

## Article

# What Framework Promotes Saliency of Climate Change Issues on Online Public Agenda: A Quantitative Study of Online Knowledge Community Quora

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Received: 31 January 2019; Accepted: 13 March 2019; Published: 18 March 2019



**Abstract:** Though scientists have achieved consensus on the severity and urgency of climate change years ago, the public still considers this issue not that important, as the influence of climate change is widely thought to be geographically and temporally bounded. The discrepancy between scientific consensus and public's misperception calls for more dedicated public communication strategies to get climate change issues back on the front line of the public agenda. Based on the large-scale data acquired from the online knowledge community Quora, we conduct a computational linguistic analysis followed by the regression model to address the climate change communication from the agenda setting perspective. To be specific, our results find that certain narrative strategies may make climate change issues more salient by engaging public into discussion or evoking their long-term interest. Though scientific communicators have long been blaming lack of scientific literacy for low saliency of climate change issues, cognitive framework is proved to be least effective in raising public concern. Affective framework is relatively more influential in motivating people to participate in climate change discussion: the stronger the affective intensity is, the more prominent the issue is, but the affective polarity is not important. Perceptual framework is most powerful in promoting public discussion and the only variable that can significantly motivate the public's long-term desire to track issues, among which feeling plays the most critical role compared with seeing and hearing. This study extends existing science communication literature by shedding light on the role of previously ignored affective and perceptual frameworks in making issues salient and the conclusions may provide theoretical and practical implications for future climate change communication.

**Keywords:** climate change; science communication; risk perception; agenda setting; social science

## 1. Introduction

Public communication about climate change requires improvement. Though scientists have achieved consensus on the severity and immediacy of climate change with compelling evidence [1,2], it is of secondary importance on the public agenda [3] because of the invisibility of causes, distant impacts, lack of direct experience and delayed gratification for taking actions [4]. People feel uncertain about climate change and believe that it can only make a difference in a geographically and temporally

distant way [5,6]. According to recent reports from the Gallup Organization, 34% of the public still tends to believe that the severity of climate change has been exaggerated [7] and “Climate Change” is elicited from the leading problem list of Gallup Poll Respondents in 2018 [8], which means that less than 3% of the public regards it as an important problem according to the leading problem selection rule of Gallup, outranked by issues like government dissatisfaction and immigration [9]. Difference in demographics, social engagement and ideology also results in a divergent attitude on whether climate change is an important issue [10–12], regardless of the fact that climate change triggers multiple adverse consequences on biological, social and economic systems [13–15].

Climate change is not just a scientific issue among climate experts but a cross-discipline mixture of science, psychology and public communication. As climate change is essentially related to the issue of energy consuming [16], almost every action mitigating climate change requires changes in convenient modern lifestyle and customary spending habits, which is determined by the public willingness to conduct individual decarbonization by adjusting their living standard and expectation [17]. The public’s personal preference can make a difference on energy use [18]. In addition, public support or opposition directly results in the success or failure of legislation and implementation of related policy by serving as social and political context [19]. Raising non-experts’ concern about climate change with effective public communication skills is the prerequisite of achieving collective and sustained efforts to tackle global climate change.

Media has a significant function of influencing the distribution of the public attention by shaping the informational environment [20–22]. Currently, as an emerging information diffusion channel, the online platform provides an unprecedented chance for the spread of climate change information, where governmental agencies, academic institutes and environmental advocacy organizations are getting more and more involved to advocate for climate change mitigating measures [23–25]. Individuals form their understanding of risk and participate in collective action after searching, commenting on and sharing online information [24,26]. As social media is becoming the sensor and source of the public opinion [27,28], many scholars have realized the importance of the public discussions of climate change on social media [29,30]. However, it has been discovered that significant opinion polarization occurs among social media users and discussions towards climate change tend to take place between people with similar opinions, resulting in “echo chamber” phenomenon [31] and allowing “sceptic” and “activist” to persist within the same online community [32]. Factors raising public awareness in online environment are still not well understood.

Social scientists have noticed that not all information is created equal in online environment and content with certain characteristics [33–36] has been proved to be more popular than others in health communication [37], political communication [38], risk communication [39] and marketing [40]. These findings confirm the argument of agenda-setting theory, saying that, by focusing on different attributes of an issue, media will make the issue move up and down on the public agenda [41].

Prior scholars have discovered that diverse frameworks of climate change are adopted by people with different political opinions online [42]. In addition, discourse analysis of big data from social media also found that many different frameworks exist during climate change related extreme weather events [43], which to some extent is influenced by characteristics and socio-political background of these events. However, Pew reports revealed that, for science-related accounts on the social media, though the volume of their posts significantly increased in the past few years, the alternatives of their narrative frameworks are relatively limited [44]. Some scholars once argued that frame adoption matters for public engagement [45], while there is still little quantitative research demonstrating what narrative framework may increase the chances of climate change receiving more public attention, especially in online environments. In order to get climate change back to the front line of the public agenda and promote public support for decarbonization, it is important to empower climate change communication with more strategical skills by systematically exploring the content framework that may potentially increase the odds of the public concern in online environments.

Many researchers have shown interest in raising public concern by conducting climate change communication during the past few years, but most of them adopted a cognitive communication framework and blamed lack of scientific literacy for the skepticism of climate change according to deficit model [46–48] and regard objective scientific knowledge as the most important component of science communication [49]. Cognition is regarded as the pedestal of the public concern about climate change, while other factors are interfering with public's rationality. Many governmental and non-governmental organizations take same standpoint and believe that, if scientists provide enough statistical evidence, the public will finally make the right rational choice [50]. Thus, lots of contributions in scientific language, information flow, and public education are made for the purpose of promoting public cognitive understanding of climate change [16,32,51].

However, recent studies find that the role of statistic scientific information, such as climate assessments and analytic indicators, is overestimated in science communication [52,53]. Scientific understanding has a high threshold of knowledge and terminology, so it is long-term arduous work to completely improve the scientific literacy of the whole public [54,55], especially when the ignorance paradox caused by online informational explosion hinders the acquisition of scientific knowledge [56]. In addition, knowing about climate change is far from caring about it and the increase of scientific literacy cannot guarantee the increase of concern [16]. Evidence shows that, for some people, concern of climate change decreases as they become more science literate [57]. In addition, some scientists notice that the lack of knowledge between some environmentalists and non-environmentalists is equally serious [58].

Scholars studying risk management argue that the definition of climate change risk [59] consists of not only external definition, where risk analysis is conducted by experts according to standard criteria, but also internal definition, where individual's subjective risk judgement and perceived insecurity are recognized. In other words, more complex psychological models should be introduced to explore the role of other content framework besides the well-focused cognitive factors in promoting public concern about climate change [60–62]. In recent years, psychologists discover that sentiment of online content is a key factor that may influence the diffusion of information by inducing emotion contagion [63,64], which is examined in the spread of health suggestions [37,65], daily news [35] and crisis information [39]. In the field of climate change communication, previous study only focused on whether specific fear-inducing visual and iconic symbols may reduce public's willingness to take environmentally friendly measures [66], while comprehensive rules about how affective polarity and affective intensity of online textual content influence public concern of climate change in online environments remain to be explored. In addition, some scholars have noticed that, in terms of climate change issues, direct personal experience of local temperature change or some natural hazard can help to increase public concern [67,68] in a more effective way than cognitive factors [69]. However, compared with direct personal experience, testing whether second-hand perceptual information contained in content helps improve public concern about climate change is of more practical significance, as the majority of the public cannot directly experience natural hazards caused by climate change or distinguish them from climate variation [59], most of whom can only have an understanding of climate change through description of experience in mediated information.

