, 2005; Brossard and Nisbet, 2007). Scheufele and

Lewenstein (2005) claimed that people form opinions and attitudes even in the absence of relevant scientific or policy-related information.

Recent studies have shown that, with the development of the internet, the content of new media channels has come to affect the public's understanding of controversial technologies and its risk perceptions, including about nanotechnology (Scheufele and Lewenstein, 2005), agricultural biotechnology (Brossard and Nisbet, 2007), GMOs (Lee and Kim, 2018), climate change (Wang, 2017), and vaccines (Dunwoody and Kohl, 2017).

The factors influencing public support for controversial technologies are diverse and complex. Recent studies have also shown that the relevant variables do not affect attitudes in only one way, and different variables affect public opinion in direct and indirect ways. I thus explore both the direct and the indirect effects of particular variables on public attitudes, including scientific knowledge, the use of new media, trust in science and risk perception.

Of the models that consider the relationship between knowledge and resulting attitudes towards issues, the stimulus–response (S-R) model and the knowledge–attitude–practice (KAP) model in psychology have received the most attention. However, the KAP model ignores the influence of the environment on knowledge and attitudes. Because the public's attitudes to genetically modified (GM) food are influenced by many factors other than scientific knowledge, the S-R model is more suitable as the basic framework for studying the knowledge–attitude relationship.

The most suitable theoretical model for basic psychological concepts is the S-O-R (stimulus–organism–response) model, which is an extension of the behaviouristic S-R formulation proposed by Woodworth in 1958 (Royce and Mos, 1984). In psychology, the S-R model has long been used to study changes in public attitudes, and the S-O-R model proposed by Woodworth (Woodworth and Schlosberg, 1965) is the most widely used.

The S-O-R model posits that stimulation and human behaviour (reaction, action) are linked by an organismic component. The model differs from the traditional S-R model mainly in two aspects:

- It emphasizes that stimulation (S) does not directly respond to the behaviour of the public (R).
- The behaviour of the public is based on consciousness as a mediator.

Mehrabian and Russell (1974) improved the model to produce the O-S-O-R (orientation–stimulus–orientation–response) model, which is the best summary of the general pattern of public behaviour. O_1 in the model represents the basic characteristics of the individual in terms of structure, culture, cognition, and motivation, including demographic background and location of residence. S represents the stimulus, and, in communication, the consumption of information through mass media and social networks among people are regarded as sources of stimulation. O_1 and S jointly influence O_2, which represents knowledge and risk perception, which eventually help form the attitude and behaviour of the public (R).

The S-O-R and O-S-O-R models assume that the attitude of the public is triggered by external sources of stimulation that directly or indirectly affect its physical and psychological states. When faced with various stimulations, people generate specific motivations and behavioural intentions and make decisions about whether to buy certain products.

Brossard and Nisbet (2007) used the O-S-O-R model to discuss factors that influence the attitudes of the American public to agricultural biotechnology. As conceptualized, O_1 represents long-term social predispositions. S represents the stimulus of media consumption and attention across types of news outlets and

other information sources. O_2 signifies intervening orientations or behaviours between stimulus and outcome, such as knowledge and trust or generalized reservations about science. R represents the final outcomes of both sets of orientations and the communication stimuli—in that case, public views about agricultural biotechnology. According to Brossard and Nisbet, these variables are typically classified as 'endogenous' variables, and the primary emphasis is on analysing the inter-relationships among them and their direct and indirect effects on the response or dependent variables of interest. They found that the level of knowledge of agricultural biotechnology was positively correlated with the attitudes of the public. The factors influencing its attitudes are diverse and complex, so it is not sufficient to examine only the linear relationship between specific variables.

From Brossard and Nisbet's examination of the structural relationship between variables, we learn that it is necessary to consider the impact of the environment, in addition to knowledge variables, on the construction of knowledge. Therefore, to examine the factors affecting the public's attitudes and behaviours regarding GMO technology, my study refers to the O-S-O-R model: O_1 is the demographic variable of the individual; S is the source of new media exposure; O_2 consists of trust, perceived risk and scientific knowledge. That is how the attitudes and behaviour of the public (R) are formed. The variables are listed in Table 1 and elaborated in subsequent sections of this paper.

3. Direct and indirect effects of new media (S)

In the Information Age, new media channels are important sources through which people acquire information easily when faced with a new scientific concept, such as GMO technology. The use of new media is a major factor influencing the public's attitudes to GMO technology (Brossard and Nisbet, 2007). Past research has shown that new media content (such as online news, WeChat information and Weibo posts) influences public knowledge and risk perceptions of science (Nisbet and Lewenstein, 2002; Agha, 2003; Wang, 2017). New media channels can not only be used to communicate scientific knowledge but also as a platform for online rumours. A variety of comments and opinions on GMO technology can be found online. Scientists, organic food companies, and online opinion leaders want to influence the public's understanding of GMO technology and thereby gradually affect its attitude to GM food and its behaviour.

Most initial discussions about GMO technology took place on online bulletin boards, but interest was not high. Only about 36% of users discussed GMO-related issues on bulletin boards (Triunfol and Hines, 2004). Even so, those online discussions did help form the public's initial impressions and perceptions of GMO technology. In China, the 2012 'golden rice' event marked the arrival of wide discussion about GM food among the public. Golden rice is genetically engineered to be high in vitamin A. As Fan

Table 1: An O-S-O-R model explaining support for controversial technology

Exogenous variables		**Endogenous variables**	
Orientation (O_1)	Stimulus (S)	Orientation (O_2)	Response (R)
Demographics	Attention to controversial technology on the internet	Scientific knowledge of controversial technology	Attitudes to controversial technology
Age	Attention to controversial technology on WeChat	Trust in controversial technology	Behaviour regarding controversial technology
Education	Attention to controversial technology on Weibo	Risk perception of controversial technology	

et al. (2013) noted, netizens often paid attention only to opinions with which they agreed when discussing the trial of golden rice on children in Hunan; there was a distinct 'echo chamber' effect.

Internet platforms such as Sina Weibo brought GMO technology to the public's attention, but the complexity of the issue made it difficult for people to distinguish between correct and incorrect information. Using a website quality assessment tool, McInerney et al. (2004) found that only a third of 100 GMO-related websites had good-quality content.

The popularization of science through new media has become an important aim for various countries in promoting GMO technology and its products, but the popularization of GMO-related science entails far more than simply setting up a science communication website. According to a study by Wang and Waters (2012), the websites of American and German agricultural associations publish only regular agricultural scientific knowledge without interactive functions, and the effect of such communication is limited. This problem has also been observed on GMO-related websites in China. Overall, past studies have found that the potential of new media in the dissemination of GMO-related knowledge has not been well developed (Wang and Waters, 2012).

The internet has become an important tool for people seeking to acquire scientific knowledge (Jin et al., 2017), but it is necessary to clarify the following questions:

- How does the public use different channels of new media to acquire information about GMO-related issues when faced with a large amount of information?
- How do various new media channels affect the public's access to GMO-related knowledge?
- How does the content of new media affect the public's understanding and risk perception of GMOs, and how does the public ultimately form an attitude?

This study addresses these questions by examining the public's interest in GMO-related content in new media.

4. The influence of scientific knowledge on attitude (O_2)

The development and industrialization of GM food require the support of the public, so people's acceptance of GM food has become a focus of research in recent years. The earliest study on the relationship between knowledge of and attitudes to GM food was conducted by Frewer et al. (1994) based on an experiment. Two packages labelled 'GM food' and 'non-GM food' were used to wrap products, and the advantages of each were explained to test the public's purchasing attitudes. Frewer et al. found that, owing to the public's limited understanding of GM food, it was difficult for people to determine whether it posed risks to their health. Thus, they needed to turn to other credible sources of information for help.

With the development of GMO technology, more people have begun eating GM foods. 'GMO' is no longer an unfamiliar term to the public. An increasing number of studies have tested and attempted to explain the influence of GMO-related knowledge on public attitudes. Different theories have been developed using varying assumptions about the influence of scientific knowledge on public attitudes. In science communication, researchers consider scientific knowledge to be a key factor influencing public attitudes. The assumption is that improving the scientific knowledge of the public has positive effects on people's attitudes to new technologies (Miller, 1983). The Foreign Citizen Science Literacy Survey Report found that the public's scientific knowledge is correlated with its support for new technologies (Alum et al, 2008). A number of studies have found that the public's knowledge of GM food affects people's attitude to it: the higher the public's level of

knowledge, the more positive are its attitudes to GMO technology (Hoban et al., 1992; Hallman et al., 2002; Hallman et al., 2003). That conclusion has also been drawn by some Chinese scholars (Huang et al., 2006; Tang, 2015). According to the 2015 National Science Literacy Survey, the higher the public's scientific literacy, the higher its support for the application of GMO technology (Ren et al., 2016).

In the field of risk communication, however, researchers have different opinions on the influence of scientific knowledge. They argue that the public's risk perception is the key variable affecting its attitudes to controversial technologies and that its level of scientific knowledge does not determine its acceptance of GMOs (Fan and Jia, 2015). Thus, from the perspective of risk communication, the relationship between scientific knowledge and public attitudes involves risk perception as a mediating factor. The impact of knowledge on public attitudes is indirect rather than direct. For example, in Bredahl's (2001) research on attitudes to GM yogurt and GM beer in Denmark, Germany, Italy and the United Kingdom, scientific knowledge was used only as an exogenous variable to study the impact of perceived risks and benefits on attitudes when designing the survey model. That study found that only with perceived risks and benefits does scientific knowledge have a significant negative impact on the public's attitudes.

Verdurme and Viaene (2003) modified Bredahl's model. In addition to retaining the original variables, they added such variables as culture and socio-economic status to further study their impact on public attitudes. The results confirmed Bredahl's conclusion that scientific knowledge can indirectly influence attitudes through risk perception. But some studies have also concluded that scientific knowledge has no influence on risk perception and that there is no correlation between scientific knowledge and risk perception (Sjoberg, 2001; Jia et al., 2015).

From the above literature, it is clear that, in risk communication, most studies classify knowledge as a factor that requires intermediaries to influence attitudes and have rarely focused on the direct impact of knowledge on attitudes (Bredahl, 2001; Sjoberg, 2001; Verdurme and Viaene, 2003).

Scientific knowledge causes science communication and risk communication to intersect in research. Although opinions on the relationship between scientific knowledge and attitudes differ, it is undeniable that scientific knowledge has an important position in both types of research.

5. Scientific literacy and the measurement of GMO-related knowledge (O_2)

As discussed above, science communication and risk communication are highly correlated due to scientific knowledge. However, some scholars have noted that scientific knowledge varies owing to different issues (Alum et al., 2008). Therefore, general scientific principles cannot be applied directly to the public's level of GMO-related knowledge.

Scientific literacy, which refers to the public's understanding of science (Jin, 2002), has an important position in knowledge measurement. The most fruitful scientific literacy scale, proposed by Miller (1983), measures whether a person has:

- a vocabulary of basic scientific constructs sufficient to read competing views in a newspaper or magazine
- an understanding of the process or nature of scientific inquiry
- some level of understanding of the impact of science and technology on individuals and society.

The first study on the public's GMO-related knowledge was a survey by Kamaldeen and Powell (2000) when GM food was first

launched in Brazil. In China, a similar study was conducted by Zhong et al. (2002). The results showed that most Chinese people had little knowledge of GM food, and more than 50% of urban residents had never heard of it. However, as GMO technology has been more widely discussed at home and abroad in recent years, the public has become more familiar with GMO science. Research by Tang (2015) indicates that 90.9% of the public knows the term 'GMO science', even though people's knowledge of GMO science remains limited.

Past related studies in China show that knowledge of GMO technology has an impact on the public's attitudes (Xiang et al., 2005; Liu, 2010; Tang, 2015). However, people are most commonly asked whether they 'know' the term 'GMO technology'. For example, in a study by Tang (2015), respondents were asked how much they knew about GMO technology and were given options for answers ranging from 'don't know' to 'expert'. However, those options can be used only to assess their own assessments of their GMO-related knowledge but not to measure their GMO-related knowledge. Even if two people had possessed the same level of knowledge, their answers might still have been different because of different assessments of their own judgements.

Measuring the scientific literacy of the public simply by asking people whether they have ever heard of GMO technology is inaccurate. Frewer et al. (1997) and Bredahl (2001) proposed additional questions. For example, they asked respondents whether all processed foods are made from GM products. In their survey, Xiang et al. (2005) developed a new question about whether traditional soybeans and GM soybeans all possess genes. Only 49.3% of the respondents answered correctly.

No mature theory or scale is available to measure GMO-related knowledge, and such a scale is needed to study the relationship between knowledge and public attitudes to GMOs. Based on Miller's scientific literacy scale, and combined with scientific knowledge of GMOs, I designed such a scale consisting of three dimensions:

- scientific principles (understanding the scientific approach)
- GMO development (understanding basic GMO science)
- social impact (understanding science policy issues).

Based on this scale, I discuss the impact of GMO-related knowledge on attitudes and the core problem: how does GMO-related knowledge (scientific principles, GMO development and social impact) affect the attitudes and behaviours of the public?

6. Moderator variable: Trust and risk perception (O_2)

Public opposition to a controversial technology is often fuelled by perceived risks. Past research has shown that perceived risks and benefits act as key predictors of public attitude to a controversial technology (Alhakami and Slovic, 1994; Arning et al., 2019). Risk perception refers to beliefs about potential harm or the possibility of a loss. It is a subjective judgement that people make about the perceived probability and negative outcome of an adverse event (Slovic, 1987).

Most of the public uses trust to evaluate risk (Freudenburg, 1993). The role of trust in explaining public acceptance of controversial technologies has been studied at length. Brossard and Nisbet (2007) claimed that trust enables the public to act without knowledge of the technical nature of the relevant risks. As a substitute for information about a vast array of possible threats in everyday life, people are forced to rely heavily on the endorsement of regulators, officials, industry, scientists and other experts (Priest et al., 2003; Brossard and Nisbet, 2007). Slovic

(1999) claimed that, if trust in the government is high, the public is less likely to worry about the unforeseen risks posed by a controversial technology. In addition, trust in institutions directly influences risk perception and fear, which in turn affect the acceptance of biotechnology (Brossard and Shanahan, 2003). Hence, in this case, I return to aspects of the conceptualization and measurement of institutional trust, perceived risk and scientific literacy as key variables in my model.

7. Methods

7.1 Research questions

This study focuses on how the public supports GMO technology in China and poses the following three research questions:

- *RQ 1:* How does new media content (online news, WeChat information, Weibo posts) directly and indirectly influence public attitudes?
- *RQ 2:* How does scientific knowledge directly and indirectly affect public attitudes?
- *RQ 3:* How do risk perception, institutional trust and trust in scientists influence public attitudes and behaviours?

7.2 Sample

The data for this study were collected in 2016. The survey was conducted by the Media Survey Laboratory at the School of Journalism and Communication of Tsinghua University. I obtained 1,235 valid cases from an online panel with more than 200,000 registered users. Using a non-probability sampling method, the respondents were sampled based on their gender, education and geographical location. Such a sampling design enhances the representativeness of the sample. The sample featured males (n = 662) and females (n = 573) with varying levels of education: elementary school and below (n = 173), junior high school (n = 452), high school (n = 358), junior college (n = 102), bachelor's degree (n = 115), master's degree (n = 28), and doctorate (n = 7). The geographical regions represented were north China (n = 169), north-east China (n = 102), east China (n = 397), south China (n = 180), central China (n = 159), south-west China (n = 142), and north-west China (n = 86). The sample had roughly the same distributions as the gender, education and geographical distributions published by the China Internet Network Information Center. Despite the carefully constructed quota, however, the use of non-probability sampling limited the generalizability of the findings.

7.3 Measurement

The survey contained questions on a five-point scale, including questions about new media use, institutional trust, perceived risk, scientific literacy, attitudes to GMOs and consumer behaviour. Questions on demographic information, such as education, age and gender, were also included. Analyses of variance were run for comparisons. 'Don't know' responses were removed from the analyses.

7.3.1 New media use

The respondents were asked to score the following statements about how they acquired information by using new media (1 = strongly disagree; 5 = strongly agree; M denotes 'mean' and SD denotes 'standard deviation'):

a 'I am following GMO-related information on the internet.' (M = 3.07, SD = 1.2)
b 'I am following GMO-related information on Weibo.' (M = 2.75, SD = 1.23)
c 'I am following GMO-related information on WeChat.' (M = 2.85, SD = 1.27)

7.3.2 Institutional trust and trust in scientists

Trust has two dimensions: institutional trust and trust in scientists. The respondents were asked how strongly they agreed or disagreed with each of the following statements (1 = strongly disagree; 3 = neutral; 5 = strongly agree):

a ‘In formulating policy on GM foods, the government will establish complete regulations.’ (M = 3.48; SD = 1.19)
b ‘The government has the ability to oversee the safe management of GM foods, and can set standards concerning them.’ (M = 3.46; SD = 1.21)
c ‘The government can ensure the safety of GM foods.’ (M = 3.11; SD = 1.25)
d ‘The first consideration for the government to develop GM foods is food safety.’ (M = 3.33; SD = 1.24)
e ‘The government does not tend to target specific groups during the testing of GM foods.’ (M = 3.24; SD = 1.26)
f ‘Domestic GM foods companies will comply with government regulations.’ (M = 3.03; SD = 1.25)
g ‘The government will severely punish violations by companies making GM foods.’ (M = 3.29; SD = 1.22)

To measure trust in scientists, the respondents were asked to verify the following statement:

> ‘In research on and development of GM food, Chinese scientists are trustworthy.’ (M = 3.26; SD = 1.23)

7.3.3 Risk perception

To measure perceived risk, the respondents were asked to answer the following questions, and their responses were scored on a five-point scale (1 = benefits strongly outweigh risks; 5 = risks strongly outweigh benefits):

a ‘Do you think the risks of GMOs for the environment outweigh their benefits?’ (M = 3.11; SD = 1.16)
b ‘As long as GM products are listed through national security certification, is food safety guaranteed?’ (M = 3.17; SD = 1.12)

7.3.4 Scientific literacy

I measured the public’s ability to understand scientific research, its comprehension of selected constructs, and people’s understanding of contemporary political issues that involve science and technology (Miller, 1983). Scientific literacy has three dimensions: understanding the scientific approach, understanding basic scientific constructs, and understanding science policy issues (Miller, 1983).

To measure GMO-related knowledge, the respondents were asked to quantify how much they had heard about a certain issue (1 = never, 2 = seldom, 3 = occasionally, 4 = often, 5 = very often):

a plant breeding (M = 3.35, SD = 1.16)
b GMOs (M = 3.37, SD = 1.14)
c agricultural biotechnology (M = 3.06, SD = 1.22)
d GM foods (M = 3.42, SD = 1.18).

