UNDERSTANDING THE SCHOLARLY COMMUNICATION PROCESS THROUGH DIGITAL TRACES: A STUDY OF TWITTER

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ABSTRACT

Shenmeng Xu: Understanding the Scholarly Communication Process Through Digital Traces: a Study of Twitter
(Under the direction of Bradley M. Hemminger)

Through the lens of the exploratory framework of Digital Trace of Scholarly Acts (DTSA), this dissertation study explored researchers' activities around scholarly articles on Twitter. Using a mixed-methods design, this study analyzed data collected from a large-scale survey and twenty interviews with researchers on Twitter. The Critical Incident Technique was used as part of the interview study to learn about the full stories behind researchers' sharing of scholarly articles on Twitter.

There were variations in the researcher's sentiment of opinions on articles they tweeted, retweeted, replied, and liked, based on their demographics. Despite a general positive tendency, researchers' Twitter activities were associated with different sentiment due to their different perceptions of these activities. Variations were also found in how sharing scholarly articles on Twitter fit into researchers' scholarly acts workflow with no monolithic pattern.

This study contributed to a better understanding of the digital traces left by researchers on Twitter by providing richer descriptions and narratives of their activities. Researchers shared scholarly articles on Twitter for a variety of motivations: networking, promoting, disseminating, commenting, communicating with intended users, acknowledgment, and saving for later reference. The findings particularly shed light on the role of Twitter in communicating research and network building.

Investigating the impact of the articles on the researchers led to a better understanding of what types of articles had a higher premium of sharing by researchers on Twitter. Evidence was found to support both the normative theory and the constructivist theory – the categories of impact included connecting, informing, practice-changing, beyond research, and potential impact. However, more than half of the shared articles examined had no impact on the researchers' own work, indicating that Twitter metrics, even solely based on researchers' Twitter activities, should not be used as an evaluative metric of the articles shared.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

According to the Association of College & Research Libraries (ACRL), division of American Library Association (ALA), scholarly communication is "the system through which research and other scholarly writings are created, evaluated for quality, disseminated to the scholarly community, and preserved for future use" (American Library Association, 2006). In this definition, the scholarly communication process covers a wide range of scholarly activities. Scholarly works being discovered and used are not spelled out, but they are important latent components in the scholarly communication lifecycle, connecting the preservation of scholarly works and the creation of new scholarship.

This dissertation research chooses this definition as the working definition of scholarly communication because the scope of scholarly communication in this dissertation is more than "communicative" activities (Borgman & Furner, 2002, pp. 6). In addition to being "writers", "linkers", "submitters", and "collaborators" (Borgman & Furner, 2002, pp. 6), researchers' activities in their workflow, such as searching for, obtaining access to, initial evaluation of, reading and sensemaking of, organization and knowledge structuring of scholarly works, are also of importance to be explored.

The term "*scholarly act*" (Haustein, Bowman, & Costas, 2016) is adopted in this dissertation to describe scholarly activities occurring in the context of diverse scholarly communication tools, publishers, online repositories, and general social media. In the proposed exploratory framework of the Digital Trace of Scholarly Acts (DTSA) (Figure 1.1) in this dissertation, the traceable digital footprints of these acts are defined as *digital traces* in the

broadly defined scholarly communication process. By conducting these "scholarly acts," researchers leave digital traces online, indicating their engagement with the scholarly objects. In other words, a *digital trace* is the electronic record of a user-generated scholarly act on a particular scholarly object, mediated by a particular information service or platform. Digital traces data, accordingly, are collections of individual digital traces captured and recorded for a given period of time.