To bridge this research gap, we chose online knowledge community Quora as a platform to offer an empirical assessment of how different frameworks of climate change information improve its saliency. Quora is designed for the purpose of sharing and growing knowledge of world, where large amounts of questions from various topics are generated everyday, competing for users' limited attention. Users have total information selection freedom when faced with huge information flow. When, in the content of climate change, certain question does not look attractive, they can avoid it and turn to other climate change issues or issues under the other topic, such as technology and politics. However, they will spend efforts to browse, follow, or answer questions when they are touched by the description of climate change questions. In this case of Quora, we want to explore how content framework can make climate change issues rise or fall on the public agenda by evoking different

psychological process. To be specific, we focus on three types of content framework mentioned above, including affective, perceptual and the well-focused cognitive framework, to examine their influence on issue saliency. The research questions are listed as follows:

RQ 1: What framework, affective, perceptual or the well-focused cognitive framework, plays a most critical role in making climate issue salient?

RQ 2: How do different components of affective, perceptual, cognitive framework contribute to the saliency of climate change issues?

Adaptation and mitigation actions should be adopted to tackle anthropogenic climate change and its negative effects on natural and social systems, but current beliefs about climate change are mixed. This study tries to provide theoretical guidance to understand the mechanism of the public awareness towards climate change issues and make effective communication strategies. By analyzing large-scale data acquired from online knowledge community Quora with computational linguistic methods from the perspective of agenda-setting theory, this study provides empirical evidence to examine the relationship between framework of online information and public concern about climate change. The results make a contribution to understanding the complex dimensions of information in the communication of climate change and finding out what framework is most effective in making climate change a high ranking issue on the public agenda in online environments. In practice, our finding will help governmental agencies, academic institutes and environmental advocacy organizations adapt communication techniques and offer targeted information to help climate change issues achieve a higher status on the public agenda.

## 2. Materials and Methods

### 2.1. Framework

#### 2.1.1. Definition

In social science, the terminology of framing is conceptualized to describe how the reality is reconstructed by individuals and organizations. To be specific, framing refers to the process that certain parts of perceived reality is chosen and highlighted in the description of reality, just like photographers deciding which part of reality is included and how the elements are displayed in the frame when creating compositions. Though the same event is used as a base, a subtle change in framing leads to a significantly different perception of reality, casual interpretation and alternative solutions [70]. For example, previous research discovered that sacrifice framework such as “We have to drive less to stop climate change” and motivation framework such as “Our children will have a better life if climate change is stopped” tend to result in different public engagement [71].

Frameworks hidden in the text of mass communication have long been the research interest of scholars in sociology and psychology. Sociologists mainly focus on how multiple factors such as professional routines, political preference and cultural background work together to build the framework of media [72]. While psychologists devote more efforts to framing effects, which refers to how different media frameworks influence audience’s reality perception, responsibility attribution and decision-making [73]. Gamson and Modigliani define framework as the internal structure of media texts and the core idea of organizing information materials [74]. By selecting, emphasizing and excluding some aspects of information, news reports reconstruct one realm of reality and suggest how the audience should understand events [70]. How media frames a particular issue determines how it is symbolized with meaning and whether it stays high or falls down on the public agenda [75]. By influencing the way individuals notice, remember and interpret certain features of reality [70], successful framing techniques may guide their information processing and give preferences to certain choices in risky contexts [76]. Previous studies have looked into whether talking about climate change in the frame of gain or loss outcomes and the frame of local or distant impacts may contribute

more to public awareness [77], and compare the effects of motivational and sacrifice information framing strategies [71] in offline environments. However, there have been no studies paying attention to the relationship between framework and public concern in online environments or examining the effectiveness of the cognitive appealing communication strategy, which is the dominant public communication paradigm currently. In this study, we will examine how different psychological frameworks contained in online information, including cognitive framework, perceptual framework and affective framework, contribute to public concern about climate change risk.

**Cognitive Framework.** Cognition science, as a branch of psychology, focuses on how nervous systems understand, process, and generate information and try to explore the principles of intelligence [78]. The terminology of cognition always refers to individuals' conscious information processing process, including but not limited to attention, memory, and problem-solving. Cognition plays an important role in learning, decision, logic and planning, and thus has long been highly valued in science communication [47]. Accordingly, cognitive framework adopts features that need to be handled consciously and analytically by the public, including abstract processes such as attention, memory, and thinking [79]. For example, the following sentence from the IPCC Special Report 2018 [80] is a typical statement with cognition framework:

*Human activities are estimated to have caused approximately 1.0 °C of global warming above pre-industrial levels, with a likely range of 0.8 °C to 1.2 °C. Global warming is likely to reach 1.5 °C between 2030 and 2052 if it continues to increase at the current rate (high confidence).*

Traditional risk studies believe that, when people are faced with uncertain situations, they collect statistic evidence, assess the possible consequences, balance the alternatives of choice, and finally lead to rational conclusions [81–84]. Many scholars believe that cognitive-based analytical processing can increase people's understanding of complex, abstract, long-term risks [69,85] and value it a lot in improving people's understanding and concern of climate change risk [51,56], while some other scholars question its efficiency in making climate change salient [86]. In this study, we will evaluate whether a cognitive framework contained in the content leads to more concern regarding intentions towards climate change than other frameworks.

**Perceptual Framework.** Perception refers to brain's overall perception and understanding of how outside world works when the external stimulus acts on the senses. By processing raw sensory as inputs and transforming it into high-level information, perception helps individuals to organize and explain the sensory information of the outside world [87]. Typical components of perception process are vision, sound, touch, taste and smell. The following description of personal experience in Hurricane Sandy is a perception appealing statement [88]:

*There was a newborn infant across the street, two houses down, Jimmy O'Connor went over and got her and held the baby over his head while he walked through the water.*

Perceptual framework focuses on sensory information received, identified and interpreted by the nervous system [89]. Individuals' perception about the environment is shaped after processing sensory inputs and transforming them to inherent concepts [87]. Some studies have pointed out that personal experience will shape the perception of risk and behavioral response [90], which is called "prison of experience" [91]. Recent personal experiences about certain natural hazards have been proved to result in higher public attention likelihood towards climate change [92], while whether perceptual factors displayed in online content will have similar effect remains to be discovered in this study.

**Affective Framework.** Affect is related to individuals' emotional statement or response. A VAD model is traditionally adopted to describe affect [93], where valence refers to the goodness or badness of current emotion, arousal indicates to what extent the individual is provoked or active, and dominance means the sense of control of current situation. Valence is the most widely adopted dimension in sentiment analysis, which is used to evaluate positive, neutral, or negative emotion contained in a piece of text. For example, the following statement of news from CNN (Cable News Network) [94] adopts an affective framework, where the negative emotion overwhelms the positive one.