To measure people’s understanding of the scientific approach, their factual knowledge was measured using answers to the following 10 dichotomous (true/false) questions (Kamaldeen and Powell, 2000; Chern and Rickertsen, 2003; Zhong et al., 2002; Brossard and Nisbet, 2007):

a ‘The child’s sex is determined by the father’s genes.’ (True)
b ‘Human and gorilla genomes are 98% similar.’ (True)
c ‘All creatures are composed of cells.’ (True)

d ‘Transgenic technology is the introduction of known high-quality genes to the genome of the organism.’ (True)
e ‘The risk posed by licensed transgenic crops is no greater than that posed by traditional breeding crops.’ (True)
f ‘Transgenic crops and traditional crosses are all bred through genetic changes.’ (True)
g ‘GM tomatoes contain genes but ordinary tomatoes do not.’ (False)
h ‘If a person eats GM food, his/her genes will change.’ (False)
i ‘It is not possible to transfer animal genes into plants.’(False)
j ‘Transgenic tomatoes with transduced fish genes taste like fish.’ (False)

The number of correct answers ranged between zero and 10 among respondents. The answers were summed up in a single index (M = 5.60, SD = 2.28).

To measure people’s understanding of basic scientific constructs, the respondents were asked two questions:

a ‘As far as you know, does China allow GM food to be imported from other countries?’ (Yes)
b ‘Do GM foods sold in China need to be labelled?’ (Yes)

This study measured the understanding of science policy issues by scoring the responses on a five-point scale (1 = strongly disagree; 3 = neutral; 5 = strongly agree) to the following questions:

a ‘GMOs can help reduce the use of pesticides.’ (True)
b ‘GMOs can help raise the nutrient content of the crop.’ (True)
c ‘GMOs can raise crop yields.’ (True)
d ‘GM food licensed by the state may contain hazardous substances.’ (False, reverse coded)
e ‘GM food can reduce production costs.’ (True)
f ‘GM food can help reduce environmental pollution.’ (True)
g ‘GM food licensed by the state may undermine biodiversity.’ (False, reverse coded)
h ‘GM food licensed by the state may damage the soil.’ (False, reverse coded)

These eight measures were combined into a single index (M = 25.39, SD = 6.48, α =0.81), in which higher scores indicated greater knowledge.

7.3.5 Attitude to GMOs

The respondents were asked how strongly they agreed or disagreed with each of the following statements (1 = strongly oppose; 3 = neutral; 5 = strongly support):

a ‘Do you support the development of GMOs in China?’ (M = 3.33, SD = 1.22)
b ‘Do you support the commercialization of GMOs?’ (M = 3.12, SD = 1.20)
c ‘Do you support the application of GMOs to biomedical technology?’ (M = 3.42, SD = 1.20)

7.3.6 Consumer behaviour towards GM food

This study was based on GM-related products certified by the government and did not examine other products that are being developed or have not been certified. Consumer behaviour towards GM food was measured using eight items. The respondents were asked whether they would buy the following GM products that had passed national safety certification (1 = strongly disagree; 3 = neutral; 5 = strongly agree):

a high-fibre foods processed with disease- and pest-resistant wheat (M = 2.90, SD = 1.23)
b disease- and pest-resistant rice (M = 2.96, SD = 1.26)

c healthier varieties of rice (M = 3.07, SD = 1.27)
d GM fruits or vegetables resistant to pests and diseases (M = 2.96, SD = 1.21)
e GM fruits or vegetables stored for a long time (M = 2.82, SD = 1.26)
f soybean oil processed from GM soybeans (M = 2.89, SD = 1.27)
g tofu processed from GM soybeans (M = 2.75, SD = 1.27)
h livestock products that use GM corn as feed (M = 2.95, SD = 1.25).

8. Results

In statistics, confirmatory factor analysis (CFA) is a special form of factor analysis most commonly used in social research. It is used to test whether measures of a construct are consistent with a researcher's understanding of the nature of that construct (or factor). I assumed that factors affecting public attitudes to GMOs feature multilayered characteristics. To better understand the relationship between the variables, I used structural equation model (SEM) analysis. Two model components were distinguished in SEM: a structural model showed potential causal dependencies between endogenous and exogenous variables, and a measurement model showed the relations between latent variables and their indicators. Models of exploratory and confirmatory factor analyses, for example, contain only the measurement part, while path diagrams can be viewed as SEMs that contain only the structural part. Therefore, the objective of CFA is to test whether the data fit a hypothesized measurement model.

In this study, scientific knowledge, public attitudes and behaviours were used as latent variables; age and education were used as exogenous variables; and new media use, perceived risk, institutional trust, trust in scientists, scientific knowledge, attitudes and behaviour were used as endogenous variables in the model. The data in the final model fitted exceptionally well. The root mean-square error of approximation was 0.042; the goodness-of-fit index was 0.960; and the adjusted goodness-of-fit index, controlled for multivariate non-normality, was 0.944 (P-value = 0.000, degrees of freedom = 181, chi-square = 581.077, chi-square/degree of freedom = 3.210).

Of the endogenous variables shown in Figure 1, the three dimensions of new media had different degrees of influence on public attitudes and behaviours.

- Online news did not directly influence the public's attitudes and behaviour but did indirectly affect them through 'institutional trust' and 'trust in scientists'.
- WeChat information had a positive impact on public attitudes (β = 0.10) and indirectly affected them through scientific literacy.
- Weibo played a central role as an information shortcut for the public in reaching judgements about GMO technology and had a positive impact on people's behaviours (β = 0.29).

Public focus on Weibo information increased scientific literacy, which directly influenced the public's attitudes (β = 0.48) and behaviours (β = 0.31). It also indirectly affected people's attitudes through 'perceived risk', 'institutional trust' and 'trust in scientists'. Perceived risk (β = 0.09), institutional trust (β = 0.21) and trust in scientists (β = 0.13) had a positive impact on public attitudes to GMOs. Age and education were used as exogenous variables, and had a negative impact on some variables:

a Age had a negative impact on public behaviours (β = –0.14).
b Age had a negative impact on scientific literacy (β = –0.09).
c Education had a negative impact on perceived risk (β = –0.09).

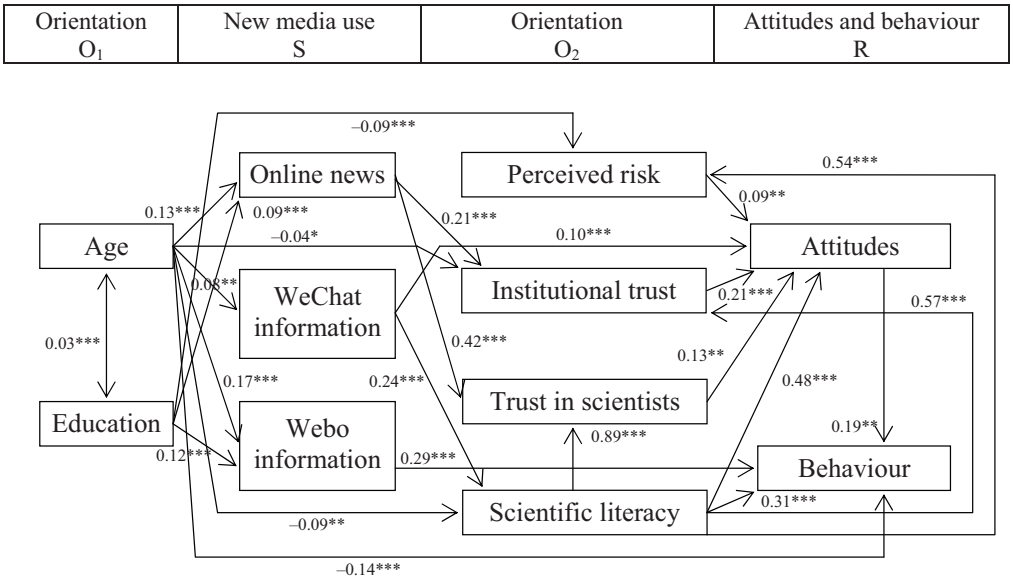

Figure 1: Relationships among endogenous variables

9. Discussion

The goal of this study was to outline a theoretical account that integrates key variables and reason from past research into a simple model that can explain opinion formation by using the contemporary debate over GMOs as a test case. The model serves as a basis for future research to explain opinion formation in the context of other science and technology debates by providing guidance for researchers in conceptualizing, specifying and testing the relationships among variables.

9.1 Scientific knowledge and public attitudes

In research on science communication and risk communication, the relationship between knowledge and attitudes has always been an important issue. This study combined the concepts of scientific literacy from science communication and transgenic cognition from risk communication to develop a GMO-related knowledge scale. By analysing data from a national survey in China, I examined whether scientific literacy and attitudes are correlated.

Having examined the relationship between knowledge-related variables and other variables by SEM, I found that knowledge had a positive overall relationship with public attitudes and behaviour. The results of this study indicate that the dimensions of scientific literacy have a positive impact on public attitudes and behaviour. Therefore, the government can improve public support for controversial technologies through the popularization of science.

Scientific literacy has a positive impact on perceived risk, institutional trust and trust in scientists. When the public is more scientifically literate, it has greater trust in scientists and higher perceived risk and institutional trust. Public trust in the government and scientists contributes to the development of new technologies and the promotion of science policy.

The results of this study show the impact of scientific knowledge on attitudes in science communication and risk communication. In science communication today, a greater

emphasis is placed on the scientific principles of genetic modification and its impact on society. The findings of this study are in line with those of previous studies (Hoban et al., 1992; Hallman et al., 2002; Hallman et al., 2003).

Past research on risk communication claimed that knowledge does not directly affect public attitudes but influences them only through intermediate variables, such as risk perception, risk return and trust (Bredahl, 2001; Sjoberg, 2001; Verdurme and Viaene, 2003; Fan and Jia, 2015). Therefore, from the perspective of risk communication, scientific literacy can negatively affect public attitudes and behaviours (Bredahl, 2001). My study confirmed this result. As a way to integrate and think systematically about these variables, I applied the O–S–O–R model developed in recent psychological studies.

9.2 The impact of new media use on scientific literacy

Most consumers lack the time, ability or motivation to be fully informed about science issues and instead rely heavily on new media. As data in this study indicate, it is likely that media coverage plays an important indirect role in forming public attitudes, serving as a central mediator for informally learning about new technologies such as GMOs. According to the data, the more attention people paid to WeChat coverage of GMOs, the greater their GMO-related knowledge was. However, online news and Weibo information did not affect the public's knowledge. The higher the GMO-related knowledge of the public, the higher was its support for this technology.

The government's promotion of GMOs depends on the support of the public. If the market does not accept this technology, there is no need for extensive development. To accelerate the industrialization of GM foods, it is necessary to increase the public's scientific knowledge. However, before planning activities to promote GMO-related knowledge, we need to consider differences in the knowledge received by different groups and understand aspects of it that can effectively influence public behaviour. We should start with the following to improve the public's support for GMO technology:

1. As shown in Figure 1, scientific literacy can have varying impacts on public purchasing behaviour. Thus, faced with different consumer groups, we must communicate in different ways and convey GMO-related knowledge in language that the audience can understand. China invests a large amount of resources every year in popular science activities, but the effect is not satisfactory. The most important reason for this is that scientists do not understand 'science communication'. Sometimes, scientists disseminate only scientific knowledge but ignore the different modes of understanding of it by different groups. Moreover, scientists often lack the ability to promote difficult scientific knowledge in a way comprehensible to the public.

   In China, scientists believe that the public generally does not understand science, especially GMOs. They spend a lot of time and money explaining the technology to the public, but the public still does not believe in the safety of GMOs. The public believes that scientists spread GMO-related knowledge only for their own benefit. Science communication should consider the level of education, living environment and differences in media usage among different groups in China.
2. Chinese people interact on WeChat every day. This study found that the public's attention to WeChat can improve its knowledge of GMO technology. However, WeChat can also help spread false news and information related to GMOs. Therefore, scientists should consider clarifying rumours in science communication.

3. A number of studies in the past have confirmed that strengthening the public's understanding of scientific knowledge can help enhance its support for and behaviour towards GMO technology (Xiang et al., 2005; Liu, 2010; Tang, 2015; Brossard and Shanahan, 2003; Brossard and Nisbet, 2007; Mielby et al., 2013). If the government wants to change the public's attitudes to GMOs, it should focus first on the relevant knowledge needed to understand the basic scientific constructs and science policy issues.

The public has changed its attitudes to GMOs and started to support their use. The focus can now be further directed to helping people to understand the scientific approach and science policy issues in order to improve their willingness to purchase GM products.

My study shows that knowledge might not always lead to greater public support for science. At the same time, it is unlikely that a lack of knowledge always translates into reduced support. If we want to change public attitudes to and behaviour towards GMOs, the focus of knowledge publicity ought to be different. Only by letting the public correctly understand the advantages and disadvantages of GMO technology can GM foods be popularized.

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Author biography

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Why do intuitions differ? Explaining how individual and scenario features influence disgust and moral judgements on GMOs

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Abstract

Moral psychology holds that negative judgements on genetically modified organisms (GMOs) are likely to be intuitive reactions driven by trait disgust without deliberation, which brings difficulty to genetic science communication. Based on two interrelated experiments examining the processes and conditions of individual and scenario features influencing disgust and moral judgement about GMOs, this study aims to identify the different routes through which disgust influences moral judgement about GMOs in the physical and social dimensions. We found that the process of elicited state disgust influencing moral judgement on GMOs is regulated by pathogen disgust sensitivity and moral disgust sensitivity. The difference in opposition to GMOs brought by preferences for precepts implied in moral theories is evidently subject to the joint effect of the disgust elicitation type and emotion reappraisal (ER). This study clarifies the relationship between disgust for GMOs and moral judgement. It also confirms the effectiveness of ER in promoting the transition of moral judgement on GMOs from intuitive reaction to deliberation, thus offering benefits for science communicators targeting audiences who differ in their preferences for precepts implied in moral theories and trait disgust.

Key words

Genetically modified organisms (GMOs), disgust, moral judgement, emotion reappraisal (ER), preferences for precepts implied in moral theories (PPIMT), science communication

1. Disgust for GMOs in science communication: From the cognitive domain to moral interpretation

Science communication generally attempts to cognitively influence GMO opponents, to inform the public of the risks and benefits of GMOs and to foster a positive attitude towards transgenic technology by increasing the public's scientific literacy and knowledge. However, whether transgenic technology is perceived as safe is a question of cognition and morality. Despite scientific consensus that genetically improved crops are no more threatening to the environment or dangerous

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to humans than traditional crops (Nicolia et al., 2014), there remain many GMO opponents who ignore factual evidence and remain unaffected by the risk–benefit analysis. This group of absolutists forms the majority of GMO opponents. In contrast to consequentialists, they believe that a technology with potential risks 'should be prohibited absolutely no matter how great the benefits and minor the risks from allowing it' (Scott et al., 2016). Research finds that, for products with the same chemical components, people still tend to prefer the 'natural' one (Rozin, 2005; Rozin et al., 2004); the low perceived naturalness of genetically modified (GM) crops indicates that negative public attitudes towards them will persist in the long term (Tenbült et al., 2005). Researchers have advocated investigating the underlying intuitions and emotions of disgust for GMOs and examining food disgust as a moralization process (Rozin, 1999; Rozin et al., 1997).

The social intuitionist model explains the above situation by emphatically justifying emotions and intuitions in moral judgement (Haidt, 2001). In the discourse of GMO opponents, representations that appeal to the audience intuitively are mainly based on folk biology steeped in psychological essentialism, with the belief that organisms are immutable rather than the result of resource competition or reproduction (Gelman, 2004); and nature worship, with the teleological/intentional intuition that views nature as purposefully created and genetic engineering as a god-playing act against nature (Järnefelt et al., 2015).

In addition, emotional disgust also plays an important role in the assessment of the risks of GMOs (Savadori et al., 2004). Emotional disgust for GMOs possibly arises from psychological essentialism, whereby people intuitively interpret genetic modification as an unwarranted and contaminating intervention into the essence of an organism, rendering it impure and, therefore, no longer consumable. The effect is probably greater when the introduced DNA derives from a different species, especially one considered 'dirty'. Compared with scientific discourse that requires enhanced cognitive effort, such representations can better capture attention and are more easily understood, remembered, mentally processed and disseminated; consequently, they are termed 'cultural attractors' (Blancke et al., 2015).

For this study, we conducted two interrelated experiments from the perspective of moral psychology, examining how the intuitive moral judgement underlying disgust for GMOs is influenced by scenario features, individual differences and emotions in response to the current theoretical debate, hence offering practical advice for science communication on GMOs.

2. The nature of moral judgement and emotional disgust

Moral judgement is the evaluation of moral values, such as right versus wrong or good versus bad (Chapman and Anderson, 2013), and is often made quickly by relying on feelings after the heuristic process, without involving cognitive efforts or deliberation (Sinnott-Armstrong et al., 2010). In the process of moral intuition, affective valence appears suddenly and without any conscious awareness by the subject of having searched for and weighed evidence before inferring a conclusion (Haidt, 2001). Therefore, automatic moral intuition is core to moral judgement, while moral reasoning is just a tool for justifying an already made intuitive judgement or for sharing or solving intuitive contradictions with others. In the process of moral judgement, emotional disgust is a better indicator than rational cognition. According to moral foundations theory, disgust originated from purity/sanctity—one of the five moral domains (Horberg et al., 2009)—and evolved to motivate the avoidance of contact with disease-causing organisms and toxins

(Tybur et al., 2013). This evolutionary view on emotional disgust is called the 'pathogen avoidance perspective'. The public's disgust for GM food shows the pursuit of purity.

Narrowly speaking, disgust is a food-related emotion of revulsion at the prospect of oral incorporation of offensive objects (Rozin and Fallon, 1987). Broadly speaking, it is part of the behavioural immune system that guards the body, soul and social order against defilement, protecting people against harmful food, sex and interpersonal contact (Haidt et al., 1994), as well as illness (Schaller and Park, 2011), and keeping potential toxins outside the body (Toronchuk and Ellis, 2007). Emotional disgust is often elicited by particular foods, even when they are completely non-toxic. People's intuitive avoidance of GMO crops and overestimation of their risks represents the operation of the disease avoidance mechanism, which is prone to false alarms and magnifies disgust despite worry being unnecessary (Oaten et al., 2009). It is very difficult to transcend and overthrow the clues of contamination, and the influence of affective clues of diseases and contagion cannot be thoroughly replaced cognitively. Consequently, it is difficult for people to thoroughly overcome disgust (Rozin et al., 1986).

Emotional disgust incites people to condemn not only GM foods but also the producers and developers of GM products as immoral (Blancke et al., 2015). However, this emotion is not directly elicited by the elicitor but, rather, occurs when individuals evaluate it according to their goals and resources. Although disgust, fear, anger and contempt are highly interrelated and will all trigger strict condemnation (Royzman et al., 2014), disgust is not the only emotion related to morality, and negative emotions differ from each other: for example, physical disgust relates to avoidance (Rozin et al., 1999a), anger relates to approach (Fischer and Roseman, 2007) and fear results from neophobia (Sjöberg, 2000). Negative emotions may occur simultaneously, so they should be investigated together with emotional disgust to better understand which emotions truly influence opposition to GMOs and to establish more accurate relationships between different emotions and moral judgements on GMOs.