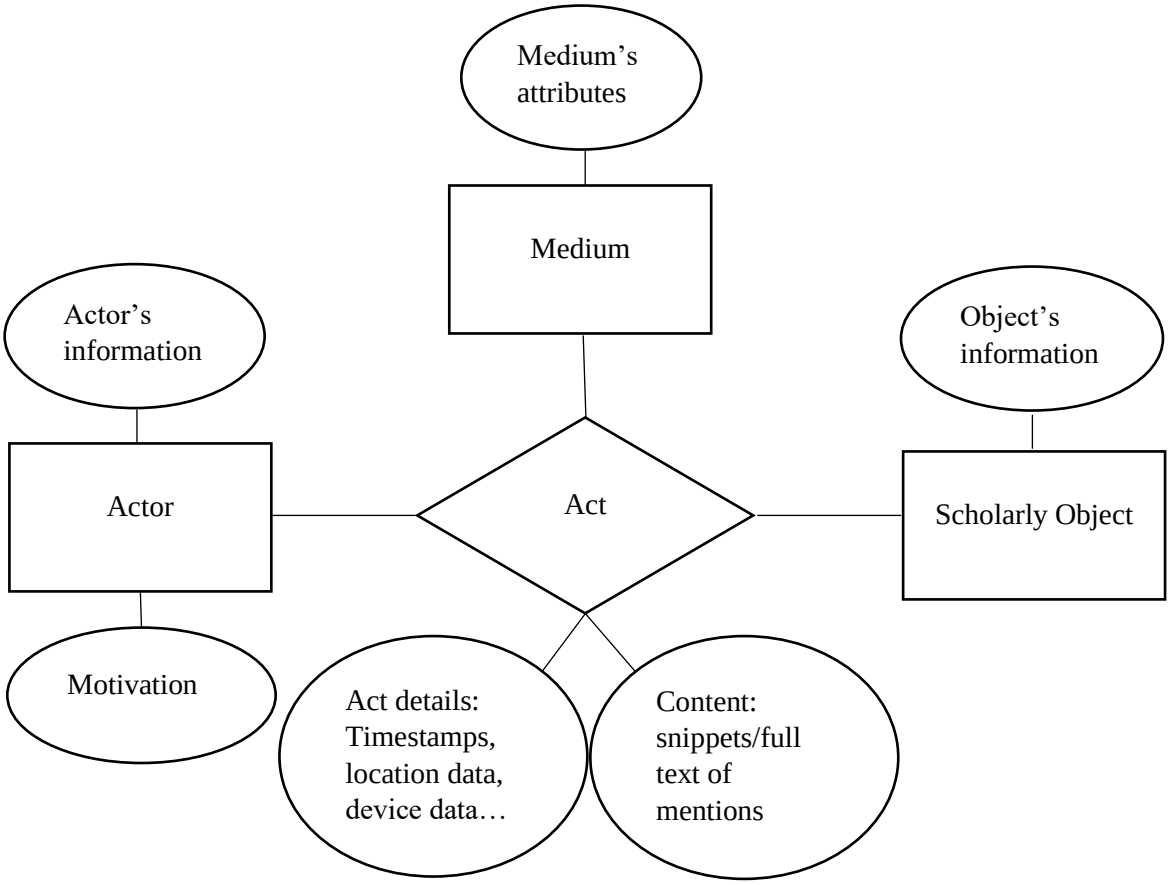

Figure 1.1 Framework of the Digital Trace of Scholarly Acts (DTSA)

As is shown in Figure 1.1, when an *actor* conducts an activity on a *scholarly object* in a *medium*, a ternary relationship, *act*, is created among these three entities. The actor, the scholarly object, and the medium all have their own attributes and information. The act mainly has two

categories of attributes: *act details* and *act content.* The *act details* are the pieces of information associated with the actor, scholarly object, and medium. The *content* is what an actor generates to describe or comment on the scholarly object, which is also based on the affordances of the medium. These two types of attributes, especially the act details, abound in the digital environment of researchers' workflow today. They are regarded as the digital traces of scholarly activities providing evidence in understanding researchers' interactions with scholarly works. These act details can be viewed as metadata of the acts. However, in this study, the term "act details" is proposed and used to specifically describe the metadata of the scholarly acts instead of using the generic term "metadata."