*Climate change will shrink the US economy and kill thousands, a government report warns.*

Affective framework refers to content that can induce negative emotions such as fear, anxiety, and sadness, or positive emotions such as happiness and inspiration [95,96]. A psychological study indicates that emotion is a kind of information and it can shape our attitude or response towards risk automatically and unconsciously [97,98]. Scientists have found that people with empathy ability are more easy to hold a pro-environment attitude [99]. However, academic community has not reached a consensus on how affective factors increase saliency of climate change issue. Some scholars believe that negative emotions such as fear and pain can make people helpless, self-defense and indifference [86], but other scholars believe that negative emotions can motivate people to adopt self-protective measures and save themselves from uncertain situations [100,101]. In this study, we will examine how affective frameworks in content influence saliency of climate change.

### 2.1.2. Measurement

We use a natural language processing tool called LIWC2015 (Linguistic Inquiry and Word Count) [102,103] to automate the extraction of psychological frameworks in the text. LIWC is widely adopted and validated by computer science, psychology and linguistics in several applications of web texts analysis [35,39,104]. LIWC believes that language psychometrics of words reflect people's mental pattern process and it relies on a built-in dictionary evaluated by experts from 181,000 texts to make calculations. These linguistic features are related to different mental states and include common cognitive, sensory, and emotional vocabulary in psychology. LIWC can generate ninety indicators in all to analyze the content characteristics and these indicators are designed following hierarchy rules [103]. For example, Perceptual Process is a first-class indicator and it includes See, Hear and Feel as sub-category indicators.

In this paper, we adopt thirteen indicators as shown in Table 1, including Cognitive Processes, Perceptual Processes, Affective Processes as three first-class frameworks and ten indicators belonging to the three major categories as second-class factors. We believe that it is difficult to say that the content of certain questions is completely cognitive, perceptual or affective, but a relative proportion of the three frameworks can reflect the overall tendency and the score of ten second-class factors will help us look into the components of three frameworks in detail. For each input text, we can get thirteen scores ranging from 0 to 100 as output and each score refers the proportion of words of corresponding categories in the input text.

**Table 1.** Content characteristics from LIWC.

Framework	Factor	Example
Cognitive Processes	Cause	because, effect
	Insight	think, know
	Discrepancy	should, would
	Tentative	maybe, perhaps
Affective Processes	Certainty	always, never
	Positive	love, nice, sweet
Perceptual Processes	Negative	hurt, ugly, nasty
	See	view, saw, seen
	Hear	listen, hearing
	Feel	feels, touch

For affective framework, we can get the score of positive and negative sentiment in the text with LIWC as described above and we also need to calculate another two affective indicators based on formulas discovered in previous literature [39,63,105].

**Affective polarity.** We need to calculate the overall affective tendency of each text, that is, if the text contains both positive and negative emotions, it can be judged whether the overall mood of the

text is positive or negative by comparing the strength of positive and negative emotions. Value ranging from 50 to 100 indicates a positive tendency, and value ranging from 0 to 50 indicates a negative tendency, and 50 indicates a neutral tendency:

$$polarity = 1/2 \times (positive - negative) + 50.$$

**Affective intensity.** We also need to get the affective intensity of the text with the following measurement, which refers to total amount of affective factors of an issue regardless of affective valence. The intensity value is normalized to range between 0 and 100, by multiplying by 1/2. High affective intensity means high affective arousal ability of the text:

$$intensity = 1/2 \times (positive + negative).$$

For example, if the positive score of a question content is 23 and the negative score is 11, then we can lead to polarity of 56 and intensity of 17.

## 2.2. Saliency

### 2.2.1. Definition

The degree to which the agenda is important to the public is called the saliency of the issue, and high saliency means the issue has a high status on the public agenda list [20]. As public attention is a kind of limited resources [106], only salient issues can be recognized, concerned and remembered by the public. In traditional communication studies, scientists usually measure saliency of issue by asking participants to evaluate certain issues in a scale ranging from ‘not care about it at all’ to ‘care about it very much’, or to sort several issues to get a relative rank [107,108]. However, sampling error, question inducibility, and self-reported inaccuracy when carrying out the survey may all lead to bias from the real situation [109]. In addition, it is hard and costly to deal with large-scale data on the Internet with these traditional methods.

Digital trace on Quora provides us with an alternative way to measure saliency. For each question under the topic of Climate Change, users can click into the homepage of every question to browse details, provide answers, or click the follow button to track future activities if they think the question is worth their time. The home page of each question not only contains the answer list, but also displays the number of views, followers, and answers to the question. We believe that these indicators are natural records of users’ behavior, and can be used to quantify the questions’ saliency on users’ agenda.

### 2.2.2. Measurement

The metrics that can be obtained on Quora concerning questions’ saliency are the number of views, the number of followers, and the number of answers. Among the three, the number of views should be excluded because Quora adopts an intelligent news feed algorithm to selectively recommend content to the user. As browsing is a low threshold behavior that requires least efforts compared with answering or following, users are rather likely to click into the home page of questions recommended accidentally and passively. The opacity of the recommendation algorithm introduces an uncertain interference factor for observing the actual saliency with number of views, while both the number of question followers and the number of answers are adopted to measure the degree of saliency because they both require high level of consciousness and willingness, which can reflect users’ real interest.

The number of answers to the questions indicates public willingness to participate in discussion. Since answering questions means that users need to spend a lot of time on thinking, writing, and even interacting with others in the comment area of his or her answer, the number of answers indicates whether the question is important enough and worthy of being discussed in the answerer’s opinion.

The number of followers indicates public’s willingness to track issues. On Quora, if clicking on the follow button below the question, to subscribe to a question, the user will receive updates of the

question on their notification bar in the future by getting his account linked to the question. Thus, when users choose to follow questions, it means they are interested in the question very much and regard it worthy of being tracked in the long run.

### 2.3. Data Collection

As one of the largest online knowledge communities worldwide, Quora claims to have 300 million monthly users and more than 400,000 topics [110]. By encouraging users to ask and answer questions, Quora promotes knowledge to flow from one to another and shapes audiences' understanding of world, attracting large numbers of users who may be potentially interested in climate change and making Quora an important forum for the dissemination of climate change information. Though Quora doesn't collect or disclose users' demographic data, statistics released by Alexa indicates that Quora users are mainly from the United States (36.2%), India (21.3%), the UK (5.2%), Canada (4.0%) and Japan (3.1%). Relative to the general Internet population, 18–24 year olds are over-represented, 25–34 year olds are similar, and people over 35 year olds are under-represented in Quora. Compared with the average education level of the Internet population, people who went to graduate school occupy a larger proportion, people with college experience occupy a similar proportion and people who did not go to college occupy a smaller proportion. In addition, males are more likely, but females are less likely to visit Quora relative to the general Internet population [111].