3. The dual physical–social characteristic of moral disgust for GMOs

People's absolute opposition to GM foods reflects their trait disgust sensitivity (Scott et al., 2016). This shows that state disgust for GM foods results from interactions between the disgust elicitor and trait disgust. State disgust is a transitory emotional state, while trait disgust is a dispositional trait reflecting how readily and intensely a particular individual experiences disgust in response to a potential disgust elicitor (Clifford and Wendell, 2016). Trait disgust does not equate to state disgust. It regulates how an individual selects and experiences specific environments and requires interactions with disgust elicitors to influence the formation of emotional states and attitudes.

The elicitors of trait disgust and state disgust all possess multiple orientations of physicality and social morality. Disgust not only relates to food but also includes the social rejection of acts of injustice, such as moral transgressions (for example, hypocrisy, flattery, betrayal, theft, cheating and fraud) (Tybur et al., 2009). People in different cultures use similar words (such as 'disgust', 'abhorrence' and 'repulsion') and facial expressions in rejecting physically disgusting or socially inappropriate people and behaviours.

Moral disgust is elicited by violations of social and moral norms, which do not have to involve any bodily aggression and may take the form of moral transgression or purity transgression (Chapman and Anderson, 2013). These mainly manifest as individuals' failure to fulfil their community or hierarchical

responsibility, or as contempt or autonomy violations infringing others' rights or eliciting anger (Rozin et al., 1999b). On the one hand, transgenic technology elicits people's suspicion of species purity and their physical disgust. On the other hand, the prevalence of conspiracy theories increasingly convinces people that transgenic technology will undermine domains of autonomy, including the public's right to know. Therefore, moral disgust for GMOs is close to an intersecting-appraisal model fusing distaste appraisal and physical disgust appraisal (Chapman and Anderson, 2013). Further investigation is therefore needed to differentiate the physical and social dimensions of state disgust and trait disgust for GMOs.

Disgust elicitors may be divided into non-social and social elicitors. The former mainly refers to elicitors of physical (or core) disgust (Nabi, 2002), which involves the oral rejection system; the latter mainly refers to elicitors of sociomoral disgust at the violation and contamination of social norms (Rubenking and Lang, 2014). Existing research has focused on the effect of physical disgust elicitation on the strictness of moral judgement (Wheatley and Haidt, 2005), with little consideration of the possible different routes through which physical disgust and sociomoral disgust elicitors influence moral judgement.

Disgust sensitivity is also a multidimensional construct. It includes pathogen disgust, which serves as a first line of defence that functions as a behavioural immune system, preventing contact with and the intake of pathogens; and moral disgust, which motivates the individual to avoid violations of social norms (Tybur et al., 2009). Existing research, when using individual differences in trait disgust to explain attitudes towards GMOs, does not generally distinguish between the two. Since excessive stimuli will divert cognition from information encoding and reduce memory (Bradley et al., 2001), and because sociomoral disgust elicits a slower response pattern than core disgust (Rubenking and Lang, 2014), sociomoral disgust may possess certain cognition-enhancing functions that motivate people to form a fairer moral judgement on GMOs.

Based on the foregoing, this study investigated the following research question:

RQ1: How do individual differences in pathogen disgust sensitivity and moral disgust sensitivity influence passive emotional states (disgust, fear and anger) elicited in people by different types of disgust (non-disgust, core disgust or sociomoral disgust) and affect their judgements on GMOs?

4. The conditionality of intuitive judgement: Examining preferences for precepts implied in moral theories and emotion reappraisal underlying disgust for GMOs

People make some moral judgements intuitively, without awareness or deliberate processing (Lazarus, 1991), and make other judgements by resorting to moral theories with high normative and cognitive requirements, in a counter-intuitive way (Kahane et al., 2012). Research finds that people in whom positive emotions are elicited are less prone to making intuitive moral judgements (Valdesolo and DeSteno, 2006), leading to debate on the role of intuitions and the deliberative process. Some scholars propose dual-process models of moral judgement (Feinberg et al., 2012), contending that emotion-driven intuitive moral judgements can be replaced by deliberate moral judgements in certain conditions. The emotion-regulation perspective posits that individuals regulate themselves by the types and degrees of emotions they feel (Gross and John, 2003). Besides strategies such as expressive suppression and attentional deployment (Gross, 2007), emotion reappraisal (ER) allows individuals

to lower the intensity of emotional experiences by constructing emotion-eliciting conditions or events (Gross, 2002). When people face potential immoral behaviours, ER will bring reduced emotional intensity, thereby restricting the impact of intuitions and allowing the more deliberative formation of moral judgements.

The degree to which moral intuitions are suppressed by ER can vary among individuals. In view of the flexibility of moral judgement, some scholars propose the agent–deed–consequence (ADC) model to supplement the moral foundations theory, which states that, although most untrained individuals lack explicit knowledge of philosophical ethics, their intuitive moral judgements correspond to certain moral precepts implied in key ethical theories (Dewey, 2009), such as:

- *virtue ethics*, which focuses on the intentions and character of a person involved in a morally salient situation
- *deontology*, which focuses on the analysis of actions that a person is duty-bound to undertake
- *consequentialism*, which focuses on the balance of harms and gains resulting from the morally salient situation (Dubljević and Racine, 2014).

According to the integrative approach of the ADC model, when the three moral intuitions diverge, people will show preferences for precepts implied in moral theories (PPIMT). Those preferences are acquired through social learning and remain relatively stable as personality traits over time (Railton, 2017). As an ethical framework, moral preferences produce a framing effect by moderating the accessibility, focus or awareness of key information and influencing people's perception of scenarios and the focus of moral precepts. They also regulate attention allocation in the process of moral judgement, causing people to not consider and even neglect other information, ultimately influencing their moral judgements (Tanner et al., 2008). Absolutist opposition to GMOs reflects absolute moral values without regard to consequentialist precepts, in which generalizations elicit emotions and lead to wrong judgements (Baron and Spranca, 1997), whereas the consequentialist reasoning of the deliberative process may transcend intuitions (Greene et al., 2004).

Based on the foregoing, this study investigated the following research question:

RQ2: How are different types of disgust influencing individuals' moral judgement and ultimate stance on GMOs regulated by the ER process and moral preferences?

We have answered the two research questions through two experiments, as described below, and offer a detailed supplementary dialogue on existing theories based on a summary of the findings.

5. Experiment 1: External disgust elicits moral judgement on GMOs

Experiment 1 examined, through a single-factor between-subject experiment, whether different types of disgust elicitation (non-disgust elicitation, core disgust elicitation or sociomoral disgust elicitation) can elicit different degrees of disgust, fear and anger in people and, consequently, influence their moral judgements on GMOs. The research controlled for subjects' existing absolute opposition to GMOs and included pathogen disgust sensitivity and moral disgust sensitivity in the scope of analysis as moderating variables.

5.1 Research method

5.1.1 Sample composition

A total of 209 students from two universities, one in Southeast China (n = 161, 77%) and

the other in Northwest China (n = 48, 23%), participated in the experiment. Their average age was 20.73 years (SD = 1.482); most were Chinese (n = 202, 96.7%) and the remainder were foreign (n = 7, 3.3%); 58 were male (27.8%) and 151 were female (72.2%); 177 studied humanities (84.7%) and 32 studied sciences (15.3%); 190 were undergraduates (90.9%) and 19 were graduates (9.1%); 26 were freshmen (12.4%), 22 were sophomores (10.5%), 120 were juniors (57.4%) and 41 were seniors (19.6%).

5.1.2 Experimental process and the measurement of variables

The experiment took the form of an online Chinese-language questionnaire survey in which additional course credits were offered to all participants. Wherever the concept of 'disgust' appeared in the questionnaire, disgust was expressed by the two Chinese words *yanwu* and *e'xin* side by side to avoid cross-cultural misunderstanding (Barger et al., 2010). To measure trait disgust, participants first completed the section of the Disgust Domain Scale on pathogen disgust sensitivity and moral disgust sensitivity: the former included seven items, such as 'stepping in dog poop' (mean = 4.612, SD = 1.112), with fairly good internal consistency (Cronbach's α = 0.804); the latter also included seven items, such as 'cheating friends' (mean = 5.807, SD = 0.843), with acceptable reliability (Cronbach's α = 0.769) (for more detail on the scales, see Tybur et al., 2009). Participants' absolute opposition to GMOs was measured by four items, including 'GMOs should be banned no matter how great the benefits and minor the risks' (Baron and Spranca, 1997). The average score on a 7-point scale was 2.88 (SD = 1.18), and the scale showed good reliability (Cronbach's α = 0.767).

The next step was an autobiographical writing task for disgust elicitation (Schnall et al., 2008). Participants were randomly allocated to the control group (n = 70), core disgust elicitation group (n = 69) or socio-moral disgust elicitation group (n = 70) and were required to describe, in at least four sentences, an event they had recently experienced. Participants in the control group were required to describe 'a typical or everyday behavioural event'; those in the core disgust group had to describe 'a physically disgusting event causing physical discomfort, disgust, unpleasant oral sensation or stomach upset' (Clifford and Wendell, 2016); those in the moral disgust group had to describe 'a morally disgusting event violating social norms' (Rubenking and Lang, 2014). The three groups did not significantly differ in gender (P = 0.188), age (P = 0.424), major discipline (P = 0.374), training category (P = 0.459), nationality (P = 0.345), region (P = 0.563) or grade (P = 0.773).

To measure emotional state, participants were asked to describe disgust (mean = 4.22, SD = 2.08), fear (mean = 2.60, SD = 1.76) and anger (mean = 3.68, SD = 2.05) on a 7-point Likert scale (Scott et al., 2016). To better reflect the research context, the moral acceptability scale (Tannenbaum et al., 2011) was revised to measure moral judgement, including two items such as 'With all factors considered, GMOs are morally acceptable to me/society' (Cronbach's α = 0.648, mean = 4.36, SD = 1.24), which showed average moral acceptability of 4.86 (SD = 1.48) and average social acceptability of 3.86 (SD = 1.41).

5.2 Results for Experiment 1

Using the SPSS PROCESS package (Hayes, 2013), bootstrap sampling was set at 5,000 with a confidence interval of 95%, and a conditional process model was established, as shown in Table 1. After controlling for the degree of existing absolute opposition to GMOs, participants' state disgust (b = 8.97, P < 0.001) and state anger (b = 6.60, P < 0.01)

Table 1: Effects of disgust elicitation types and trait disgust on emotional state and moral judgement on GMOs ($n = 209$)

	State disgust	State fear	State anger	Moral judgement on GMOs
	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)	Coeff. (SE)
Constant	–18.15 (5.44) **	–4.80 (4.86)	–15.90 (5.49) **	13.08 (2.93) ***
Absolutism	0.19 (0.06) **	0.13 (0.05) *	0.17 (0.06) **	–0.54 (0.03) ***
Disgust elicitation type	8.97 (2.39) ***	3.41 (2.14)	6.60 (2.41) **	–3.42 (1.29) **
Trait disgust—Pathogen	3.65 (1.31) ***	1.19 (1.17)	3.10 (1.32) *	–2.30 (0.70) **
Trait disgust—Moral	3.49 (0.94) ***	1.10 (0.84)	3.48 (0.94) ***	–1.19 (0.50) *
Treatment * Pathogen	–1.55 (0.57) **	–0.52 (0.51)	–1.04 (0.58)	1.04 (0.31) **
Treatment * Moral	–1.54 (0.41) ***	–0.64 (0.37)	–1.30 (0.42) **	0.54 (0.22) *
Pathogen * Moral	–0.61 (0.22) **	–0.18 (0.20)	–0.60 (0.22) **	0.37 (0.12) **
Treatment * Pathogen * Moral	0.29 (0.10) **	0.10 (0.09)	0.23 (0.10) *	–0.17 (0.05) **
State disgust				0.12 (0.03) ***
State fear				–0.02 (0.02)
State anger				–0.01 (0.03)
F	17.23 ***	4.09 **	11.81 ***	34.73 ***
R^2	14.29%	3.81%	10.25%	31.67%

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

were significantly influenced by different types of disgust elicitation conditions, and their moral judgements on GMOs were also significantly influenced by the different types of disgust elicitation (b = –3.42, $P < 0.01$). Consistent with prior findings, there was a positive correlation between an individual's pathogen disgust sensitivity and their state disgust (b = 3.65, $P < 0.001$), state anger (b = 3.10, $P < 0.05$) and tendency to morally reject GMOs (b = –2.30, $P < 0.01$). Moral disgust sensitivity works in roughly the same direction as pathogen disgust in increasing state disgust (b = 3.49, $P < 0.001$) and state anger (b = 3.48, $P < 0.001$) and in reducing moral judgement (b = –1.19, $P < 0.05$) on GMOs.

When disgust elicitation conditions and the two types of trait disgust influenced state disgust, state anger and moral judgement on GMOs, they exhibited significant second-order and third-order interaction effects.

As shown in Figure 1-a, one type of trait disgust may increase the state disgust of the other (weaker) type of trait disgust. When core disgust is elicited, the two types of trait disgust independently increase state disgust in individuals. Under the condition of socio-moral disgust, the lower the individual's moral disgust sensitivity, the lower the increase in their perceived moral acceptability of GMOs as trait pathogen disgust increased; when individuals with higher trait pathogen disgust had a medium or higher level of trait moral disgust, their perceived moral acceptance of GMOs increased with their moral disgust sensitivity.

Figure 1-b shows how the direct effects of moral judgement on GMOs changed with disgust elicitation types and trait disgust. Unlike in Figure 1-a, in the absence of disgust elicitation, trait pathogen disgust motivated individuals to make stricter moral judgements on GMOs, while trait moral disgust increased their moral tolerance of GMOs. Core disgust elicitation made people's moral judgements on GMOs less regulated by trait disgust. When sociomoral disgust was elicited, trait pathogen disgust and trait moral disgust were jointly operational: if individuals had high sensitivity to both types of disgust, then their moral evaluation of GMOs decreased more as trait disgust increased.

When the three types of emotional state (intermediary variables), the control variables and regulation variables were included in the regression model predicting moral judgement on GMOs, only state disgust exhibited a significant intermediary effect on moral judgement (b = 0.12, $P < 0.001$). State anger was not influenced by trait disgust, tasks that elicited disgust or the type of such tasks. It was also not related with moral judgement on GMOs. While state fear was related to disgust sensitivity and could be elicited by different types of disgust, that emotional state was not necessarily related to moral judgement on GMOs. Therefore, even though disgust elicitation tasks could produce other emotions simultaneously, moral judgement was subject only to the influence of disgust type, trait disgust and state disgust. This result bears out the indirect effect of state disgust on moral judgement about GMOs and supports the single-emotion theory of intuitive judgement of moral disgust.

6. Experiment 2: Intuitive judgement on GMOs through moral concepts and ER

Experiment 2 adopted a 3 (disgust types: non-disgust, core disgust, sociomoral disgust) * 2 (ER: no vs. yes) two-factor between-subject design, in which individuals' moral preference served as a moderating variable, to examine whether the influence of disgust types and ER on people's moral judgement and ultimate stance on GMOs varies among individuals.

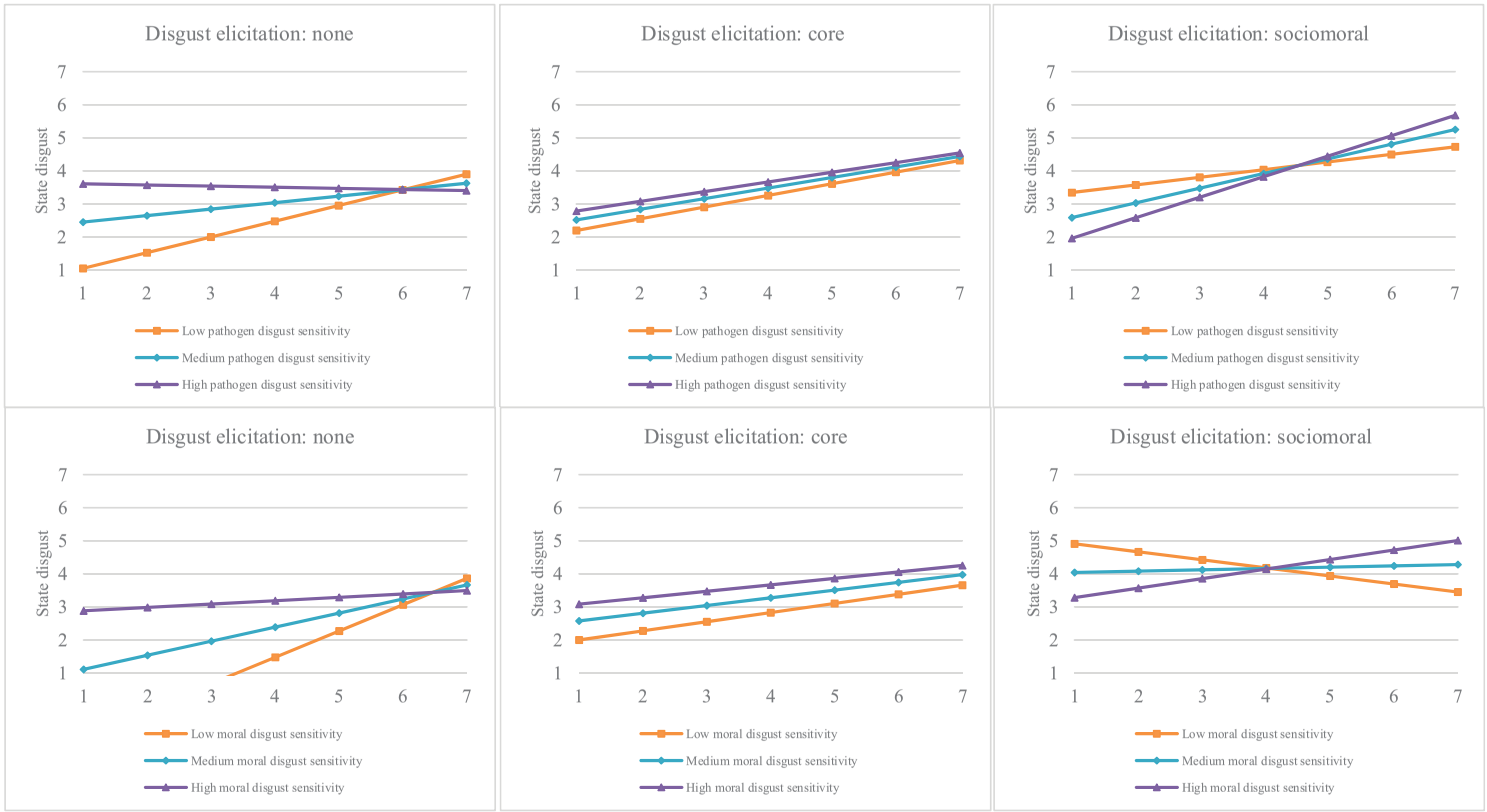

Figure 1-a: Moderating effects of pathogen disgust sensitivity (top) and moral disgust sensitivity (bottom) on state disgust under the conditions of no disgust elicitation (left), core disgust elicitation (middle) and sociomoral disgust elicitation (right)

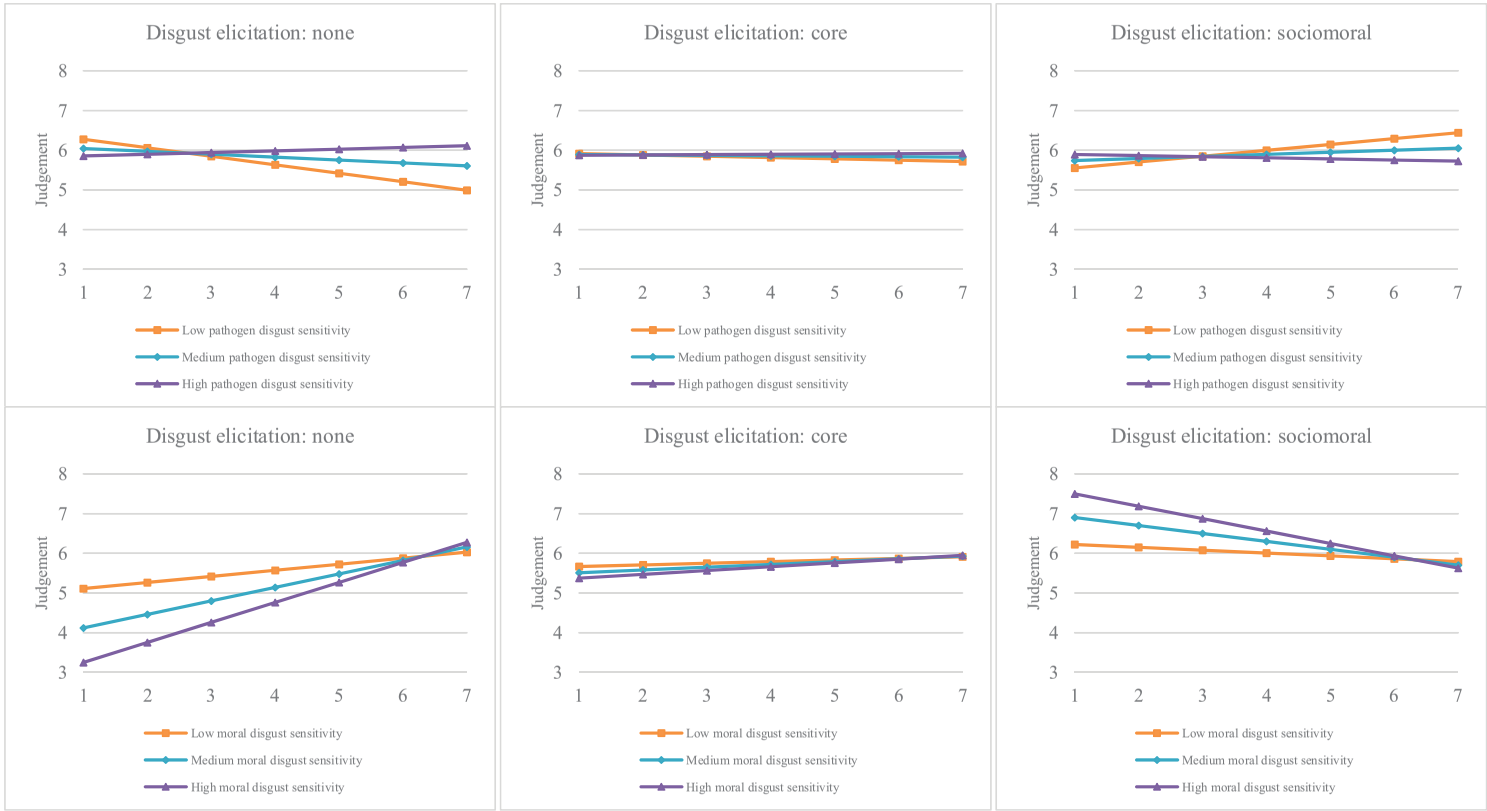

Figure 1-b: Moderating effects on the direct effect of pathogen disgust sensitivity (top) and moral disgust sensitivity (bottom) on moral judgement on GMOs under the conditions of no disgust elicitation (left), core disgust elicitation (middle) and sociomoral disgust elicitation (right)

6.1 Research method

Experiment 2 used the same sample as Experiment 1. For the control of variables before disgust elicitation, this experiment not only measured pathogen disgust sensitivity, moral disgust sensitivity and existing absolutist opposition to GMOs, but also drew on a tool used previously to measure individuals' normative moral preferences, by asking them to rate a series of factors influencing their moral judgements (Dubljević et al., 2018). As shown by factor analysis, the average score on a 7-point Likert scale was 5.71 (SD = 1.03) for the four virtue ethics items, including 'Is this well-intended or ill-intended?' (Cronbach's $\alpha = 0.884$); 5.48 (SD = 0.98) for the five moralist items, including 'Does this comply with a specific duty?' (Cronbach's $\alpha = 0.896$); 5.62 (SD = 0.87) for the six consequentialism items, including 'Will this bring well-being or harm?' (Cronbach's $\alpha = 0.820$). The moral concept on which a participant scored highest was then set as their moral preference, and those with the same score for two or more moral concepts were classified as 'other'. According to their moral preferences, the participants comprised 70 virtue ethicists (33.5%), 37 deontologists (17.7%), 56 consequentialists (26.8%) and 46 in the 'other' category (22.0%).

To manipulate disgust type, each participant was randomly assigned to one of the four conditions to read the purchase and use scenarios of four products: papaya, tuna, a cotton shirt and laboratory mice. The disgust type of the reading content was consistent with the result of the random allocation in Experiment 1. The non-disgust group read about ordinary products (for example, 'Xiao Zhang bought and ate a papaya'); the core disgust group read about the informed purchase of GM products (for example, 'Xiao Li, with informed consent, bought and ate a tuna sandwich containing GM tuna with growth-boosting DNA'); and the sociomoral disgust group read about the uninformed purchase of GM products (for example, 'Medical student Xiao Zhao, without informed consent, bought a batch of GM mice to facilitate genetic research in the laboratory') (Scott et al., 2016).

To manipulate ER, participants were randomly allocated to experimental groups with or without ER: those in the groups with ER were asked to use at least four sentences to describe their main thinking process when completing the questionnaire (Feinberg et al., 2012). The six experimental groups with different combinations of the three disgust types and two ER conditions did not vary significantly in gender ($P = 0.346$), age ($P = 0.603$), major discipline ($P = 0.701$), training category ($P = 0.329$), nationality ($P = 0.547$), region ($P = 0.330$), or grade ($P = 0.331$). Finally, all participants were asked to rate four items on absolutist opposition to GMOs on a 7-point Likert scale (Cronbach's $\alpha = 0.815$, mean = 2.93, SD = 1.22). Moral judgement on GMOs as an intermediary variable was measured as in Experiment 1.

6.2 Results for Experiment 2

The stronger a participant's existing absolute opposition to GMOs, the more likely they were to consider GMOs immoral ($b = -0.54$, $P < 0.001$); and participants maintained a significant anti-GMO stance even after ER ($b = 0.72$, $P < 0.001$). Opposition to GMOs was increased by pathogen disgust sensitivity ($b = 0.09$, $P < 0.001$) and suppressed by moral disgust sensitivity ($b = -0.08$, $P < 0.01$), while moral judgement on GMOs was not affected by trait disgust. Individuals with different moral preferences differed significantly in their moral judgements on GMOs ($b = -0.65$, $P < 0.05$) and absolute opposition to GMOs after ER ($b = 0.71$, $P < 0.001$). Moral preferences also regulated the effects of disgust types, ER and their interactions on moral judgement on GMOs and opposition to GMOs after ER. Moral judgement could

significantly reduce opposition to GMOs (b = –0.16, $P < 0.001$) and partially mediate the effect of independent variables and moderating variables on dependent variables (see Table 2).

As Figure 2 shows, in the non-disgust scenario for non-GM products, consequentialists were the most likely to be influenced by the moderating effect of ER, to positively assess the morality of GMOs and to have lowered absolute opposition. They were followed by deontologists, while virtue ethicists remained relatively stable in their stance and moral judgement on GMOs. In the core disgust scenario of the informed purchase of GM products, ER helped to increase deontologists' and consequentialists' assessment of the morality of GMOs and lower their GMO opposition; only virtue ethicists showed increased opposition to GMOs after the ER intervention. In the sociomoral disgust scenario of the uninformed purchase of GM products, ER positively changed moral judgement on GMOs in consequentialists (the strongest effect), deontologists and virtue ethicists (the weakest effect), but, due to the elicitation of sociomoral disgust, opposition to GMOs also increased, indicating that such opposition is generally more stable than moral judgement and that its formation requires the mobilization of moral deliberation and cognitive reasoning.

7. Discussion and conclusions

When shaping individuals' expectations of the world and their evaluation of the risks of new technologies, emotions and intuitions may lead to rational judgement or the dissolution of rationality (Finucane et al., 2000). People make some decisions quickly, without awareness of their decision-making process. Intuitions may oppose rationality, especially when people face complicated and abstract situations. Due to lack of interest, thinking or attention concerning complicated questions such as genetic modification technology, laypeople evaluating the risk of GMOs tend to rely on their intuitive mind and choose expressions conforming to their expectations to facilitate understanding and memorization.

Table 2: Moderating effects of disgust types and ER on the influence of moral preferences on judgement and stance on GMOs ($n = 209$)

	Moral judgement on GMOs		**Absolutism—after ER**	
	Coeff. (SE)		**Coeff. (SE)**	
Constant	6.20 (0.55)	***	1.10 (0.40)	**
Absolutism—before ER	–0.54 (0.03)	***	0.72 (0.02)	***
Pathogen disgust sensitivity	0.01 (0.04)		0.09 (0.02)	***
Moral disgust sensitivity	0.07 (0.05)		–0.08 (0.03)	**
Disgust type	–0.46 (0.24)		0.12 (0.16)	
PPIMT	–0.65 (0.28)	*	0.71 (0.19)	***
ER	–0.48 (0.32)		0.43 (0.22)	
Type * PPIMT	0.31 (0.13)	*	–0.29 (0.09)	**
Type * ER	0.28 (0.15)		–0.10 (0.10)	
PPIMT * ER	0.37 (0.17)	*	–0.50 (0.12)	***
Type * PPIMT * ER	–0.16 (0.08)	*	0.19 (0.06)	**
Judgement			–0.16 (0.02)	***
F	32.51	***	144.12	***
R^2	28.27%		65.80%	

*$P < 0.05$; **$P < 0.01$, ***$P < 0.001$

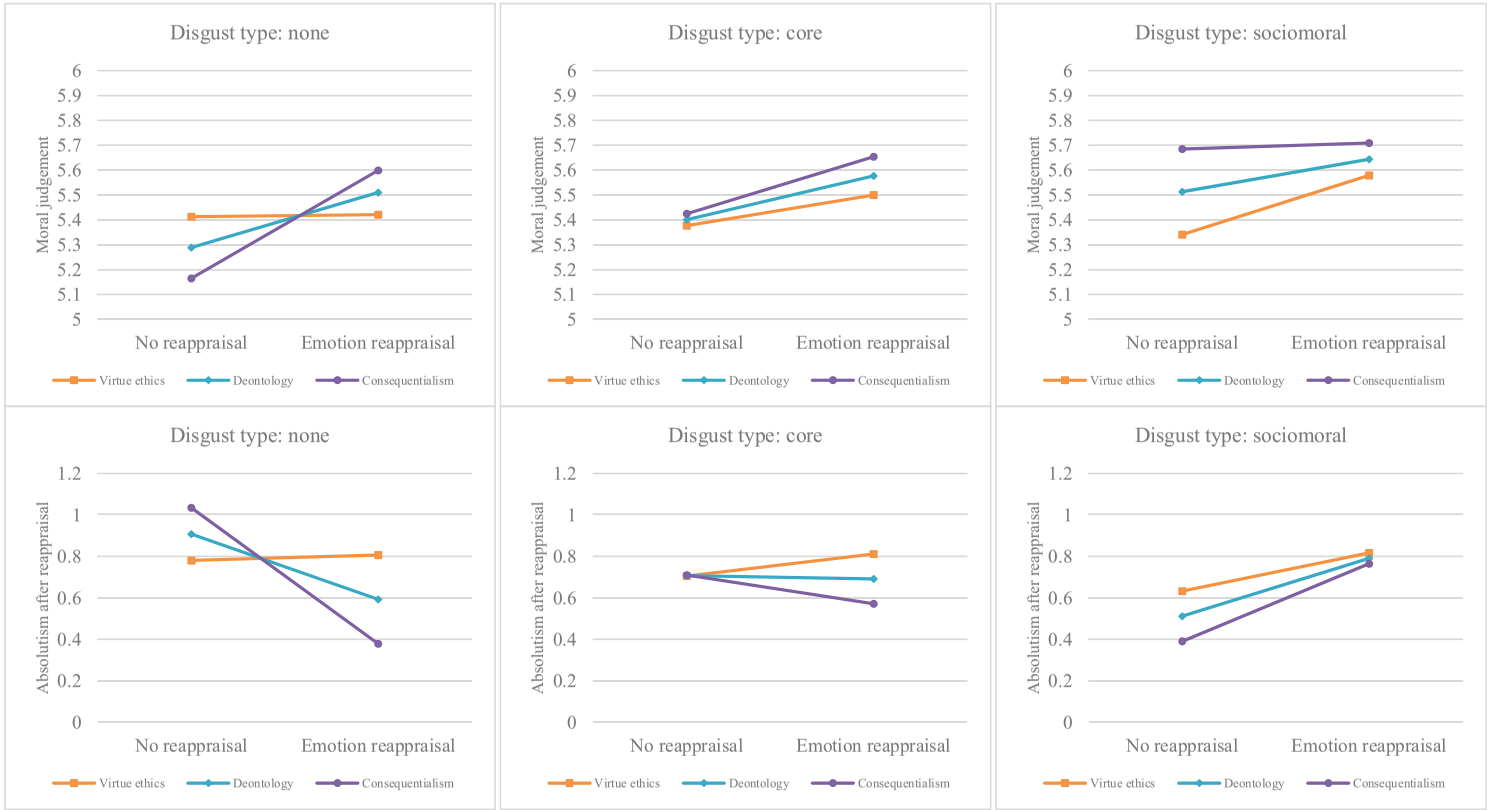

Figure 2: Moderating effects of emotion reappraisal and moral preferences on the direct effect of moral evaluation of GMOs (top) and absolute opposition to GMOs (bottom) under the conditions of no disgust elicitation (left), core disgust elicitation (middle) and sociomoral disgust elicitation (right)

Intuitions do not directly undermine rationality. Absolute opposition to GMOs arises from the absence of factors suppressing intuitive thinking, especially when scientific discourse lacks cultural appeal. Therefore, although disgust for GMOs has a strong attraction for the public, scientific discourse should not withdraw (Blancke et al., 2015).

Through two interrelated experiments, this study revealed the mechanism of disgust influencing moral judgement on GMOs, and demonstrated the effects of scenario factors such as disgust elicitation types and ER, as well as individual differences such as trait disgust and moral preferences. The main findings of the experiments are shown in Figure 3.

State disgust and trait disgust are mutually conditional or interacting. Disgust, anger and fear differ in their elicitation mechanisms and mediating effect on moral judgement, while external disgust elicitation types act only on disgust and anger, which is related to sociomoral factors.

Our study examined the different routes through which sociomoral disgust and moral disgust influence moral judgements on GMOs. When sociomoral disgust elicitation was matched with higher moral disgust sensitivity, trait disgust differed from the other five conditions in moderating state disgust (see the bottom right of Figure 1-a). There was a positive correlation between the perceived morality of GMOs and state disgust: the more

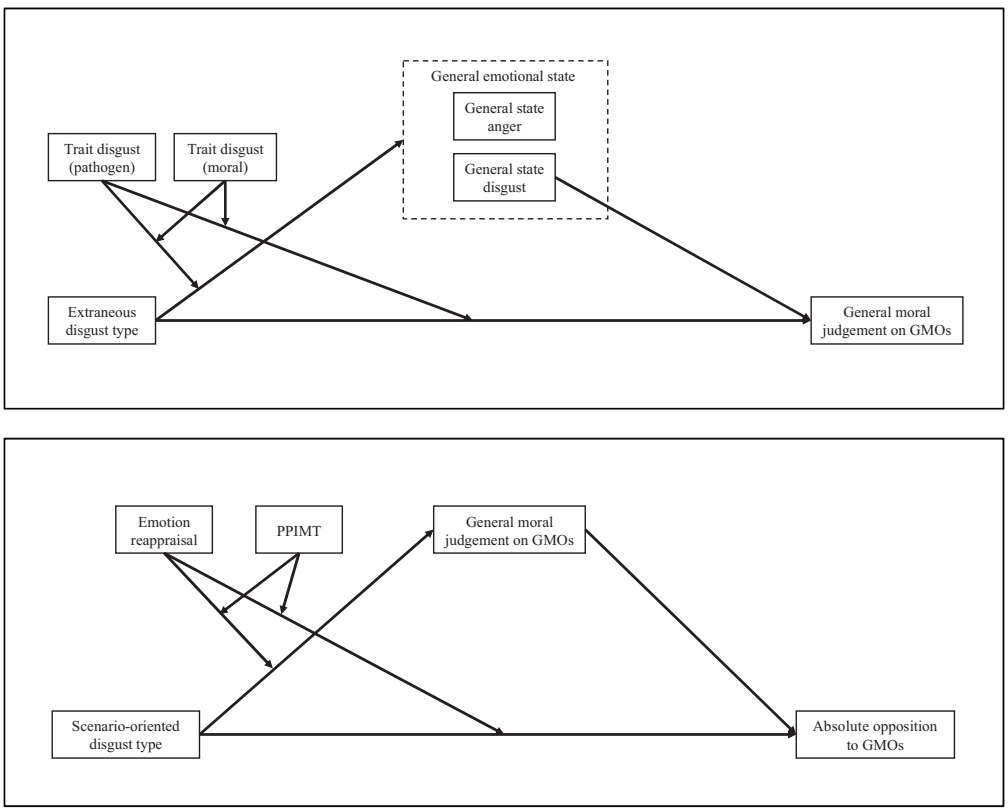

Figure 3: Main conclusions of Experiment 1 (top) and Experiment 2 (bottom)
PPIMT = preferences for precepts implied in moral theories

clearly people experienced disgust, the more directly their moral judgement was influenced by it; negative situational emotions were also suppressed by moral disgust sensitivity.

Our findings provide evidence that:

- emotional states cannot be equated to moral judgements in certain scenarios
- compared with core disgust, sociomoral disgust elicitation has a lower emotion elicitation potential and higher cognitive level
- emotional awareness can, to some extent, play the role of ER (Gross and John, 2003)
- moral disgust can also promote moral cognition and lower the harshness of moral evaluation.

Real-world science communication on GMOs should feature contents informed by these insights to promote individuals' emotional awareness and the transition from intuitive thinking to rational moral attribution.

Moral awareness may, together with ethical predispositions, act on moral judgement and activate preferences for precepts (Dubljević et al., 2018). Communicators of genetic science could appeal to the audience's moralization process by priming their moral precepts to motivate moral deliberation (Horberg et al., 2009). Science communication should overcome the inherent bias in everyday Chinese discourse that vulgarizes utilitarianism/consequentialism and even ethical egoism as being 'immoral': consequentialists can overcome moral intuitions by weighing harms and gains, while deontologists also value the possible outcomes of GMOs through gain–risk evaluations of genetic modification technology (Tanner et al., 2008). Only by educating and training the audience in reflective ability can the damage of intuitive thinking be avoided.