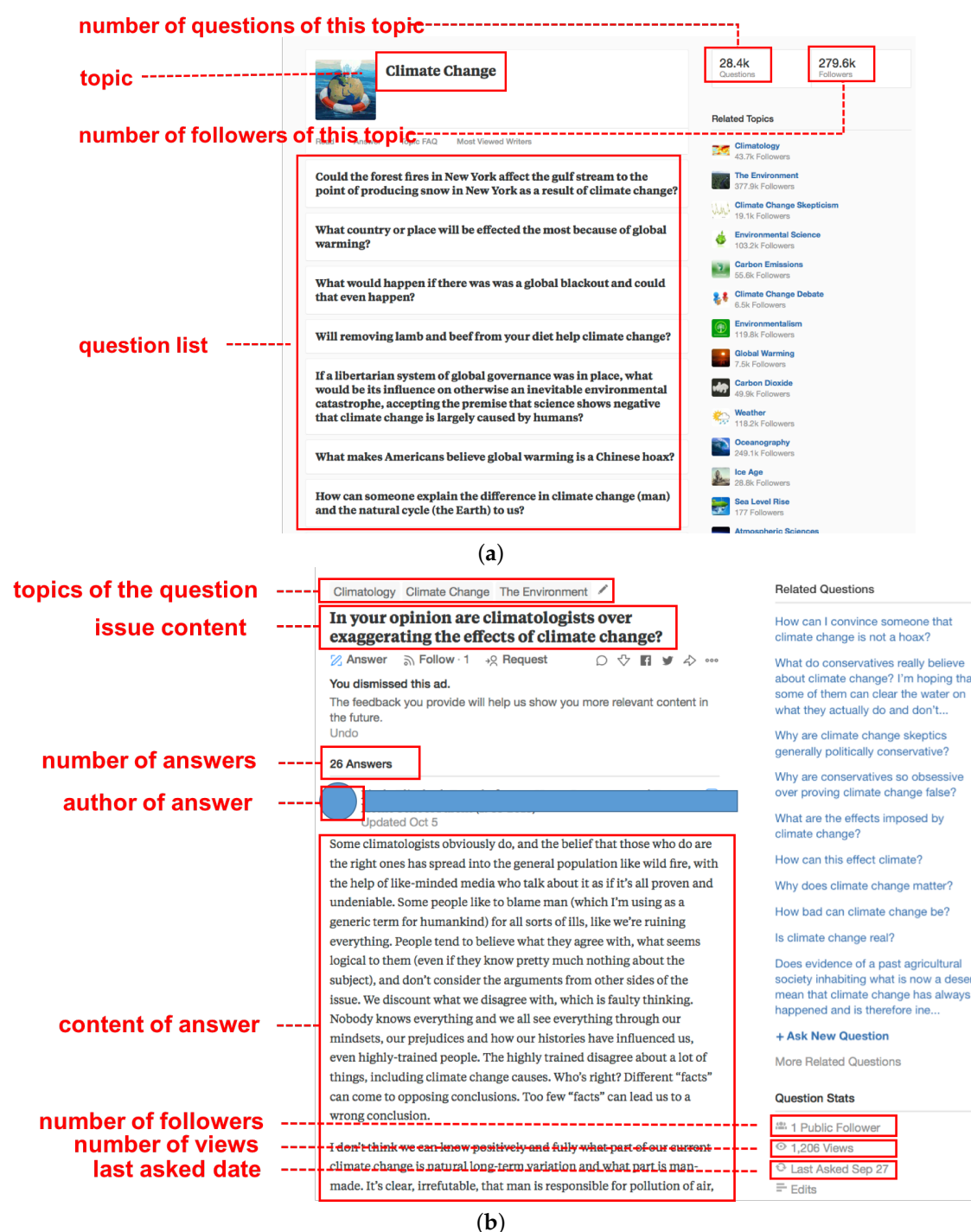
As an online knowledge community, Quora adopts a topic–question–answer structure to organize its content, creating a centralized public sphere for users to get access to science information. People who want to raise questions about climate change can add their questions under the topic of Climate Change. Other users will provide answers to these questions or choose to follow the updates if they feel concerned after seeing the question [110]. On Quora, lay public and experts can conduct serious discussions and form understanding towards scientific issues, with the help of a rigorous review mechanism to remove irrelevant and inappropriate questions and answers [112,113]. More detailed mechanism of Quora is explained in Appendix A.

Taking sharing and growing the world's knowledge as its mission, the online knowledge community Quora is more proper for investigating the relationship between content framework and saliency on the public agenda, compared with other websites such as Twitter and Facebook. With the mission statement “bring the world closer together” and “give everyone power to create and share ideas and information”, Facebook and Twitter are designed for social purposes, encouraging people to share daily life or news. The discussions of scientific knowledge, such as climate change, are less dominating on Facebook and Twitter, failing to provide enough alternative climate change questions at one time. In addition, the content is mainly organized and filtered by personal social relationships on Twitter and Facebook, leading to difficulties and interferences in systematic research on the correlation between content characteristics and issue saliency of climate change.

Computer scientists have proved statistically that the distribution of users' attention follows the power-law distribution on Quora. The majority of questions attract few answers and views, but some questions are more capable of getting views and answers compared with others [114], making Quora an ideal environment to observe how content characteristics help certain issues to compete for limited attention resources.

Digital trace [115] provided by Quora allows us to quantitatively analyze the interaction between users and questions. For example, all the questions are organized by topic [116] as shown in Figure 1a and each question [117] has an independent homepage displaying its answers and statistic information as Figure 1b, and the log of question [118] will record its history since it was put forward, such as the date it was asked for the first time and the user who asked it (Figure 2a). Users' profile, such as the number of followers, is also available on the individual homepage as shown in Figure 2b.





**Figure 1.** (a) questions under topic of climate change; (b) questions' main homepage.

We collected data of Quora using web-based crawling, with the prerequisite of obeying the Quora robot.txt. We designed a crawler by calling the automation tool Selenium to invoke headless browser PhantomJS with a script in Python and simulated clicks and scrolls to load the target page. The operation frequency was limited to three requests per second to minimize the impact on the Quora server. Climate change is an independent topic of Quora, containing more than 284,000 questions until 14 November 2018. Since not all questions but only recent questions on Quora are accessible, we collected the latest 5301 questions under the topic of climate change raised between 22 April and 14 November.

The question content, number of views, number of followers, and number of answers were collected. If the answer number is larger than 100, it will show '100+' rather than the accurate number on the webpage, and we will automatically scroll the window of web browser to the bottom and count the exact number of answers. In addition, the date question was raised for the first time and the user who raised it up were also collected as ancillary information. Furthermore, we collected the public information of askers, such as the number of their followers, as ancillary information. When questions are raised by anonymous users [119], information of askers is recorded as 0.

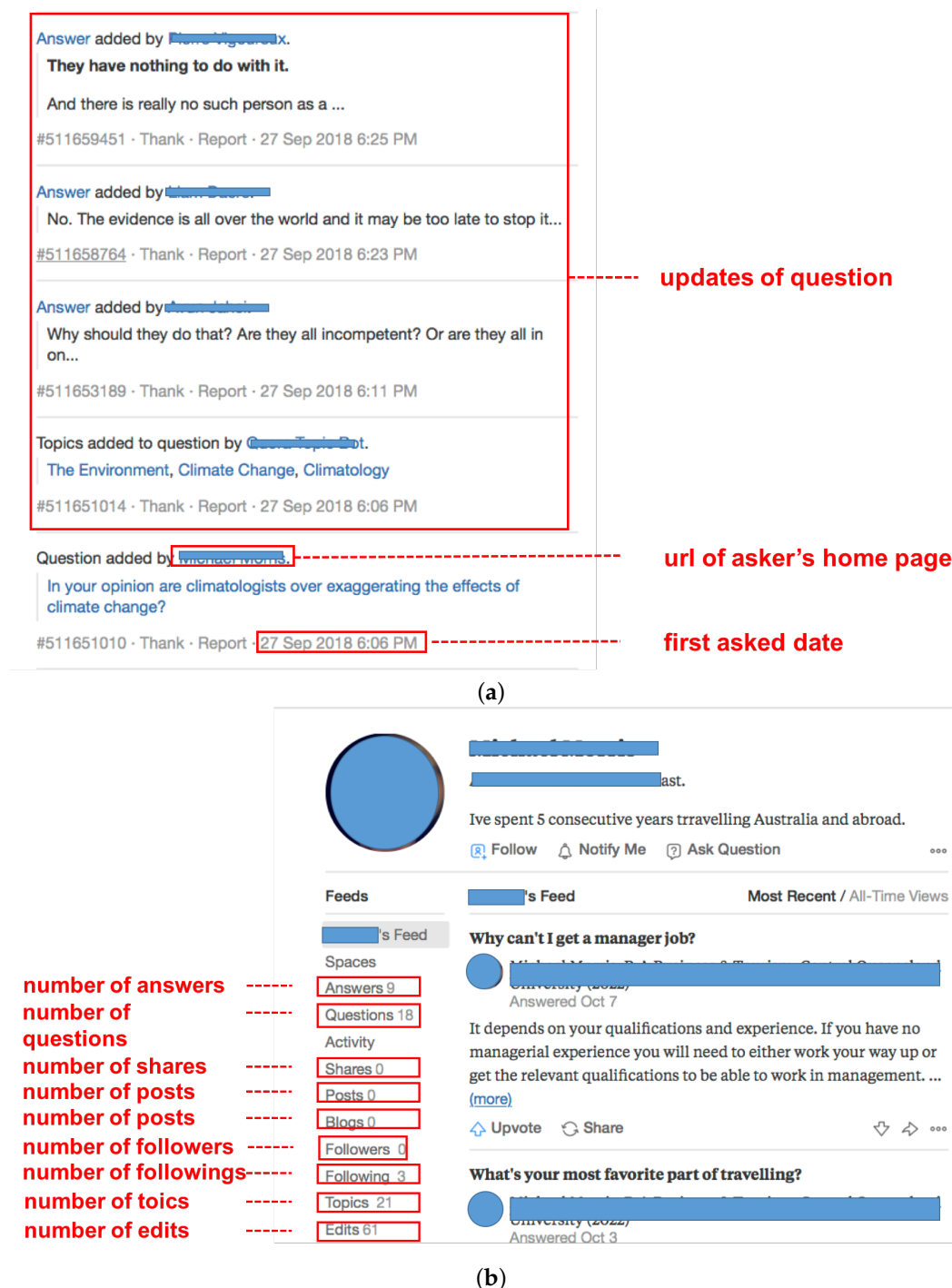


Figure 2. (a) questions' log page; (b) users' public information.

## 2.4. Regression Analysis

### 2.4.1. Variables

Based on the analysis above, we choose the number of answers and the number of followers as dependent variables to measure the saliency of climate change issues.

- *answer\_num*: number of answers the question received
- *follow\_num*: number of followers the question received

In addition, the variables below are independent variables for RQ1:

- *cog*: proportion of cognitive framework in the question content
- *percept*: proportion of perceptual framework in the question content
- *affect*: proportion of affective framework in the question content

The following variables are independent variables for RQ2:

- *cause*: causation factors in the question content, a kind of cognitive factor
- *insight*: insight related content characteristics, a kind of cognitive factor
- *discrep*: discrepancy related content characteristics, a kind of cognitive factor
- *tentative*: tentative related content characteristics, a kind of cognitive factor
- *certain*: certainty related content characteristics, a kind of cognitive factor
- *see*: seeing related content characteristics, a kind of perceptual factor
- *hear*: hearing related content characteristics, a kind of perceptual factor
- *feel*: feeling related elated content characteristics, a kind of perceptual factor
- *pos*: positive affect factors in the question content, a kind of affective factor
- *neg*: negative affect factors in the question content, a kind of affective factor
- *intensity*: affective intensity of question content, a kind of affective factor
- *polarity*: affective polarity factors in the question content, a kind of affective factor

### 2.4.2. Control Variables

In addition to the dependent variables and independent variables mentioned above, we have selected several variables as control variables following previous literature. Since Quora has a social networking mechanism where content produced by different people may have different influences [120], the popularity of question-asker is measured by the number of his or her followers as a control variable. In addition, the number of words has been proved to influence content popularity, so the length of each question is counted [121,122]. In addition, the questions put forward earlier have a longer lifespan until they are collected by crawler [123], so the date when questions are generated is controlled. For climate change issues, previous research has proved that urgency is a factor that affects the public's attention [4] and it is likely that questions focusing on the present situation are more concerned than those focusing on the past and future, so we introduce time orientation indicators provided by LIWC to examine the extent to which the content is related to current situation. The statics of control variables is shown in Table 2.

**Table 2.** Summary statistics for control variables.

Variables	Description	Min	Max	Mean	Std. Dev.
wc	word count of the question	2.00	49.00	16.73	8.55
now	the time orientation of the question	0.00	50.00	11.30	6.76
user_follower	the follower numbers of the asker	0.00	176,624.00	343.44	3900.82
date	the first asked date of question	0.00	201.00	121.21	56.37

### 2.4.3. Model

Both dependent variables are count variables and have a variance ( $Var_{num\_answer} = 40.195$ ,  $Var_{num\_follower} = 41.979$ ) much larger than the mean ( $Mean_{num\_answer} = 3.989$ ,  $Mean_{num\_follower} = 2.356$ ). Thus, we adopt negative binomial model in this study to deal with the skewed variables, assuming that the dependent variables follow the negative binomial distribution.