Science communication on GMOs should comprehensively consider differences in individual and scenario features by adopting formats capable of motivating the audience's emotional awareness and reflection; it should avoid content that elicits sociomoral disgust and adjust content according to individual differences in moral preferences and disgust sensitivity.

This study had four main limitations.

First, since the sample mainly consisted of Chinese college students, our conclusions might not apply to other groups of the population. Moral disgust is a phenomenon of developmental psychology. The psychological traits of teenagers and their underlying mechanisms are not necessarily stable over time, and there might be generational differences in the acceptance of GMOs in China due to a combination of factors, such as education, cultural tradition and knowledge gaps. Accordingly, caution should be exercised in applying the experimental conclusions of this study to other groups.

Second, moral acceptability does not equate to cognitive or behavioural acceptance, and GMO opponents may nonetheless buy GM food (Scott, et al., 2016). Emotional disgust may affect how much money people are willing to spend on specific products (Lerner et al., 2004). Future research should focus on the relationship between emotions and the purchase intent of prospective consumers of GM products.

Third, people's evaluation of public policy relies more on their existing political attitudes than on manipulated disgust. Whether risk assessment of GMOs relies on emotions (Schnall et al., 2008) and whether the rejection of GMOs is immoral or non-moral also deserve further investigation.

Finally, it is difficult to differentiate disgust for GMOs and other negative emotions through oral self-reports (Chapman and Anderson, 2013). Further validation by functional neuroimaging and psychophysiological research is needed.

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The evolution of online discussions about GMOs in China over the past decade: Changes, causes and characteristics

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Abstract

This paper uses word frequency statistics and semantic network analysis to analyse text related to genetically modified organisms (GMOs) in microblog in China. We discuss the structure of the main discourses and changes in them over the past decade, explore the reasons for those changes and provide possible references that may be useful when related problems or situations occur in future. We have found that conspiracy theories permeated online discussions and that netizens' emotions had a nationalist tendency. The GMO issue was highly socialized. Participants in online discussions were from different backgrounds, and the topics went far beyond GMO technology. The public tended to trust the government, rather than experts, while opinion leaders also played a role in guiding public opinion. The keywords in this discussion have gradually changed in recent years from clustering around 'harmful' to clustering around 'scientific', and new participation models brought about by new media have provided new reference paths for problem solving.

Key words

GMOs, microblogging, discourse changes, semantic network

1. Introduction

As a controversial socio-scientific issue, genetically modified organisms (GMOs) have attracted extensive attention in recent years. In this mediated era, the 'socialization of science and scientization of society have become prominent features of contemporary society, as communication between science and society has become ever deeper' (Jin and

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Xu, 2017). In the debate about GMOs, the public has gradually become indifferent to the scientific nature of agricultural biotechnology. The scientific issue has gradually evolved into a social issue, while the scientific aspects of the debate have been gradually eliminated. GMO technology and its products are closely related to the public's life. When GMO-related events occur, digital media platforms are the sites of much discussion and extremely heated debates. While digital technologies have given more citizens a voice in the debates, different views can hinder the development and promotion of agricultural biotechnology and related knowledge, as well as the formulation of appropriate policies.

At present, although the government offers more support for the GMO industry and helps promote GMO production, and the online debate has come to a relative silent state, there has been no evident improvement in public acceptance of GMOs (Jia and Fan, 2016). Why have debates about GMOs not yet been resolved till now? Some studies have found that the main reason is that the public cannot trust the government and scientists. In other words, there is an insurmountable lack of trust (Jia and Fan, 2015; Jin and Chu, 2015). Some studies have indicated that this is because people in China are susceptible to the traditional Chinese thinking mode of intuitive extrapolation (Fan et al., 2013), making it hard for them to accept GMOs. In addition, some studies have collected data on the media's performance on GMO topics and demonstrated that the audiences' attitudes have been influenced to some degree by the media chosen by the audiences and the orientation of those media (Cheng, 2016; Xu and Liu, 2018a). Other studies have suggested that experts play a vital role in guiding the public's attitudes (Dai et al., 2015), but that there has been little timely and effective communication between experts and the public (Xu and Liu, 2018b). Such attitude-influencing factors all have rational foundations, but some core elements remain unclear, such as how to enhance communications between science and public opinion and establish a trust mechanism.

In this paper, we contend that only by finding out what the public is concerned about, based on online public discourse, can we identify the key elements that influence people's attitudes, better understand the nature of the debates on GMOs and ultimately solve the communication problem. We describe trends in the public discourse using word frequency statistics and semantic network analysis, and discuss the policies and specific cases that have changed discourse over time.

2. Changes in the public discourse on GMOs

With the 'public participation' shift in science communication, laypeople are able to express their opinions on accessible media platforms and negotiate with other discourses. Gradually, public views about and attitudes to scientific and technological issues have come to be taken seriously and to some extent have affected policymaking. However, the relatively free and relaxed environment for public comment has caused a confrontation between heterogeneous discourses, and the debate about GMOs was born in those circumstances. Generally, the Chinese public's opinions about and attitudes towards GMOs have been greatly affected by online debate and have moved through three discernible stages.

In 2002, the proportion of respondents who thought genetically modified (GM) foods were unsafe was about 13%; due to media reports, online debates and related events, that proportion rose to 45% in 2012 (Huang and Peng, 2015). The 'golden rice' incident at the end of 2012 further strengthened people's negative attitude to GM foods and marked a turning point in public opinion about GMOs (Cui and Shoemaker, 2018). At the same time, online debates had an impact on the opinions of

offline society and managers, interrupting policymaking and policy implementation.

From 2013 to 2015, the GMO debate became very heated, and the 'for' and 'against' ('pro-GMO' and 'con-GMO') factions turned from online to offline, leading to the consolidation of each of the two factions. In most cases, the focus of controversy was not on the technical attributes of GMOs but on issues such as conspiracy theories and the academic ability and integrity of the scientists involved. The debate had a negative influence on decision-making agencies, the public, researchers and scientific research institutions. In 2015, the publication of a clear statement on GMOs in the 'No. 1 Central Document', which aimed to popularize GMO-related knowledge, and the Ministry of Agriculture's response to relevant proposals created a temporary pause in the GMO debate (Chen and Zhang, 2016).

After 2015, although the appeal of the con-GMO faction was somewhat weaker, public opinion online did not show a trend towards support for the pro-GMO faction, following the rule of "the spiral of silence". In fact, both of the two factions are trapped in a state of relative silence (Li and Jin, 2019). This kind of silence does not necessarily mean acceptance, concession or compromise by the two parties. Instead, it occurs because the parties do not pay attention to or actively participate in the debate. Once relevant issues or sensitive events re-emerge, the two sides will be very likely to return to and even intensify the debate. For example, in May 2018, GM golden rice was approved by FDA in the United States, once again triggering a heated discussion among netizens in China.

To explore these phenomena, we proposed two research questions:

RQ1: What have been the topics of online discourse in the three stages of the GMO discussion?

RQ2: What are the characteristics of online discourse in the three stages?

3. Methodologies

Based on the above discussion, we divided the evolution of online debate concerning GMOs in China into three periods:

- The first period, which was the preliminary stage in the discourse, was before 2012. Incidents related to genetic modification had attracted public attention and public attitudes to GMO technology started to become negative.
- The second period, from 2013 to 2015, involved much heated discussion. The pro-GMO and con-GMO factions were diametrically opposed to each other, and the discussion had negative impacts on both sides.
- In the third period, from 2016, debates between the two factions became calmer after researchers, the government and relevant agencies expressed their opinions.

In this research, we used semantic network analysis to analyse public opinion towards GMOs, as expressed in cyberspace, over time. By using the method, researchers can discern variations in the themes under discussion and infer possible causes for those changes.

Semantic network analysis derives from cognitive science and treats human memory as a structured meaning system. Linguists using this approach claim that it is effective in unearthing hidden structures and latent frameworks of meaning by considering word frequency, word co-occurrence and distances between words (Collins and Quillian, 1972; Danowski, 1993; Doerfel, 1998). By abstracting and simplifying complex texts, semantic network analysis can discern texts' deep meaning and sum up a number of key dimensions.

Sina Weibo is China's most widely known social media platform. Its technical features and diverse users make it an opinion-exchange space in which competition between heterogeneous discourses is common (Lu and Qiu, 2013). Previous studies have explored

network debate and the evolution of discourse on particular issues by analysing the Weibo corpus to track the social ethos (Zheng et al., 2019). Researchers have found that GMO issues are less visible in traditional Chinese media but are being actively discussed on social media platforms (Li and Jin, 2019; Wen and Wei, 2018). Therefore, we adopted the Weibo corpus as raw data for our study.

We retrieved posts by using 'GM' as search term, and the advanced search platform of Sina Weibo returned 886,837 pieces of text. A crawler program written by one of us was used to collect the text data. We divided the texts into three chunks according to the development trend of online GMO discussions (Chunk 1, 173,699 texts from 2009 to 2012; Chunk 2, 389,254 texts from 2013 to 2015; Chunk 3, 323,884 texts from 2016 to 2018). We used random sampling to extract 20,000 texts from each chunk as the final sample.

To process the data, we proceeded as follows:

- First, we performed a first round of tokenization and compared segmentation results with original texts. We created a customized dictionary to ensure that meaningful terminologies and noun phrases would not be segmented.
- Second, we incorporated a list of predefined Chinese stop-words from Harbin Institute of Technology and replenished our specific stop-words list.
- Third, we wrote a parallel tokenization program to perform a second round of word segmentation on all texts in the final sample. Considering the words' scale and informational value, we selected nouns, verbs and adjectives for our analysis by referring to predecessors' work (Yuan et al., 2013; Zhang et al., 2018). We thus produced a file with precise and accurate tokens.

The frequency and co-occurrence of words were two focuses in our research, as the co-occurrence of words is the bedrock of semantic network analysis. We calculated those two indicators in each period in order to describe and summarize discussions of GMO-related issues over time:

- First, we removed duplicate words in each tokenized text and computed combinations of different words. The cumulative value was regarded as the co-occurrence weight.
- Second, we excluded co-occurrence relationships including the word 'GM', as 'GM' was the essential element in every text. This treatment reduced the disturbance of extreme values in subsequent handling (Yuan et al., 2013).
- Third, not all words could be displayed in the final semantic networks to reveal clear semantic relevance. We removed duplicate co-occurrence values and sorted the remaining values. The value corresponding to the first percentile point was taken as the truncated value.

We detected communities in semantic networks in each period and calculated several network indicators. Combining visual presentations, high-frequency words and semantic communities, we returned to the original text for qualitative interpretation and decoded the meaning in each semantic community.

4. Results

From the word frequency statistics, we found that 'China', 'USA' and 'GMF' (for 'GM food') occupied the first three positions in the three periods, which revealed that discussions about GMOs did not stick to their original technical implications but focused more on the game played between powerful countries, the comparison of different policies and the close relation between GMO technology and people's daily life, such as the safety and reliability of GM foods. Since GMO technology is

mainly adopted in agriculture, words such as 'GM-soy' and 'GM-maize' appear frequently. The 'Ministry of Agriculture' (MA), as the official department in charge of agricultural production and relevant activities, was also mentioned frequently in our corpus. MA is not only closely involved in the adoption and application of GMO technology in agriculture, but also manages the import, experiments and research of agricultural products.

In addition to the commonalities, there were differences in the three periods. For example, the high-frequency word switched from "Fang Zhouzi" to "Cui Yongyuan". This clearly reflected a change in the main opinion leader in the GMO discussion before and after 2013 (Fang Zhouzi is pro-GMO, while Cui Yongyuan is con-GMO). The use of 'harm', which was a high-frequency word in the first period, declined in the latter two periods, while the use of 'science' increased. The rank of 'health' decreased year by year.

Such changes reflect the shift of Weibo users' focus from initial doubts about the risks and health concerns of GMOs to scientific evidence. The results also demonstrate that, with the deepening of GMO technology in all aspects of daily life, public concerns and issues discussed have become more diverse.

The top 20 high-frequency words in the three periods are shown in Table 1.

Figures 1 to 3 show the semantic networks in the three periods. The nodes in the network represent words, while the edges indicate the co-occurrence relationship between words. We adopted the eigenvector centrality as the indicator to measure the importance of nodes. The higher the eigenvector centrality of a word, the greater its influence in the network (Calabrese et al., 2019) and, accordingly, the larger the node size. In addition, the thickness of nodes' edges indicates the frequency of co-occurrence between words. The colour of nodes and edges corresponds to the community detection result: nodes and edges in

Table 1: The top 20 high-frequency words in the three periods

2009–2012		2013–2015		2016–2018	
Word	**Frequency**	**Word**	**Frequency**	**Word**	**Frequency**
China	6335	China	7060	China	7006
GMF	4153	GMF	4964	USA	4749
USA	3806	USA	4941	GMF	4340
GM-soy	1816	Cui Yongyuan	2132	Cui Yongyuan	2866
food	1678	MA	2062	gene	2234
soybean	1582	import	2042	MA	2024
gene	1428	GM-soy	1888	plant	1922
GM-maize	1413	food	1664	food	1757
import	1360	gene	1485	GM-crops	1733
maize	1268	science	1471	country	1595
plant	1264	plant	1459	agriculture	1525
health	1246	GM-maize	1422	GM-maize	1499
research	1239	maize	1400	science	1418
Fang Zhouzi	1221	GM-crops	1356	import	1415
production	1157	country	1330	maize	1405
harm	1147	health	1247	GM-soy	1358
test	1079	expert	1245	soybean	1351
experiment	1075	soybean	1238	technology	1126
MA	1071	research	1198	seed	1125
Monsanto	1061	production	1121	research	1123

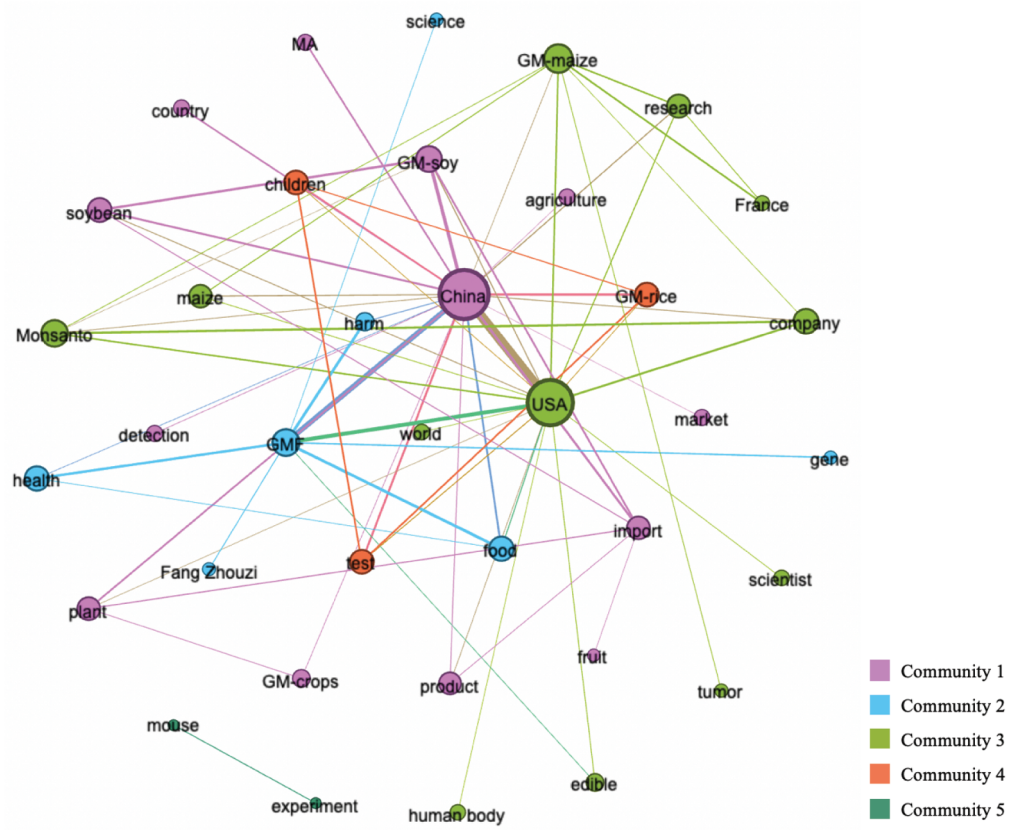

Figure 1: Semantic network of GMO discussion from 2009 to 2012 (no. of nodes: 37, no. of edges: 71, value of truncation: 192)

the same community share one colour. Our semantic network rendering follows the Fruchterman-Reingold layout, which is part of the force-oriented layout algorithm. This layout pattern is based on the strength of nodes' connections, and the resulting visual effect looks smoother compared with other layout algorithms (Fruchterman and Reingold, 1991).

4.1 Analysis of the semantic network from 2009 to 2012

Figure 1 shows that the largest community in the semantic network from 2009 to 2012 (Community 1, percentage (p) = 35.14%) contained words such as 'China', 'GM-soy', 'import', 'detection', 'country', 'market' and 'MA'. The co-occurrence of those words revealed public vigilance about imported GM products and public appeals for the urgent detection, labelling and regulation of GM products under the guidance of relevant government departments. For example, *Nanfang Daily* published an article titled 'Supplier of Golden Dragon Fish oil is accused of illegal use of GM-soy' in 2011. As a response to that article, a media account with many followers forwarded the following message:

> After questioning and verification, Golden Dragon Fish, an edible oil brand that almost monopolizes the edible oil market of China, used GM-soy without the approval by the Ministry of Health, and the approval for its use

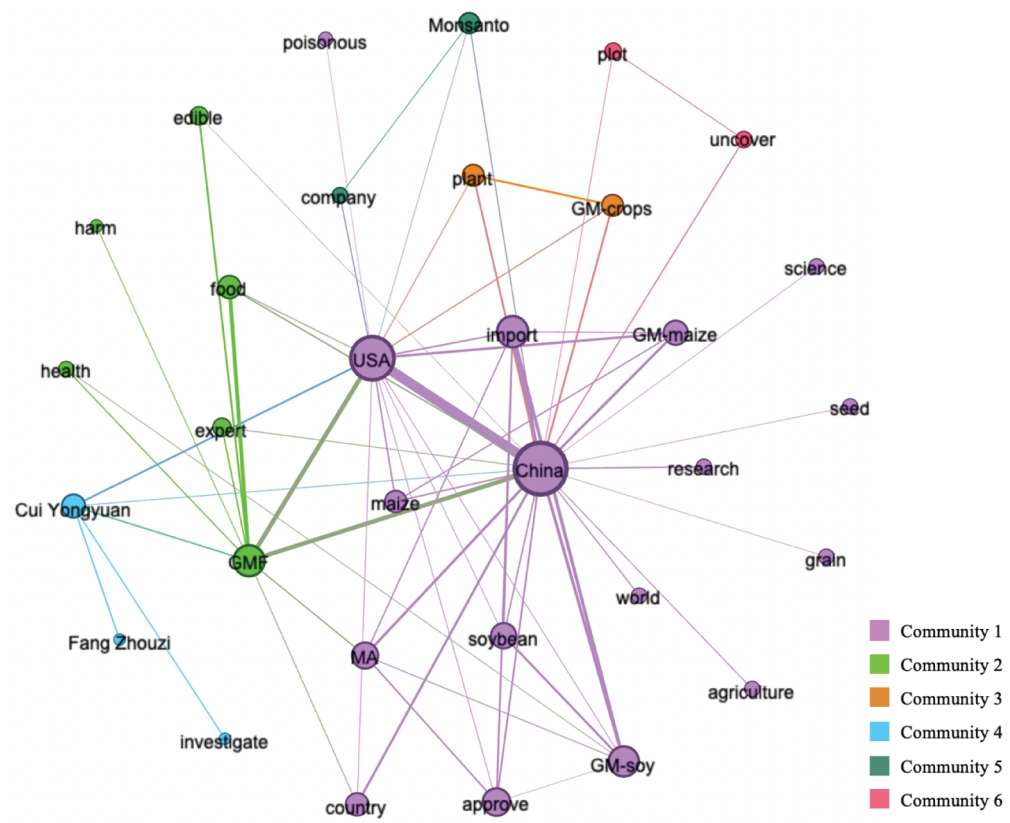

Figure 2: Semantic network of GMO discussion from 2013 to 2015
(no. of nodes: 32, no. of edges: 64, value of truncation: 179)

> of GM-soy by the MA did not follow regular procedures and no safety certificate was granted. This way of entering the market can be viewed as illegal.[1]

In Community 2, 'GMF' was tightly bound up with 'harm' and 'health' (p = 18.92%). 'Fang Zhouzi', as a most prominent GMO supporter at that time, often appeared along with 'GMF', but most Weibo users were inclined to describe him as 'a GMO promoter with ulterior motives'.