For RQ1, the following regression model is used to examine the influence that cognitive, affective and perceptual content framework have on public willingness to get involved in discussion:

$$\log(E(answer\_num)) = \beta_0 + \beta_1 cog + \beta_2 affect + \beta_3 percept + \beta_4 wc + \beta_5 now + \beta_6 \log(user\_follower) + \beta_7 date. \quad (1)$$

In addition, the following regression model is used to examine the influence that cognitive, affective and perceptual content characteristics have on public willingness to receive future updates of certain issues:

$$\log(E(follower\_num)) = \beta_0 + \beta_1 cog + \beta_2 affect + \beta_3 percept + \beta_4 wc + \beta_5 now + \beta_6 \log(user\_follower) + \beta_7 date. \quad (2)$$

For RQ2, to examine how specific cognitive, affective and perceptual content characteristics influence the willingness to participate in discussion, the following regression model is adopted. In addition, considering the fact that affective intensity and affective polarity is calculated based on pos and neg, they cannot appear in the same equation with pos and neg to avoid multicollinearity, and we will examine affective intensity and polarity in the second equation:

$$\log(E(answer\_num)) = \beta_0 + \beta_1 cause + \beta_2 insight + \beta_3 discrep + \beta_4 tentative + \beta_5 certain + \beta_6 \log(see) + \beta_7 \log(hear) + \beta_8 \log(feel) + \beta_9 pos + \beta_{10} neg + \beta_{11} wc + \beta_{12} now + \beta_{13} \log(user\_follower) + \beta_{14} date, \quad (3)$$

$$\log(E(answer\_num)) = \beta_0 + \beta_1 cause + \beta_2 insight + \beta_3 discrep + \beta_4 tentative + \beta_5 certain + \beta_6 \log(see) + \beta_7 \log(hear) + \beta_8 \log(feel) + \beta_9 polarity + \beta_{10} intensity + \beta_{11} wc + \beta_{12} now + \beta_{13} \log(user\_follower) + \beta_{14} date. \quad (4)$$

For RQ2, to examine how specific cognitive, affective and perceptual content characteristics influence the willingness to track the issue, the following regression model is adopted. Affective intensity and affective polarity are also separated from pos and neg because of multicollinearity:

$$\log(E(follower\_num)) = \beta_0 + \beta_1 cause + \beta_2 insight + \beta_3 discrep + \beta_4 tentative + \beta_5 certain + \beta_6 \log(see) + \beta_7 \log(hear) + \beta_8 \log(feel) + \beta_9 pos + \beta_{10} neg + \beta_{11} wc + \beta_{12} now + \beta_{13} \log(user\_follower) + \beta_{14} date, \quad (5)$$

$$\log(E(follower\_num)) = \beta_0 + \beta_1 cause + \beta_2 insight + \beta_3 discrep + \beta_4 tentative + \beta_5 certain + \beta_6 \log(see) + \beta_7 \log(hear) + \beta_8 \log(feel) + \beta_9 polarity + \beta_{10} intensity + \beta_{11} wc + \beta_{12} now + \beta_{13} \log(user\_follower) + \beta_{14} date. \quad (6)$$

## 3. Results

### 3.1. Description

According to the analysis of 5301 issues, the content characteristics distribution of climate change issues on Quora is displayed in the Table 3. Furthermore, 4795 issues have cognitive content, accounting for 90.455% of the total, which is in accordance with our expectation of science communication.

Affective content appears in the 2932 (55.310%) questions, and its value (Mean\_affective = 5.123) is relatively lower compared with cognitive characteristics (Mean\_cognitive = 16.114). Perceptual contents just appear in the 1984 (37.427%) questions and have a lowest proportion (Mean\_perceptual = 2.974).

Causal relationship is the most frequently mentioned aspect of cognitive characteristics, accounting for 74.571% of the total questions. As for affective dimension, positive emotion is relatively stronger (Mean\_positive = 3.460, Mean\_negative = 1.562) and appears more frequently (Frequency\_positive = 42.728%, Frequency\_negative = 22.015%) compared with negative emotion. Feeling (Frequency\_feel = 30.768%) is the most frequently used perceptual stimulation compared with seeing (Frequency\_see = 5.678%) and hearing (Frequency\_hear = 2.924%) in question content.

**Table 3.** Statistic description of variables.

Category	Characteristics	Min	Max	Mean	Std.	Issues (Percent)
Summary	cog	0.000	66.670	16.114	10.014	4795 (90.455)
	affect	0.000	50.000	5.123	6.043	2932 (55.310)
	percept	0.000	50.000	2.974	4.658	1984 (37.427)
Cognitive	insight	0.000	50.000	2.47	4.67	1715 (32.352)
	cause	0.000	50.000	8.638	7.970	3953 (74.571)
	discrep	0.000	25.000	1.879	3.681	1390 (26.221)
	tentat	0.000	30.000	2.466	4.004	1843 (34.767)
	certain	0.000	25.000	0.839	2.373	734 (13.846)
Affective	pos	0.000	40.000	3.460	4.914	2265 (42.728)
	neg	0.000	33.330	1.562	3.420	1167 (22.015)
	intensity	0.000	25.000	2.511	2.993	2892 (54.556)
	polarity	33.335	70.000	50.949	2.994	2533 (47.783)
Perceptual	see	0.000	33.330	0.344	1.631	301 (5.678)
	hear	0.000	16.670	0.147	0.935	155 (2.924)
	feel	0.000	30.77	2.407	4.246	1631 (30.768)

### 3.2. Influential

In RQ 1, we want to explore what role the cognitive framework, affective framework and perceptual framework play in improving the significance of the issue. According to the analysis results shown in Table 4, all three variables are statistically significant in promoting discussion about climate change. Among them, perceptual framework has the most powerful influence, cognitive framework has a relatively smaller influence. As for the influence on public willingness to track issues, perception is the only significant variable.

We found how three frameworks work in detail. Though causal relationship is the most frequently used cognitive factor, it cannot help to improve public engagement in issues' discussion. While insight words such as think and know may attract the public to get involved in public discussion, the result indicates that certainty may also increase public interest about climate change. In addition, we found a significant positive effect of affective factors. Both positive and negative emotion can contribute to the heat of discussion, which is in accordance with the results indicating affective intensity rather than polarity matters. Public shows a larger probability to be influenced by hearing and feeling positively, while seeing has no obvious effect. Most content characteristics cannot help with long-term public interest, while feeling, a perceptual factor, is an exception.

As for the control variables, the larger the word count is, which means that the more specific the description is, the more likely it is discussed by the public. Content related to contemporary situation and askers with more followers can both make issues more salient. The lifespan of question is relevant to the amount of users following the question.



Table 4. Regression results of variables.

Category	Variables	Num_Answer		Num_Follower	
		Coef	z-Value	Coef	z-Value
Summary	cog	0.944 ***	6.317	−0.235	−0.955
	affect	0.978 ***	5.106	−0.053	−0.162
	percept	1.142 ***	4.615	0.956 *	2.342
Cognitive	insight	1.348 ***	6.597	0.295	0.425
	cause	0.249	1.661	−0.072	0.757
	discrep	0.157	1.044	−0.271	0.303
	tentat	0.207	1.248	−0.351	0.218
	certain	0.453 *	2.150	−0.340	0.377
Affective	pos	1.903 *	0.057	0.121	0.734
	neg	0.769 ***	0.000	3.913	0.178
	intensigy	0.837 ***	4.207	−0.290	−0.834
	polarity	−0.464	−1.558	0.647	1.248
Perceptual	see	−0.547	0.585	0.248	0.345
	hear	0.458 **	2.751	0.094	0.762
	feel	0.513 ***	5.513	0.338 *	0.026
Control	wc	1.042 ***	9.042	0.149	0.566
	now	0.968 ***	6.056	0.589 *	2.490
	user_follower	0.761 ***	7.527	0.991 ***	5.997
	date	−0.0542	−0.683	−0.434 ***	−3.482

Note:  $p < 0.001$  (\*\*\*),  $p < 0.01$  (\*\*),  $p < 0.05$  (\*).

The above analysis is based on data acquired from 22 April and 14 November in the year of 2018; and the number of questions on each day is shown in Figure 3. The number of questions raised in August and September is slightly higher than that of April to July and reaches its peak on 9 October. Previous study has demonstrated that high temperature and extreme weather in summer is more likely to be associated with climate change, compared with extreme weather in colder seasons [124]. In 2018, tropical storms such as Hurricane Florence contributed to the popularity of climate change questions on Quora from August to September. The IPCC report released on 8 October and its following debates resulted in the rising number of questions since 8 October. Natural or social-political events may influence public perception of climate change as external shocks and different characteristic of events may result in diverse understanding [43,125]. However, considering the fact that tropical storms in summer and the release of the yearly IPCC report are some sort of annual practice, as such events are highly predictable. These highly predictable events, which may cause popularity of such related topics, can influence the talks of users on the general information and natural phenomenon. In addition, our empirical setting did cover these events as listed in Figure 3, which makes us believe that our data well represents the average online discussion situation.

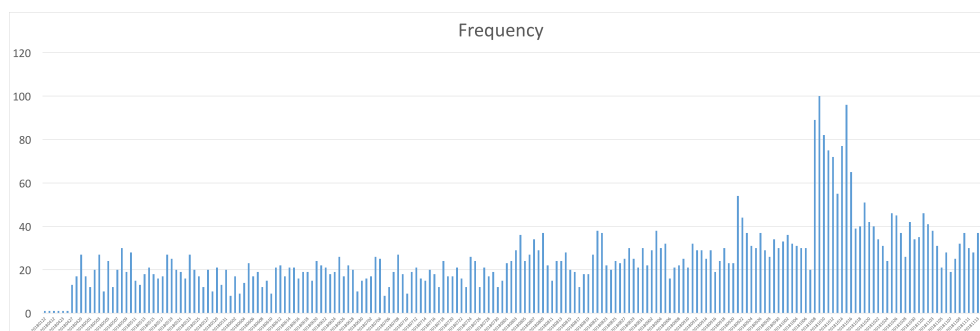


Figure 3. The frequency of questions under climate change topic on 22 April and 14 November in the year of 2018 on a day basis.

#### 4. Discussion

The Internet has become an important channel for the public to obtain information and form attitude, especially for online knowledge discussion community, where the public can ask and answer questions about scientific topics and deeply participate in the dissemination of scientific issues. A good question can help the climate change issue gain the attention it deserves and get viewed from an inspiring perspective. However, so far, few studies have analyzed what traits make certain climate change questions hot issues while what traits make issues neglected. By analyzing texts in the online discussion community Quora using automated language computing tools, we identify invisible psychological frameworks reflected in unstructured question text and study how they influence public awareness towards climate change. Compared with traditional polling methods such as questionnaires or surveys, this study adopts large-scale data provided by Quora and carries out a quantitative regression analysis based on objective digital indicators.

In addition to the methodological breakthroughs, the research results are yet to provide a complementary perspective for the subsequent science communication. The agenda setting theory in communication science points out that the public agenda is kind of limited in resources for which huge amounts of issues, group of interests and ideology compete in a zero-sum gambling [106] and media's strategic framing based on different attributes of the issue can lead to different levels of concern about the issue [96]. The attributes that can stimulate the user's attention are called the compelling arguments. Though some scholars have noticed various frameworks appearing in climate change [45], no quantitative research was made to identify what the compelling arguments are in the field of climate change. This study has finally proved how different content frameworks influence the saliency of climate change issues after analyzing 5301 questions on Quora and may help scientists to refine their communication skills by adopting proper framework in the future.

The results reveal that the strategy of current climate change communication remains to be improved. At present, cognitive, perceptual, and affective factors are not evenly distributed in the text of climate change issues, and cognitive factors have the largest proportion. We believe that, although climate change is a scientific topic with mathematical models and statistical measurements, it also reflects the neglect of the other two aspects, just as some scholars believe that people can "make systematic use of information available to them" and are not "controlled by unconscious motives or overpowering desires" [126]. In fact, for both saliency indicators, cognitive framework is not the most powerful influence compared with affective and perceptual framework. The cognitive miser model [127] assumes that people are of low-information rationality and they tend to minimize the information used for decision-making due to their limited capacity to process information. By taking cognitive shortcuts and turning complex problems into easier judgements, people go through huge amounts of information and make quick decisions under uncertainty [128]. People are not totally vulnerable to scientific cognitive information that they are exposed to and other psychological processes take place when people form their attitudes towards climate change. In addition, cause and effect, the most frequently used framework in cognitive category, cannot guarantee the improvement of saliency. Such results indicate that, if science communicators want to raise public concern for climate change, they should change their traditional cognitive-related methods and turn to affective appealing or perceptual appealing methods.

The perceptual content characteristic is the most compelling argument for both increasing current discussion and long-term interest, helping the public to lower their psychological distance with climate change and build personal bond. Hearing and feeling both have heuristic functions for improving current discussion intensity and only feeling can significantly evoke sustained concern. Previous studies have pointed out that, as climate change is intangible in everyday life, it is hard for people to worry about geographically and temporally distant effects [5,6]. Personal experience of certain natural disasters can make people regard climate change as a direct and immediate threat, rather than a distant or abstract problem, and raise concerns about environmental issues [129,130]. This study extends existing literature about experience and risk perception [67,68] by indicating that not

only direct experience but also mediated experience in text will enhance concern about risk. Textual description of perceptual factors can motivate public discussion and evoke long-term public concern. The reason that perceptual framework has a powerful influence on public awareness remains to be explored, but social scientists once put forward a media equation theory [131] proposing that people may instinctively regard the information in the media as a real thing in real life. As climate change is difficult to feel directly in real life, cyberspace provides a new medium for story-telling. The narrative factors about perception in the text can play an alternative role of real sensory stimulation and shape an individual's subjective perceived risk.

In addition, the results indicate that affective factors have a larger impact than cognitive factors but didn't get enough attention in previous climate change communication. Some psychologists believe emotion is information [132] and it may cause attention bias [133], resulting in change of attitude, response and judgement of risk. Emotions of different valence, arousal and dominance can change the popularity of content [134]. As an intrinsic response, emotional factors affect risk perception more than external factors. In particular, online information overload [135] and the upper limit of people's information processing capabilities [136] make processing resources limited and emotions rather than rationality are more likely to occupy a dominant position [137].

Although some scholars believe that people are more willing to discuss and share positive news [35] to acquire pleasure, according to current data, the ability of negative information to increase attention is particularly higher than positive information in the field of climate change. The difference may be due to the fact that, as climate change is a kind of risk situation, negative information can work as a monitoring system to protect individuals from danger and get current situations refined [138]. In addition, some studies have pointed out that, in climate change communication, evoking negative psychological response such as fear will reduce the users' concern because it will increase the public's sense of helplessness [66], which contradicts our results. It can be explained that the adverse effect of fear appeal only occurs when the intensity of fear is relatively high and there is no solution provided after fear is aroused [139]. In the current situation shown in Table 3, the frequency and intensity of negative emotions is relatively low, and climate communicators do not need to worry about the bad effects caused by fear appealing. Increasing the negative mood is a suitable strategy to increase public attention for the current situation.