In the discussion online, Weibo users often compared China with other countries. Community 3 included such words as 'USA' and 'France' (p = 32.43%). The corpus often focused on Americans' GM food consumption, GMO regulations, and French GMO detection. In addition, 'research' carried out in those countries also attracted a lot of attention. For example, one French research institute in University of Caen Normandy published a scientific report claiming that the US GM-maize NK603 would induce tumour and organ damage on experimental mice (Huang, 2012). Negative and critical attitudes pervaded the discussion and even led to a series of rumours and speculations without scientific evidence.

The typical characteristics of GMO discussion during this period were that negative opinions prevailed over positive opinions, the technical attributes of GMOs were far from the centre of discussion, and the prevalence of unproven inferences and lack of evidence

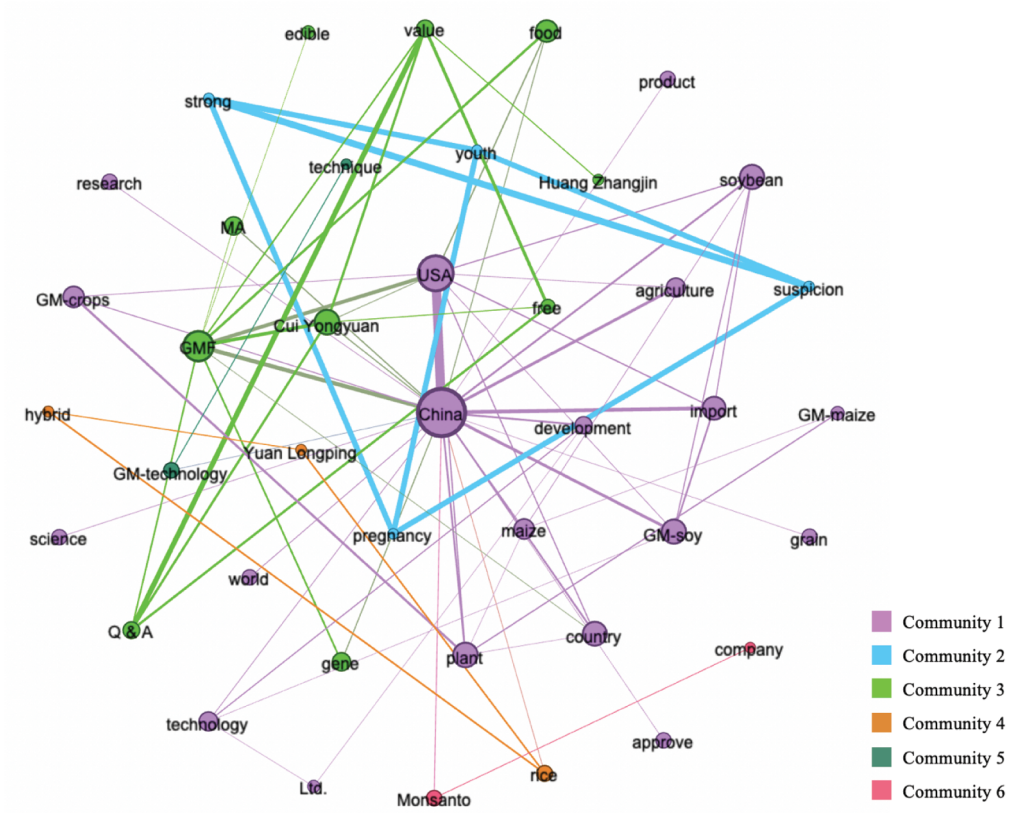

Figure 3: Semantic network of GMO discussion from 2016 to 2018
(no. of nodes: 41, no. of edges: 74, value of truncation: 189)

jointly contributed to public suspicion and vigilance. Furthermore, the discussions conveyed some tone of nationalism.

4.2 Analysis of the semantic network from 2013 to 2015

The semantic network established on the basis of discussions from 2013 to 2015 can be split into six communities. 'China' and 'USA' were in a quite stable relationship, and those two words had the highest frequency. In the largest community (Community 1, p = 53.12%), words that co-occurred with 'China' and 'USA' did not differ much from the previous period, but the word 'science' occurred and was juxtaposed with 'China'. In the discussion in this period, Weibo users started to pay attention to scientific experimental evidence rather than believe rumours blindly. Hence, discourses followed objective logic, and logical deductions appeared more often. For example, one article stated:

> Although everyone can comment on the GMO issue, the real decision should come from genuine scientists, rather than celebrities who have hundreds of millions of fans, especially singers or movie stars who are fond of giving opinions on professional issues; some of them are incapable of science and mathematics since childhood. As for those political speculators who are likely to be reactionists and anxious to see the world in disorder, there is no need to pay attention to them.[2]

In the research corpus, discourse focusing on 'science' did not fully represent objective and hard-headed thinking. Some users preferred to see 'science' as a target; they held the view that pure science does not exist and that interests and secret intentions were hidden behind 'science'. Therefore, true science may be covered by deliberate ulterior motives. For example, one article noted:

> The core of GMO problems is the combining role of 'athlete' and 'referee' in the field. They always cheat for huge profits, conceal the scientific truth and harm the nation and its people. This core problem needs to be resolved; otherwise, the so-called 'safety' and 'management' of GMOs are all nonsense.[3]

Doubts about GM food in this period were not completely eliminated. In Community 2 (p = 18.75%), 'GMF' is tied with 'harm', 'health' and 'edible'. Related arguments that had not been confirmed appeared quite often, and discussions about GM foods were quite active, as food is part of everyone's daily life.

Words co-occurring in other communities included 'plant' and 'GM-crops' (Community 3, p = 6.25%); corresponding discussions focused mainly on the commercial development and industrialization of GM crops. However, comparative perspectives were hidden behind those discussions, such as the global ranking of China's area of planted GM crops and the differences between China's regulation of GM crops and regulation in Western countries.

Other word links included 'plot' and 'uncover' (Community 6, p = 6.25%). This pair of words was closely related with rumours and tied tightly with nationalism. For example, stirring titles such as 'Revealing the truth of GMOs, very shocking, Chinese must watch this video!' appeared frequently on the internet.

It can be inferred that some people still regarded GMOs as being confidential, being manipulated by the authorities and being difficult for ordinary people to understand. Words such as 'Cui Yongyuan', 'Fang Zhouzi' and 'investigate' (Community 4, p = 9.38%) referred to the two main intellectuals involved in GMO discussions during this period. Fang and Cui launched a series of network debates in which they took different stances on GMOs and were seen as the leaders of the pro-GMO and con-GMO factions. Weibo users' discussions were not closely related to GMO technology or GM products, but to personal reputations, supportive forces and so on. Elements closely pertinent to GMOs did not attract enough attention.

In summary, we can discern some remarkable features of GMO discussions in the 2013–2015 period. First, scientific perspectives, rational discourse and empirical thoughts received more attention, while 'science' itself evolved into a resource in controversial discourse. Second, the comparative perspective was prevalent, and the GMO issue was not only regarded as a security or technical issue but was also connected with various social factors, including politics and economics. Third, the emergence and actions of opinion leaders led the public discussion to some extent, but the discussion went beyond GMOs; some irrelevant issues were repeatedly mentioned, which diluted the discussion about the central problem.

4.3 Analysis of the semantic network from 2016 to 2018

From 2016 to 2018, the dominant Community 1 (p = 48.78%) continued to make the most use of two keywords: 'China' and 'USA'. According to the eigenvector centrality value, important words included 'plant', 'soybean', 'GM-soy', 'import', 'technology', 'development', 'research' and 'approve'. They occupied central positions, just as in the earlier two periods, but the inclusion of 'development' and 'research' reflected Weibo users' supportive attitude towards the development of GMO technology. This transformation from negative attitudes to positive attitudes cannot be

separated from the enthusiastic voices of scientific workers and statements promulgated at the national level. For example, in an interview, Zhu Zuoyan, an academician of the Chinese Academy of Sciences, noted that after 20 years the present GMO debate would be simply a joke:

> 'I don't like the name "genetically modified", because people will get panicked when hearing this terminology.' Zhu Zuoyan, an academician of the Chinese Academy of Sciences, said that genetic modification is a kind of molecular hybridization or molecular hybrid breeding more exactly. The Chinese Academy of Sciences issued statements supporting GMO, but they produced limited effect. Zhu believes that after 20 years, when we look back at the GMO debate, it is just a joke. The development of science experiences a similar process, like the scientific discoveries by Bruno, Copernicus and Galileo. The whole world condemned it vehemently when the first test-tube baby came out 40 years ago, but how about now? Progress in science is unstoppable.[4]

A document released by the government also showed a positive attitude towards the development of GMO technology:

> The recently issued *Thirteenth Five-Year Plan for National Science and Technology Innovation* clarifies that a series of major national science and technology projects including genetic modification will be accelerated, and the key technological hindrance will be overcome during the Thirteenth Five-Year Plan period to gain a competitive edge in strategically important areas.[5]

The above-mentioned texts revealed the alliance of expert and administrative discourses, which undermined conspiracy theories, rumours and disinformation to a certain extent.

In the second largest community (Community 3, p = 24.39%), new opinion leaders joined the discussion (such as 'Huang Zhangjin') and a new opinion-exchange system emerged: 'Q&A' (questions and answers). As a new feature of the Sina Weibo platform launched at the end of 2016, Q&A allows users to publish questions and invite other users to answer them for a monetary reward. Other users who are interested in those questions can share their answers freely or for a fee. The juxtaposition of the terms 'value', 'Q&A' and 'free' indicated that the new information-exchange mechanism had arisen from the GMO discussion. While the two earlier periods featured much self-talking and disorderly debate, the introduction of Q&A during this period provided a platform for scientific and technical experts and gave them more influence, which was valuable in alleviating the dilemma of self-referential speech and salvaging the professional discourse. For example, a Weibo user said:

> I saw Cai Lan's answer. It is worth 39 yuan, but you can just spend 1 yuan to look at the answer. Question: How do you think about GMO technology? Do you buy non-GM foods?[6]

This kind of content accelerated information dissemination on Weibo, helped to create an orderly diffusion of professional opinions and set up reasonable information-receiving mechanisms. The Q&A mode even guided the direction of future discussion and avoided deadlocks after continuous blind debates.

Words that co-occurred in Community 2 (p = 9.76%) indicated that this semantic community indulged in a kind of teasing; the use of 'youth', 'strong', 'suspicion' and 'pregnancy' corresponded to the following widely told joke:

> A pregnant cat and the tiger had never before met each other. The cat looked at the tiger with curiosity: 'How could a cat be so strong? Genetically modified cat?' The tiger also had a strong feeling after seeing the cat and thought: 'The young are not taking care of themselves; they are pregnant at such a young age.'[7]

The joke looks funny at first glance but it reflects the suspicion and ridicule of Weibo users towards GMO technology. Similarly, other co-occurring words, such as 'Monsanto' and 'company', 'Yuan Longping' and 'rice' also demonstrate people's doubts and concerns about the uncertain development of GMO technology (Yuan Longping developed the world's first hybrid rice varieties in the 1970s). What's more, subjective inferences that had not been substantiated were put forward as facts. For example, an article claimed that 'Monsanto Nongda 1988 pesticide registration deceives the Chinese Government and Chinese people in eight aspects':

> 1. Based on experimental results, the US Environmental Protection Agency classified glyphosate as a carcinogen (Group C) on March 4, 1985. However, Monsanto claims that Nongda/glyphosate 'is not carcinogenic'! . . . 6. Monsanto's 1983 metabolic test report reveals that 'glyphosate will be accumulated in humans' bodies', but now, Monsanto claims that using glyphosate will not cause accumulation. . .![8]

Our analyses showed that the third period inherited representative characteristics from the first two periods: scepticism based on technological uncertainty and discourse related to conspiracy theories continued, but that was perhaps inevitable. However, due to the combined influence of scientists, administrative officials and new modes of information dissemination, the GMO discussion entered into a more dialectical phase. Discursive debates and discussions that deviated from the subject decreased eventually. Furthermore, due to the evolution of communication mechanisms, some creative discourses about GMO technology (such as the joke cited above) also emerged. Those factors showed the creativity and initiative of discussion participants in the virtual Weibo space, which was relatively rare in the previous two periods.

5. Discussion and conclusions

By processing more than 800,000 Sina Weibo microblog posts from 2009 to 2018 using 'GM' as a search term, and with the help of word frequency statistics and semantic network analysis, we analysed the characteristics of and trends in discourses related to GMOs. In this paper, we have discussed the different themes and their causes in three consecutive periods. In the first period, when most of the public did not pay much attention to GMOs, online public opinion was dominated by negative emotions. Netizens focused on discussing what benefits China and the United States could get from the technology. In the second period, when the discussions were most intense, public opinion divided into pro-GMO and con-GMO factions, and elite discourses began to dominate the discussion. In the third period, after the publication of relevant policies and the efforts of all parties in society, positive views appeared online. After opinion leaders left the debate, discussions about GMO-related topics gradually became less intense and public opinion became more muted.

After examining and analysing the data, we believe that public discourses about GMOs have the characteristics of a new technology. They are also influenced by various factors and developmental stages in Chinese society and thus show some new traits. We have explored the dominant GMO discourse and its characteristics, and now discuss possible causes in order to offer suggestions for the resolution of related issues and a reference path for further research.

First, discussion about the gains and losses of China and the United States brought by GMOs runs through the core semantic subgroups from the beginning to the end of the study period. The most representative view is that GMOs are a 'new way of aggression' by the United States against China. All of its research, development, production and promotion of GMOs in China is regarded as

a 'conspiracy'. Public opinion on this topic expresses a certain nationalism. Reviewing the history of science and technology, we have found that the popularization of some technologies and innovations has been susceptible to factors such as religion, cultural trends and ideology (Brossard et al., 2009, Gaskell et al., 2000; Lu and Chu, 2016). Due to the particularity of GMO technology and the influence of Sino-US relations, such a standpoint in public opinion is reasonable. With the improvement of China's GMO technology and industrial autonomy, the popularization of relevant knowledge and technology, and the transparency of supervision and policies, the public's level of trust in the research, development and management of GM products in China has increased, while negative public opinions are gradually decreasing.

Second, GMO technology has been applied widely and relates to almost every citizen's daily life. The social implications of GMOs are relatively great, and the resolution of scientific problems in the field is likely to be affected by those implications. As our semantic network analysis shows, most of the discourses regard GMOs as an 'industry' rather than a 'technology'. This makes the public more concerned about the necessity for and short-term benefits of GMO technology, rather than its nature as a scientific technology. As this technology penetrates deeper into public life, its beneficial aspects are constantly emerging, and the public is beginning to care about its 'certainty' and discuss it more rationally on the internet. We believe that relevant parties' communication strategies should still be closely based on the 'deficit model' in science communication, so that the public can better understand GMO technology and its advantages as well as its disadvantages and then talk about other aspects of the technology democratically and cautiously.

Third, public attitudes towards scientific issues are generally influenced by professionals in related fields (Dai et al., 2015). However, by analysing public opinions on Weibo, we found that the Chinese people are more likely to rely on the official discourse on GMO issues. On the one hand, this is because early reports and academic papers on GMOs included errors; elite public discourse diverged, and rumours occurred frequently before 2015, which briefly led the public to nowhere. People were at a loss and looking for a trustworthy and authoritative source of information. On the other hand, although some responses were delayed, the government has since defined its attitude to GMOs. Because the government takes a neutral stand, weighing various stakeholders' views and interests when making decisions, as well as acting for the benefit of the country and the people, the public trusts the government more and has become more tolerant of GMOs endorsed by officials (Brossard and Shanahan, 2007). This should remind us that, when discussing controversial topics, the official discourse may be an indispensable component, but officials must always ensure the seriousness and timeliness of their contributions and pay attention to maintaining and enhancing the government's credibility in the daily lives of the people.

Fourth, another distinctive feature of public opinion about GMOs is the emergence of the discourse of the elite. The pro-GMO and con-GMO factions each have their own opinion leaders, including professional experts, intellectuals with particular reputations and non-profit organizations. In the second stage of our study period, which included the most heated discussion, the opinions and attitudes of several opinion leaders led trends in the entire field of public debate. After years of stalemate between the factions, some major opinion leaders have become less vocal, and online public discussion about GMOs has cooled down. In online discussion, due to a lack of traditional gatekeepers, opinion leaders could form a strong framework for discussion, and that played an important role in guiding public opinion (Yang, 2016). Therefore, to influence public opinion on controversial issues, we should cultivate public

opinion leaders. We can encourage leaders in professional fields to become public opinion leaders, cooperate with the media and officials and turn to the democratic participation mode when necessary, which means incorporating ordinary citizens into deliberations.

Finally, many changes in online GMO discussions took place during our 2009–2018 study period. For example, the clustering of keywords in our semantic network analysis gradually turned from 'harmful' to 'scientific', which indicates that the continuous and joint efforts of various parties began to have beneficial effects. The topics discussed in the semantic network became more pluralistic, more nuanced and culturally richer. With the constant participation of the audience, the discourse was filled with new power; new forms of participation brought about by the new media also provided new paths for all parties into the discussion about GMOs.

This paper sheds light on the evolution of discussions concerning GMO-related issues in China. We believe that our research also contributes to the understanding of controversial technological issues in developing countries. As a branch of biotechnology, GMO technology is a relatively new thing for ordinary citizens. In its early stages, doubts and suspicions caused by uncertainty were inevitable. Also, in the era of globalization, GMO technology's implications for developed countries (such as the United States) and developing countries (such as China) are quite different, so it is understandable that the discussion on Sina Weibo was filled with comparisons and speculations. As the technology attracted more and more attention from society, its social meaning transcended its technological meaning, leaving some space for public deliberation. In that phase, opinion leaders were actively engaged in the discussion, exerting agenda-setting influence over the public.

However, central government and other public agencies still serve as authorities. Their decisions and regulations affect ordinary citizens to a great extent. Thus, although citizens were facing a contentious technology, they were still inclined to trust the government. With the emergence of new communication mechanisms, clear support from the state and more active experts, negative attitudes to GMO technology—attitudes based on unsubstantiated evidence—were weakened. Also, scientific evidence received extended endorsements. Correspondingly, the keyword clusters gradually changed from 'harmful' to 'scientific'.

For all those reasons, we propose that the deficit model of science communication should be still adopted to improve the public's understanding of GMO technology. We also encourage a new participation pattern to widen communication channels and enhance mutual understanding between professionals and laypeople. In short, online discussions about GMOs in China reflect the interaction and competition behind newborn things, and stakeholders from diverse backgrounds contend for their own places in the discussions. Accompanied by state intervention and timely adjustments, the development of public opinion will eventually follow the right direction.

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Notes

Original microblog posts are available at the following addresses.

1 https://weibo.com/1642482194/xCUf1saq7?refer_flag = 1001030103_.
2 https://weibo.com/1245325743/zBPWJeWMk?refer_flag = 1001030103_.
3 https://weibo.com/1744665532/ClaNNwWJi?refer_flag = 1001030103_.
4 https://weibo.com/5044281310/DEh1rsNuk?refer_flag = 1001030103_.
5 https://weibo.com/2427364747/E2UtDpbTZ?refer_flag = 1001030103_.

[6] https://weibo.com/5812499409/F7vDGnKUI?refer_flag = 1001030103_.
[7] https://weibo.com/3898533894/H08JYz4ME?refer_flag = 1001030103_.
[8] https://weibo.com/1269923485/DDywLl8Ns?refer_flag = 1001030103_.

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Misinformation and disinformation in science: Examining the social diffusion of rumours about GMOs

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Abstract

Genetically modified organisms (GMOs) have caused considerable controversy in China in recent years. Uncertainty about the technology, ineffective channels for releasing official information and a lack of sufficient public trust in the government and scientists have led to rampant rumours about genetic modification technology, making it hard for the public to acquire scientific knowledge about it and a rational attitude towards it. In this paper, by using as an example the rumour that genetically modified (GM) soybeans cause cancer, we discuss the content and diffusion of rumours related to genetic modification technology in the new media environment. Based on an analysis of content on the social media platform Weibo one week after the rumour began, we discovered that the ensuing cyber discussions reflected reality, that netizens expressed anxiety and panic while stressing social injustice and reflecting conflict between social classes, and that they exhibited little trust in scientists and the government. On the mechanism of diffusion of rumours on Weibo, we observed that 'evidence' that directly or indirectly purported to show that GM soybeans cause cancer was added to the rumours and that the rumours were 'assimilated' into people's perception through the stigmatization of GMOs and through conspiracy theories.

Key words

Rumours, GMO, trust, new media

1. Introduction

In the mid-1990s, genetic modification technology emerged as a source of polarizing debate. Since then, the use of genetically modified organisms (GMOs) has not been treated as a simple scientific issue in Europe and the United States. Instead, discussions about it have drawn on history, politics and international relations.

In China, the GMO controversy came to the fore with the Nestlé food incident in December 2002, when the Shanghai-based magazine *The Bund* reported a claim by Greenpeace Hong Kong that food sold by Nestlé in China contained unknown genes. That triggered media coverage on such topics as the safety of genetically modified (GM) foods and consumers' 'right to know'.

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Extensive public interest in GMOs in China was sparked by the 'golden rice' incident in 2012. Researchers provided 72 primary school students in Hengyang City, Hunan Province, with GM rice developed by Syngenta AG, without the informed consent of the children being tested.

The subsequent cyber debate in 2013 and 2014, the banning of GM crops in Heilongjiang Province at the end of 2016 and other events have brought the debate on GMOs to the front of people's minds.

Genetic modification technology not only affects people's daily lives but also features in the national consideration of industrial policy and international trade. The doubts expressed by scientists and the public on this cutting-edge technology have not been addressed in the past several decades. On such specifics as the application and introduction of genetic modification technology, the public is excluded from the decision-making process, and the government lacks timely and smooth channels for information dissemination. This results in the coexistence of, and competition and antagonism between, the official and the civilian spaces for discourse on the issue (He and Chen, 2010). In addition, due to the decline of public trust in the government caused by the friction between the old and new economic systems and differentiation in social interests, as well as the waning of public trust in scientists owing to increased scientific misconduct, public opinion about GMOs is full of conflicts and contradictions. Consequently, in addition to cyber controversies, a number of rumours about GMOs have spread. This is a reflection of public panic about the safety of GM food, ecological security and industrial security. Widely circulated false and erroneous messages, such as 'GM maize has reduced the production of sows and wiped out mice in Shanxi Province' and 'purple potatoes and cherry tomatoes are GM varieties', have greatly compromised the scientific community's efforts to popularize GMOs while preventing the public from acquiring a scientific and rational understanding of them. To a certain extent, even public decision-making has been affected.

Thoroughly exploring the process of diffusion of rumours about GMOs and its consequences is important for understanding the occurrence of such rumours and curbing them. Using the rumour that 'GM soybeans cause cancer' as an example, this paper explores the content and cyber diffusion of rumours about GMOs and the mechanisms of diffusion.

2. Literature review

2.1 Rumour: Its definition, generation and diffusion

2.1.1 The definition of 'rumour'

In the 1940s, the notion of rumour formally became an academic concept. Knapp (1944) defined it as 'a proposition for belief of typical reference disseminated without official verification'. Allport and Postman (1947a: ix) claimed that a rumour is a 'specific (or topical) proposition for belief, passed along from person to person, usually by word of mouth, without secure standards of evidence being present'.

Starting from the 1960s, a number of scholars criticized the psychological perspective on rumours and claimed that social factors cannot be ignored in the generation and diffusion of rumours. Shibutani (1966: 62) held that rumours are collective transactions and 'improvised news generated in the process of discussion by a group of people'. Similar viewpoints are as follows. A rumour is information about current events passed along by word of mouth but without any factual basis (Morin, 1971); rumours are 'public communications that reflect private hypotheses about how the world works' (Rosnow, 1988); and they are 'information that is neither not yet publicly confirmed by official sources nor denied by them' (Kapferer, 2008: 15).

Systematic research on rumours in China began with *A Perspective in Rumours*, which considered all rumours to be false (Jiang, 1991: 17). This was a common opinion among scholars of early communication in modern China. For example, Liu (2002: 211) claimed that rumours often have defamatory tendencies and are 'negative public opinions of a critical nature'. Guo (2011: 88) held that 'rumours are intentionally fabricated news or information out of thin air.' In recent years, a new generation of scholars has paid greater attention to the social background of rumours and examined them from a neutral perspective. Zhou (2012: 14) even highlighted a positive side of rumours: although not officially confirmed, they emerge from public discussion, including assumptions about the real world, and can be used to help people understand ambiguous but important situations.

Misinformation and disinformation are two concepts related to rumours. The former expresses erroneous information and assertions that cause panic and confusion owing to unintentional dissemination, whereas the latter expresses erroneous, false information disseminated intentionally. Iyengar and Massey (2019) noted that misleading and biased information is responsible for people's mistrust of the scientific enterprise and the resulting misperceptions about knowledge.

2.1.2 The generation and diffusion of rumours

Allport and Postman (1947a: 17–18) used psychological experiments to review rumours in wartime and proposed a formula for them: Rumour = Importance × Ambiguity. They believed that story-related themes are important for both the spreader of the rumour and its recipient, whereas a certain degree of ambiguity conceals authenticity. Therefore, without either of importance and ambiguity, rumours cannot exist.

Specifically, the generation and diffusion of rumours are related to personal psychological factors and social environmental factors.

As far as psychological factors are concerned, initial studies showed that the human behaviour of forming and spreading rumours is one of mutual mapping with inner sentiment, and is driven by such personal emotions as anxiety, desire and fear (Allport and Postman, 1947b).

A large number of subsequent studies in social psychology have identified five factors related to the motivation for spreading rumours (Bordia and DiFonzo, 2002; Rosnow, 1991; Walker and Blaine, 1991): uncertainty; importance or outcome-relevant involvement; lack of control; anxiety; and belief. In their review of literature related to each of those variables, DiFonzo and Bordia (2006) examined why the variables affect the transmission of rumours and found that, in the specific context of rumour dissemination, the purposes of personal participation in spreading rumours can be described by three motivations: fact-finding, relationship enhancement and self-enhancement.

With regard to social factors, rumours often have the characteristics of the time and region in which they emerge. For example, the famous 'Maid of Orleans' rumour, which circulated in France in the mid-1960s, was about clothing stores being used to traffic white women. This rumour was related to 'sex' and 'Jews', reflecting the still unstable and complex ethnic estrangement and social contradictions after World War II. In China, the 'Soul Stealers' case that affected 200 million people and swept across 12 provinces during the Qianlong years of the Qing Dynasty, the 'Hairy Man Water Monster' scare that spread in north and east China from 1946 to 1954, rumours of the spread of AIDS propagated by natives of Henan and Xinjiang in the late 20th century, and recent rumours about 'kidney removal' and 'child kidnapping' are all closely related to the social context in which they spread.

Hu (2009) classified rumour-generating scenarios into three categories. First, rumours arise from the absence of official channels of information, and 'improvised news' is the 'collective transaction' through which people interpret their environment. Second, some problems caused by environmental and social changes undermine the overall value and interests of society, plunging people into panic, crisis and uncertainty. Rumours thus occur and stimulate the intensification of uncertainty. Third, rumours are a way of expressing social protest: 'the payback to authority' (Kapferer, 2008: 16).

In different contexts, rumours serve as 'an oral outlet to relieve tension' (Allport and Postman, 2003: 20), a 'distorting mirror' to monitor public opinion in special contexts (Wang and Hou, 2012) and a 'weapon for the weak'.

2.2 The diffusion of rumours in social media

The media environment influences the efficiency of rumour dissemination. Compared with the early stages of word-of-mouth transmission and mass communication dominated by the print media, new media have brought structural changes and accelerated the propagation of rumours. In recent years, global network penetration has been on a continual rise and has increased the availability of network equipment but lowered the access threshold, making it possible for people to access the internet quickly. In addition, the anonymity afforded to online users has caused an end to the 'spiral of silence'. However, there is a lack of effective supervision of online speech. Some netizens freely vent emotions and disseminate false information. With the intervention of commercial interests, the use of algorithms renders the environment of rumour dissemination more complex, resulting in echo chambers.

The mechanisms of distortion in the traditional media are also changing in new media. Proven distortion mechanisms for rumour dissemination include:

- *levelling*, which is the ignoring of a large number of details and gradual shortening of the length of the rumour to make it easier to understand and narrate
- *adding*, which involves the addition of details and content and is also called 'snowballing' (Rosnow, 1991), invention and elaboration (Allport and Postman, 1947a)
- *sharpening*, which emphasizes part of the information in rumours
- *assimilation*, which reshapes the rumour by levelling, adding and sharpening to make it more consistent with people's cognition.

In the social media environment, due to the one-click forwarding function, the details of a rumour are not lost or exaggerated in the dissemination process (Xu and Wang, 2015), but the headlines of posts about rumours are usually written to make them succinct and powerful (Zhou, 2012). In addition, as 'collective transaction' behaviour is strengthened, everyone can release information freely, and rumours can be constructed and enriched by 'adding' information that conforms to the intention of the disseminator, thus achieving 'assimilation'.

A study of 126,000 tweets on Twitter (Vosoughi et al., 2018) showed that false news spread six times faster than real news and had a probability of being forwarded nearly 70% higher than that of real news. False news could easily be forwarded more than 100,000 times. Research has shown that factors of online social media platforms in addition to the greater novelty of the content of false news influence the spread of rumours. First, a large number of socialbots are active on social media platforms (Lazer, et al., 2018). From 9% to 15% of active accounts on

Twitter and Facebook are held by 60 million socialbots. They are also believed to have influenced the 2016 US presidential election and the 2017 French election to some extent. Second, the rapid spread of rumours originates from the characteristics of social media: the overall web relationship features 'preferential attachment' (PA). In their research on Twitter, Doer et al. (2012) found that rumours spread faster in the PA mode than in a network of random relationships; the specific user relationship was characterized by a 'push–pull' mode; that is, the boundary between the releaser and the recipient of information was blurred (Chierichetti et al., 2011). This mode further promotes the occurrence of collective transactions.

3. Research questions and methods

3.1 Research questions

GMOs have been controversial since that subject first arose in China. All kinds of rumours about them have been remarkably resilient and have made wide and repeated appearances on traditional and new media platforms. The rumours have significantly affected people's understanding of scientific issues, which in turn has substantially compromised efforts by the scientific community to build a benign and timely mode of communication and exchanges with the public on the issue. Based on rumour theory and the characteristics of rumour dissemination in the new media environment, and taking the dissemination of rumours about GMOs as the unit and basis for analysis, this paper poses two questions:

RQ1: What is the content of cyber discussions on rumours about GMOs?

RQ2: What is the mechanism of dissemination of rumours about GMOs on social media?

3.2 Research methods

3.2.1 Case selection: 'GM soybeans cause cancer'

In June 2013, the Chinese Ministry of Agriculture approved and issued agricultural GMO security certificates for four types of soybeans, applied for by Monsanto Far East Ltd and Basf Agrochemical Products Co. Ltd. The event sparked public outcry and fierce criticism of the ministry. Subsequently, several senior officials of the ministry said that people had questioned GM food purely out of ignorance. That led to an even greater public backlash.

A week later, on 20 June 2013, www.cctv.com published an article titled 'Heilongjiang Soybean Association: GM soybeans are highly coorelated with tumors'. The author noted that an analysis by Heilongjiang Soybean Association had shown that GM soybeans were highly correlated with the incidence of tumours, and the results were shocking. The article also mentioned that foreign countries had already disclosed information on the correlation between them, citing studies by Russian scientist Alexey Surov in 2010 and French scientist Gilles-Eric Seralini in 2012 as evidence. This article attracted considerable attention. Despite denials by professional media and scientists the following day, the rumour that 'GM soybeans cause cancer' spread rapidly.

3.2.2 Data collection

We searched on Sina Weibo using the keywords 'GM soybean causing cancer'. Because discussions on the issue began immediately after the event, and rumours often immediately follow the relevant events, we set the period of the search to within one week of the publication of the report, from 21 to 27 June 2013. The scope of the search covered all Weibo users in China for a total of 2,027 Weibo posts. After similar posts were excluded,

1,888 posts remained. The collected Weibo content was analysed based on the focal points discussed by Weibo users and the mechanisms of rumour dissemination.

4. Research findings

4.1 From the real world to the web: What were Weibo users discussing?

4.1.1 Real-world–web resonance

Following its publication on social media, the 'Heilongjiang Soybean Association' article immediately spawned wide-ranging discussion on Weibo. Figure 1 shows the numbers of daily posts on the topic on the Sina Weibo platform from 00:00 on 21 June to 24:00 on 27 June. There were as many as 700 separate discussions in the first two days, but the number of posts declined gradually over subsequent days.

Beyond the internet, experts on traditional mass media platforms repeatedly denied this rumour (Figure 2). The participants in such discussions were experts and scholars from GMO-related fields of research. They debunked rumours centred on the content of the report, especially the relationship between GM soybeans and cancer.

Online discussions coincided with offline discussions and exhibited two stages of development.

Stage 1

Before 13:27 on 21 June 2013, when www.yicai.com published 'Expert rejects claim that GM soybeans cause cancer: Homegrown soybeans need "hematopoiesis" but not rumour mongering', discussion on Weibo focused on whether GM soybeans are safe. A total of 286 Weibo posts were published, representing three views (see Figure 3).

The largest group tended to agree that GM soybeans are indeed related to cancer (279 posts). Authors of these posts claimed that

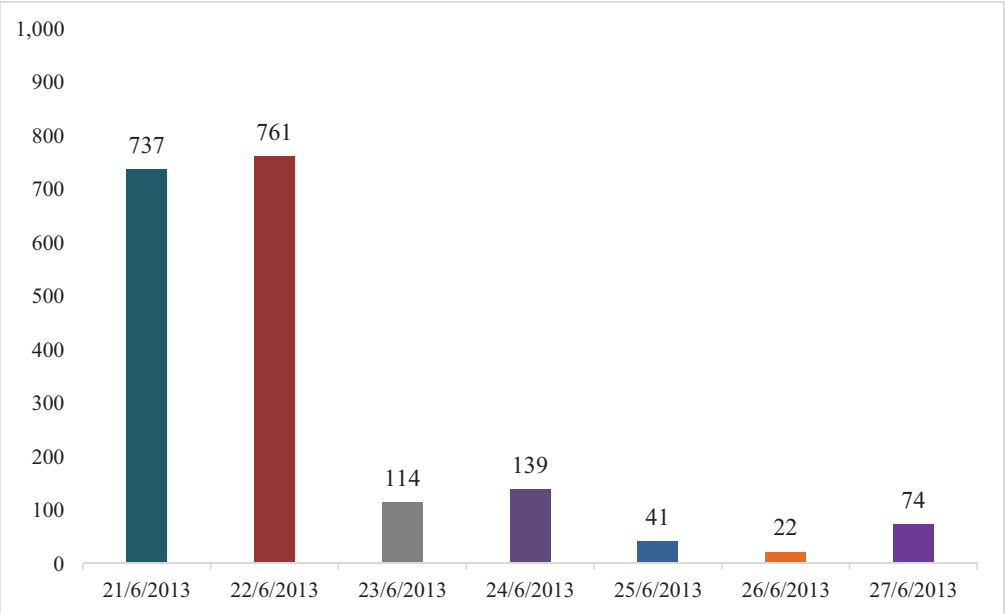

Figure 1: Frequency of occurrence of Weibo posts discussing the rumour about GM soybeans causing cancer, 21–27 June 2013

Figure 2: Media coverage of the 'GM soybeans causing cancer' issue

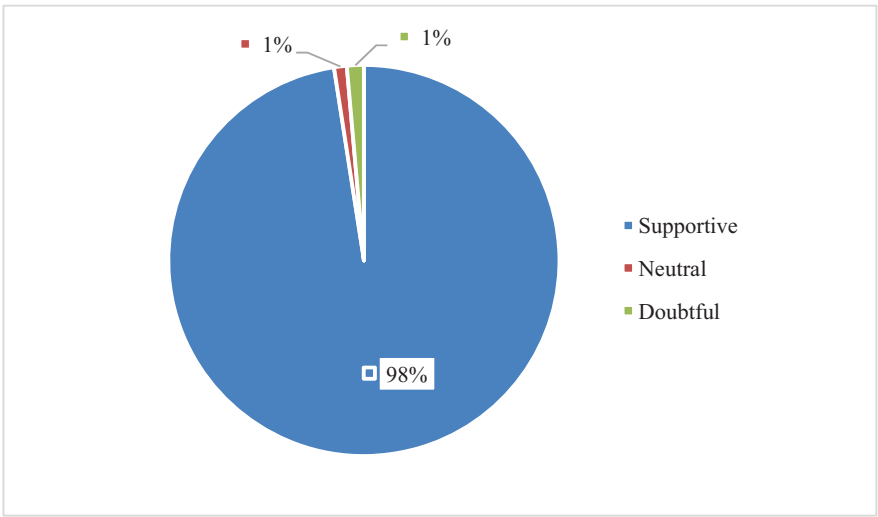

Figure 3: Frequency of attitudes to the claim that 'GM soybeans cause cancer'

they would not eat GM soybean oil, while expressing concern about the safety of such soybean products as soymilk and tofu. However, some of these users did not explain why they believed that GM soybeans cause cancer.