Two different saliency standards lead to different influential variables. For increasing the intensity of the discussion, all three frameworks have positive effects, with perceptual framework being most important, affective framework second, and cognitive framework the weakest. However, for the willingness to increase sustained attention, affective and cognitive framework has no significant effect, and perception has a significant positive effect. The reason why affective factors cannot promote long-term interest is not conclusive, but we assume that affective factors are good at motivating people to make fast and automatic decisions without analysis [140] and to allocate their attention impulsively [141], making this issue popular rather than persistent. Although it cost less effort to click the follow button than to answer a question on Quora, following means users' expectations for continuous and long-term updates of the question, which is supported by more sustainable rather than more impulsive interests. In addition, perceptual factors may provide users with stimulation of visual, auditory, tactile, and taste intake, resulting in a long-lasting and instinctive understanding of risk [69]. The divergence in the influentials shows that if public discussion and current heat of topics are needed, all three strategies can work, although to distinct extents. If gaining long-term influence is expected, science communicators need to focus on sensory stimulation and make sure users get second-hand personal experience after reading the text.

## 5. Conclusions

Though climate change is predicted to threaten the sustainability of earth and human system severely, its status on government and public agenda is not stable [107,142]. According to Downs' issue-attention model, the public's attention in the life-course of climate change issues is a five-stage

cycle [143], where public's attention comes and goes, and finally maintains a low level of attention on climate change. How to make climate change salient in online environments is little understood and extra efforts are required to get climate change back to the frontline of the public agenda, especially when public beliefs about climate change are polarized and divisive on the Internet [31]. This study takes a cross-discipline perspective and introduces psychology, public communication and computational linguistics into communication of climate change in the case of Quora, focusing on three facets of question information and revealing that saliency of climate change issues depends on how issues are expressed.

The results of computational linguistic analysis for large-scale data indicate that cognitive factors are the most frequently used framework in current climate change communication, compared with affective factors and perceptual factors. The regression model reveals that (1) cognitive framework is over-emphasized for its effect on issue saliency compared with affective framework and perceptual framework; In addition, though cause is the most frequently used cognitive factor, it cannot promote concern about climate change statistically; (2) affective intensity can significantly improve public willingness to get involved in climate change discussion, and negative emotion has a greater impact compared with positive ones; (3) perceptual frameworks play the most critical role in increasing public discussion and is the only kind of content characteristics which can raise long-term concern for climate change.

Deficit Model has long been a dominant paradigm among science communicators [47], blaming lack of scientific literacy for the skepticism of scientific consensus and regarding rigorous scientific evidence as the most important content in science communication. Pew's investigation also discovered that most posts of science-related accounts still adopted a "new discoveries" framework on social media platform [44]. Inspired by the agenda setting theory in mass communication, this study tried to examine how different frameworks of climate change information contribute to climate change awareness. The results revealed that cognitive framework, though highly-recognized in the Deficit Model, plays the least significant role in all three psychological frameworks in online knowledge communities. With quantitative analysis of large scale data, this study demonstrated the significance of perceptual and affective factors, providing supporting evidence for introducing emotional narrative storytelling [144] into online communication of climate change.

Our findings are supposed to equip climate change communicators with more effective strategies in practice. With remaining true and accurate as a prerequisite, climate communicators are expected to be a good storytellers and adopt more narrative elements to narrow the psychological distance between audience and climate change. For example, personal experience and sensory details can be adopted to help sterile scientific facts be presented in a vivid manner. In addition, literary techniques can help to generate compelling stories when describing real people and real events to audiences, factually accurate but in an attractive and memorable way. Replacing emotionless assertion or argument with emotion-driven messages can capture public attention and promote emotional understandings of climate change. In addition, though the online knowledge community Quora was rarely studied before or compared with Twitter or Facebook, it adopts a decentralized knowledge generation model and attracts users who are the potential targets of climate change communication, making it a promising communication channel and deserving of more attention for climate change communicators. Our case study of Quora may provide some references for the future for climate change scholars and policy makers.

Though this study offers a new perspective and innovative methodology for making climate change more salient on the public agenda in online environment, there are still some limitations. Firstly, due to the different users and characters of different online websites, it is true that user samples acquired from Quora can only present a part of general Internet population. However, we think that the current dominated users of Quora well represent the key stakeholders of climate change and fit the target users of the online knowledge community, as Quora users are more likely to talk about the scientific research rather than the general information on climate change as literature

indicates [123]. In addition, as Quora has been growing rapidly with more registered users in the past few years, our case study of Quora about how content frameworks influence climate change saliency is expected to provide some theoretical and practical implications for optimizing current discourse adopted by online climate change communicators. However, considering the contribution and limitation in this aspect, we suggest future studies introducing experimental methodology to thoroughly examine how demographics influence the correlations between content framework and public concern about climate change. Specially designed software can simulate online environments, making experiments about computer-mediated communication like [145] possible.

Secondly, there were no significant unusual events happening during the data collection period, so our findings are based on average online discussion situation. However, considering that online public perception of climate change may be influenced by some unusual significant events, such as natural disasters, social movements or political events, more case studies such as [43] about these unusual events can be done to understand how special natural and socio-political backgrounds play a moderate role in the relationship between narrative framework and public concern.

**Author Contributions:** W.S. designed the model, collected data and wrote the article. H.F. reviewed and edited the article by offering suggestions to the part of data analysis and discussion. C.C. contributed to the conceptualization and operationalization of variables. J.X. helped with the framing of research and contributed to manuscript revision.

**Funding:** This work was supported in part by the National Key R&D Program of China (Grant No. 2017YFA0604500), by the National Natural Science Foundation of China (Grant No. 51761135015), and by the Center for High Performance Computing and System Simulation, Pilot National Laboratory for Marine Science and Technology (Qingdao).

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

Quora is an English online Q&A community, which claims to take sharing and growing the world's knowledge as its mission. Quora started its rapid growth since it offered service to the public in June 2010. The number of monthly unique visitors had achieved 190 million in April 2017 and exceeded 300 million in September 2018.

Quora adopts a user-generate model, where all contents are generated by registered users when they ask, follow and answer questions. By clicking "Ask Question", users can raise a question and select more than one relevant topic for it, enabling other users to find the question under the topic. Users who want to share opinions about the questions can write their answers and users who want to receive the updates of questions can click the "follow" button. Quora also allows users to follow others and to receive activities of the person that they follow in their personal news feed. If the person chooses to ask or answer questions anonymously, these activities will not be available to his or her followers.

Quora adopts a series of policies to improve the quality of discussions. Quora suggests users to register with their real full names, which improve the reliability of answers. Users will be required to offer supporting evidence if Quora thinks they are using fake names. Quora Moderation will flag the profiles that do not conform to Quora real name policy to give a reminder about risk for other users. In addition, users are expected to conform to strict rules when asking and answering questions. All questions must be raised in the proper form, or they will be either edited by other users or removed by Quora. An answer will be collapsed if Quora and other users think it needs improvement to be helpful, such as unsupported personal opinions and assertions that provide minimal explanation, and insincere/not sincerely responding to the question. Harassment, spam, unhelpful credentials and joke answers will also be reported. User-voting mechanisms are also introduced to help excellent answers stand out.



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