The second view was neutral and called for a scientific and authoritative confirmation of the safety of GM soybeans. There were three Weibo posts in this category. For example, the author nicknamed Haitian Mengzhilan asked:

> Is it credible that GM soybeans cause cancer? Is there any authoritative person or department that can clearly state whether there are problems or not with GM foods, including GM soybeans and GM soybean oil?[1]

The third view claimed that it was logically impossible to draw a conclusion about the relationship between GM soybeans and cancer. At the same time, these users also cast doubt on the identity and stance of the workers mentioned in the report. There were four Weibo posts in this category. For example, the author nicknamed Guyun Laoge wrote: 'Those selling homegrown soybeans say imported soybeans cause cancer.'[2] Another author, nicknamed Mr_Felix, asked: 'Are the people of the Soybean Association doctors or scientists? Is it a rigorous inference that GM soybeans can cause cancer? Do they put their own interests first?'[3]

Stage 2

The focus of public discussion subsequently shifted to whether experts' opinions should be trusted. After experts appeared in newspapers as rumour deniers, words such as 'expert', 'academician' and 'scientist' hit the sensitive nerves of the public and also affected the fragile chain of trust between the public and scientists. Some Weibo users changed their unconditional belief that GM soybeans cause cancer and asked experts to provide scientific evidence for claims that 'GM soybeans do not cause cancer' and 'GM foods are completely healthy and harmless': 'Please come up with data and do not make subjective assumptions' (@Management_IPO Consulting).[4] The identity of the experts and their positions and motivations for refuting rumours, as well as the decision of the government, were all under scrutiny: 'Don't deceive people with the false skins of academicians' (@Sanzhuogong).[5] Some Weibo users even began to make personal attacks: 'It is totally bullshit false experts [*sic*]' (@Liangjian 7258).[6]

4.1.2 Emotions and strategy of expression

Data analysis has shown that the rumours about GM soybeans causing cancer led to emotions of pessimism, panic and anxiety among users on Weibo.

> Please tell your family members and friends to keep away from harmful food. It is too terrible. GM oils used to be considered good. Alas, what else could we eat? (@Hongda Zhanpeng Decoration Design)[7]

> What can we do to save the world? (@Hu Ge and Wu Song)[8]

In discussions among netizens, food—a necessity of life—became a risky prospect. People were afraid to bear the consequences of the risk but felt they could not escape it. In 1991, Rosnow pointed out that one of the four factors contributing to the spread of rumours is personal anxiety. On the one hand, rumours are generated and spread through the anxiety of individuals and groups; on the other hand, rumours, by expressing a mood of anxiety, subjectively ease individuals' anxiety by playing the role of 'emotional coordinator'. However, rumours consolidate and duplicate this emotion at the group level. Weibo users generally expressed concerns about the safety of GM soybeans and related foods.

In their linguistic expression, Weibo users often used exaggeration, exclamation and other rhetorical devices to produce sensational effects. The heated discussions on the rumour were largely due to the passion of online expressions. On the one hand, netizens lamented that they were excluded from the government's decision-making and could only passively accept what they were given. They had no say in the government's approval of the import of GM soybeans and did not even know the foods that were processed from GM crops and whether GM soybeans were safe. For example, some netizens called themselves 'shitizens', the victims of a China–US community of interests, the target of US 'cleansing' of the Chinese population, and 'laboratory mice' in GMO research: 'There is no need for public experiments. Aren't the Chinese people already under *in vivo* experiment?' (@Mumu's Forest 78).[9] On the other hand, netizens made the Chinese Government, represented by the Ministry of Agriculture, and the experts the objects of banter, expressing their indignation at the privileged classes of the government and authorities, which are different from grassroots citizens.

4.1.3 Lack and transfer of trust

Two nouns repeatedly mentioned by Weibo users in rumours about GM soybeans causing cancer were 'the Ministry of Agriculture' and 'experts'. The Ministry of Agriculture was the main body that approved the GM soybeans, while experts were not only members of the

group that had approved them but were also the main rumour deniers. In addition, 'civil servants' and 'leaders' frequently appeared in the discussions. In the view of most Weibo users, experts were in the same camp as the Ministry of Agriculture, the government and civil servants.

Doubts harboured by many Weibo users about experts focused on three things:

1. The authority of the experts: Were they authentically expert? How long had they been engaged in research on the relationship between GM soybeans and cancer, on the basis of which they drew their conclusions.
2. The behaviour of the experts: Did they and their family members eat GM foods?
3. The purpose of the experts' denial of the rumour: Had they been tempted by offers from the Ministry of Agriculture, the government or Monsanto? How reliable were their characters and morals?

Many Weibo users believed that the experts belonged to a privileged class that distinguished itself from the public. The scientists had lost their role as spokespersons for science. One netizen said: 'I believe in science, but I don't believe in the opinions of domestic experts (only this expert himself knows on what stance he expresses an opinion that GMO is harmless)' (@tl0222).[10] Experts were considered to lack scientific rigour. 'Experts, what do you offer when you say that others are baseless?' (@RualDLZhang).[11]

Weibo users lacked trust in what the experts said. They believed that it would be more convincing if experts, leaders, civil servants and officials of the Ministry of Agriculture ate GM soybeans: 'I will believe them if the leaders themselves also eat GM soybeans' (@hunter_luna);[12] 'Please explain to me why the following words are written on the big plaque of the Ministry of Agriculture's kindergarten: "This kindergarten has NO GM food"' (@bobo you and me).[13]

The experts' refutation of the rumour was regarded as an endorsement of the government: 'Everyone knows that our country's experts serve vested interests' (@Chengcheng 520).[14] One netizen even asked, naming one of the experts who had refuted rumours: 'Is there anybody who knows how many benefits Zhu Yi has taken from America?' (@Minzhuhua).[15]

According to our analysis of Weibo posts, when the Ministry of Agriculture and the experts could not win the trust of the public, many Weibo users regarded European countries and the United States as a reference frame to judge whether GM foods were safe. They believed that China lacked authoritative scientific institutions, and even considered the Chinese Government 'incompetent', calling for international organizations to voice their stance: 'It seems that the interpretations made by the Chinese are useless! Let's call upon the World Health Organization for help' (@Ni Xiaoping).[16]

4.2 From phenomenon to attribution: How does rumour content distort?

4.2.1 The levelling and sharpening of rumour

The spread of the rumour that GM soybeans cause cancer embodied the mechanisms of levelling and sharpening. Specifically, the content of the rumour itself came from media reports, and most Weibo users chose to express their attitudes towards this issue by way of making simple comments and forwarding the original report. Their posts generally contained a link to the original article and used concise words to express their positions. Compared with the conclusion that GM soybeans cause cancer, the process of drawing the relationship between the two (GM soybeans and cancer) seemed less important to the public. In communication, the netizens were more easily guided by the stirring headline while ignoring the process of arriving at this judgement.

4.2.2 Adding information and shifting topics

Our analysis revealed that information had been added and topics had been moved during the dissemination of the rumour. The information added was mainly in two categories.

One category focused on the evidence of 'how GM soybeans cause cancer.' For example, there were two recurring mentions of studies in discussions. One study was by Russian scientist Alexey Surov in April 2010, which had found that the offspring of hamsters fed with GM soybeans had such problems as a falling sexual maturity rate, a reduced growth rate and loss of fertility. The other study was by the Seralini team of the University of Caen, published in *Food and Chemical Toxicology* in 2012. It claimed that mice fed with GM maize and Roundup-contaminated feed were more susceptible to cancer and visceral damage. However, the research institute where Alexey Surov worked yielded no information to suggest that he had done the above research, while the Seralini team's research was later retracted by the journal that had published it, and its conclusions were also considered invalid by the European Union in 2018.

A second category of added information consisted of 'facts' that showed that GM foods were unsafe, as inferred from related information. For example: 'Academician, can you tell me why the food of the Olympic Games and the World Expo in our country is completely free from GM food?' (@Hu Lantao Alex);[17] 'How much money have you taken from others? The United States does not even allow the addition of GM materials into animal feed!' (@Wolf Falling in Love With Sheep 1796680897).[18] Claims that 'there is no GM food in the Olympic Games and the World Expo in China' and that 'there is no GM food in the animal feed of the United States' were two rumours widely circulated on the internet.

Our data also showed a shift of topics during rumour dissemination.

First, topics related to genetic modification technology were discussed in rumour dissemination, such as the 2012 Hunan golden rice incident, which caused a major controversy in China:

> Scientists who were punished in the 'golden rice incident' were from the mainstream research institutions, showing that some scientists are also blinded by greed! (@Often Walking Along the Seashore_12981)[19]

> The Ministry of Agriculture and the so-called 'experts' say that there is no basis that GM soybeans cause cancer. I want to say that there is of course no basis because you have done no experiment. You have used children in Hunan for the golden rice experiment. Have the Americans given you data? And, the so-called corn experiment has been rejected by the European Food Safety Agency. What the hell! (@U Still Shining After Seeing the Vast World)[20]

Second, other related incidents, such as 'gutter oil', 'Sudan Red' and 'PX' had featured in food safety, ecological security and environmental security controversies in recent years and were frequently mentioned on social media. As Slovic (1986) noted, the experience of a major accident or risky event can enhance the public's memory and imagery of hazards, thereby improving the public's perception of risks. In the Weibo users' posts, the following statements were notable:

> We already have gutter oil. Why should we bother about GMO? (@Li Xingbin)[21]

> In China, there are many other carcinogens (such as toxic milk, lean meat powder, gutter oil, vitamin C tablets). But, it does not mean that GM soybeans are safe. (@Toxic tongue Xiaotai)[22]

> Compared with melamine and Sudan Red, GM food is the ultimate biological weapon. If it can be said that melamine destroys an industry, then GM food may destroy a regime. (@Mr. Cheng's Assistant)[23]

4.2.3 Assimilation: Stigmatization and conspiracy theories

The rumour featured multiple emotions, including public anger, worry, fear and anxiety. The assimilation of rumours is a process of change due to personal preferences, interests and prejudices, which makes the rumour more consistent with people's cognition. This process is reflected in the stigmatization of genetic modification technology and conspiracy theories about why GM crops were introduced to China.

Stigmatization refers to the labelling of a person, region, technology or product that is given such specific attributes as abnormality, flaw, defect or unpopularity (Zeng and Dai, 2015: 24). Kasperson et al. (1988) noted that stigmatization is closely related to risk perception, which can amplify the public perception of risk. The stigmatized labelling of GMOs was achieved by emphasizing the insecurity of GM soybeans.

Our text analysis showed that Weibo users considered GMOs to be unsafe, unhealthy and dangerous and as a means for the United States to 'cleanse' the population of China. Also stigmatized were the Ministry of Agriculture and experts. The ministry was described as a 'ministry for punishment and killing' (@e Primary Meridian),[24] and critics claimed that it regarded the Chinese people as 'laboratory mice':

> From the use of GM food, we can see the determination of the government to pursue its family planning policy. In addition, is this a trap set up by countries in the world other than China, so as to lessen the burden on the Earth? (@Snow and Ice Record)[25]

Conspiracy theories thrive in the dissemination of rumours. Unlike in the controversy over GMOs in the West, one popular point of view in China's GMO controversy is that this technology is being promoted not only for surreptitious economic interests of enterprises, but also for more mysterious, malicious motives. Through this attribution, the rumour that 'GM soybeans cause cancer' was packaged into 'truth'.

In the context of this rumour, the conspiracy theory had two outlooks. First, many Weibo users believed that European countries and the United States had manipulated GMO-related projects to launch financial and political wars against China and that such projects were harming China's interests. Second, they thought that genetic modification technology had been manipulated by privileged interest groups across the world to harm the interests of the lower classes worldwide. Frequently mentioned privileged groups were the Freemasons and Monsanto. China's 'elite' class, such as government officials and scientists, were claimed to have been controlled and driven by an international privileged class. The public thus found a 'reasonable' explanation for the claim that GM soybeans cause cancer. This helped exacerbate fears that GM soybeans may lead to 'national extinction', while the commercial promotion of the product was described as something 'to make Chinese people wear their "sick man's hat" again':

> In the past, the bad officials of the Qing government brought opium and harm to our people. Now, the bad experts and officials in China are helping Western countries to introduce GM food to harm our people. The purpose is to eliminate our population from the Earth. (@xwtcwh)[26]

As a result, the dissemination of the rumour turned into a 'cyber carnival'. Some Chinese netizens resorted to conspiracy theories and cyber bullying against those whom they distrusted to confront Europe and the United States as well as the authoritative classes of China. This constitutes the current situation of Chinese society's 'struggle' against the existing social system and policies. This process is full of people's political imagination,

which makes the rumour about GM soybeans develop as people have assumed it to be true and have eventually 'assimilated' it into their thought.

5. Conclusions

By using online discussions on the rumour that GM soybeans cause cancer as an example, our study used data mining and text analysis to examine the content discussed by netizens regarding the GMO rumour and the mechanism of the online transmission of the rumour.

On the matter of the rumour's content, we found that experts' refutation of the rumour formed a dividing line. Before experts refuted the rumour, netizens generally believed that GM soybeans were related to cancer. Once the experts had stepped forward to refute it, the focus shifted to the experts' credibility. In their discussions, netizens expressed anxiety and panic in both sorrowful and playful ways.

On the matter of the transmission mechanism, the 'evidence' for GM soybeans causing cancer, and other incidents related to GMOs and food safety, were 'added' to the rumour, which ultimately achieved 'assimilation' with the stigmatization of GMOs and conspiracy theories 'explaining' why GM crops were introduced to China.

Widespread rumours about GMOs are inseparable from a lack of public trust in scientists and the government in China. They are also related to the current social system. Communication on controversial scientific issues is often full of unknowns and worries. The lack of trust can exacerbate people's fears, risk perception, anxiety and even anger over GM crop (Griffin et al., 2008). Once the government disregards the public's right to know, it leaves the public with a negative impression. In similar subsequent situations, the public forms inductive expectations based on experience and concludes that the government is incompetent.

In addition, in China's current social system, few institutionalized channels and modes of participation are available for citizens, while such practices as information control and 'black box' operations have increased public distrust of institutions that manage risks (Sun, 2012). Owing to a lack of pathways and channels for citizens to participate in risk management, distrust has become a means of self-defence by the public through which people expect to enhance their ability to perceive risks (Fang, 2013).

Given those conclusions, to curb rumours and minimize their impact on the public, the public's trust in the government and scientists needs to be rebuilt by making decisions transparent, creating smooth channels for transmitting information, maximally respecting the public's right to participate and know, implementing interaction between the public and the government and scientists, and avoiding falling into the 'Tacitus Trap' and the politicization of social issues. A necessary step to respond to rumours is to encourage the scientific community to participate in the dissemination of correct and easily understandable information concerning, in the case of this rumour, GMOs.

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Notes

All Weibo posts cited could be accessed on 10 October 2019.

1 Weibo post: https://weibo.com/1681891743/zCqMTmmBj?refer_flag=1001030103.

2 Weibo post: https://weibo.com/2484858573/zCqGSr2SK?refer_flag=1001030103.

3 Weibo post: https://weibo.com/1769920255/zCskqdIgW?refer_flag=1001030103.

4 Weibo post: https://weibo.com/1400653104/zCti6ozA1?refer_flag=1001030103.

[5] Weibo post: https://weibo.com/3269756167/zCtsi8c3E?refer_flag=1001030103.
[6] Weibo post: https://weibo.com/1880966537/zCsCWdc4B?refer_flag=1001030103.
[7] Weibo post: https://weibo.com/3541439861/zCqPx5oRX?refer_flag=1001030103.
[8] Weibo post: https://weibo.com/1895565951/zCs7HfTdW?refer_flag=1001030103.
[9] Weibo post: https://weibo.com/1726841944/zCSlZ7TTG?refer_flag=1001030103.
[10] Weibo post: https://weibo.com/2995705012/zCB2qlFi2?refer_flag=1001030103.
[11] Weibo post: https://weibo.com/2283428663/zCuV8bRLT?refer_flag=1001030103.
[12] Weibo post: https://weibo.com/1743097025/zCuyK1Eir?refer_flag=1001030103.
[13] Weibo post: https://weibo.com/1895865895/zCucYs9h4?refer_flag=1001030103.
[14] Weibo post: https://weibo.com/2178260925/zCun0bz1G?refer_flag=1001030103.
[15] Weibo post: https://weibo.com/2693368004/zCuz23l7q?refer_flag=1001030103.
[16] Weibo post: https://weibo.com/1358174583/zCzDlauFB?refer_flag=1001030103.
[17] Weibo post: https://weibo.com/1906566577/zCDY1bIz7?refer_flag=1001030103.
[18] Weibo post: https://weibo.com/1796680897/zCMaWr2Px?refer_flag=1001030103.
[19] Weibo post: https://weibo.com/3280826644/zCBFIoi5D?refer_flag=1001030103.
[20] Weibo post: https://weibo.com/2608258711/zCSwsk3XC?refer_flag=1001030103.
[21] Weibo post: https://weibo.com/1319586200/zCE8LycnE?refer_flag=1001030103.
[22] Weibo post: https://weibo.com/2164149934/zCv14mmEo?refer_flag=1001030103.
[23] Weibo post: https://weibo.com/1762470205/zCp7J9NP0?refer_flag=1001030103.
[24] Weibo post: https://weibo.com/1738360632/zCpwaq4O5?refer_flag=1001030103.
[25] Weibo post: https://weibo.com/1429036801/zCzgUdLc2?refer_flag=1001030103.
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Aims and Scope

Cultures of Science is an international journal that provides a platform for interdisciplinary research on all aspects of the intersections between culture and science.

It welcomes research articles, commentaries or essays, and book reviews with innovative ideas and shedding a fresh light on significant issues. Research articles report cutting-edge research developments and innovative ideas in related fields; commentaries provide scientific perspectives on emerging topics or social issues; book reviews evaluate and analyze the context, style and merits of published works related to cultures of science.

The topics explored include but are not limited to: science communication, history of science, philosophy of science, sociology, social psychology, public science education, public understanding of science, science fiction, political science, indicators of science literacy, values and beliefs of the scientific community, comparative study of cultures of science, public attitudes towards a new scientific and technological phenomena.

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