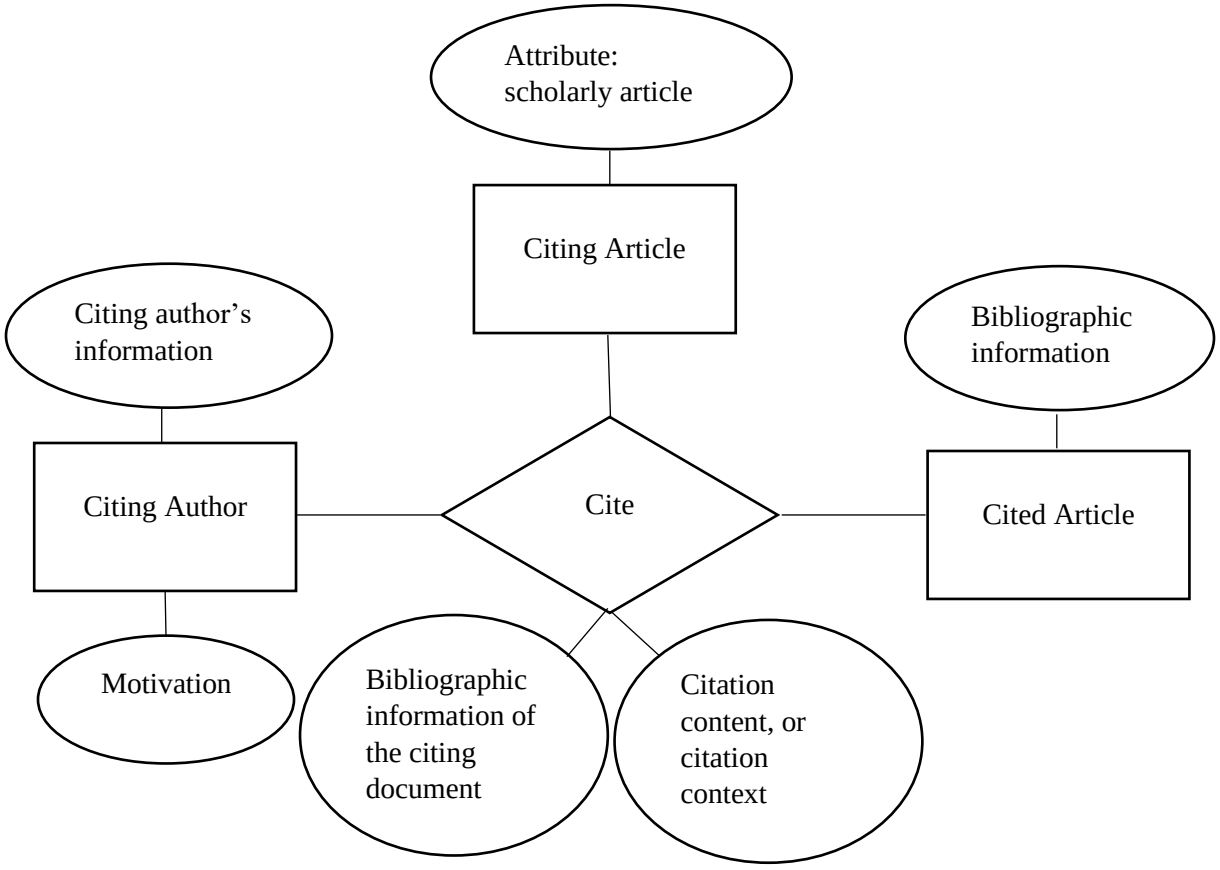

Figure 1.2 Citation as a Digital Trace of a Scholarly Act (Citing)

The type of scholarly trace that has been most thoroughly studied is citations (Bornmann & Daniel, 2008). A citation is created when a citing author cites a previously published document in a new scholarly document. As is shown in Figure 1.2, similar to what has been depicted in the Framework of the Digital Trace of Scholarly Acts (DTSA) (Figure 1.1), an *act* of citing is formed through the interaction among a citing author (*actor*), a cited document (*scholarly object*), and a citing document (*medium*). This trace of a citation can be inverted into this *act* of citing. These three elements (the citing author, the cited document, and the citing document) are essential in the creation of a citation and have been researched in extensive empirical studies. The attributes of a citation that have been studied in existing works are mainly *citation details* (bibliographic information of the citing paper), and *citation content* (or citation context).

Researchers leave traces of their behavior during many stages of their research process (Cronin, Snyder, Rosenbaum, Martinson, & Callahan, 1998; Marchionini, 2010). Parts of this process were formerly invisible. Now with scholarship moving online, we can access various types of digital traces of researchers' activities. Twitter, an open platform featured with the quick dissemination of information, sharing beyond peer groups, democratized comments, and largely unfiltered critiques, is one of the platforms that provide the richest data of digital traces around scholarly articles.

The act of sharing a scholarly article on Twitter is depicted using the Framework of the Digital Trace of Scholarly Acts (DTSA) in Figure 1.3. When a researcher (*actor*) shares a scholarly article (*scholarly object*) on Twitter (*medium*), the *act* of sharing is formed. The text of the tweet is considered the *tweet content*, while other information, including the timestamps, location data, device data, and so on, are created as the *tweet details*. Prior studies have explored

both the act details and content surrounding the communication of scholarly articles on Twitter (e.g., Na, 2015; Thelwall, Haustein, Larivière, & Sugimoto, 2013; Tsou, Bowman, Ghazinejad, & Sugimoto, 2015). However, while the tweet connects the tweeting author and the article, the intent of the author in sharing the article is often not explicitly clear. The exploration of content has revealed that the majority of tweets do not hold a positive stance or recommendation towards the scholarly articles that are included. For instance, Thelwall et al. (2013) found that more than 95% of the tweets tweeting a collection of journal articles were neutral; Tsou (2015) reported that only around 17% of tweets tweeting a collection of psychology articles revealed the intention of the recommendation of the papers. To complement these findings, in this dissertation, a different approach was used to explore researchers' sentiment of opinions on scholarly articles. Instead of examining the tweet content, surveys and interviews of the actor, the tweeting user, were used to capture their intent (RQ1, RQ3).

As can be seen in Figures 1.2 and 1.3, the occurrence of a scientific tweet resembles the creation of a scientific citation in nature. However, these two interactions differ from each other in many ways. One of the major differences is that the trace creators on Twitter are not limited to researchers. For instance, around 25.8% of Twitter accounts that have included a link to a scholarly article in four leading journals were identified as possessing a Ph.D. degree in Tsou et al. (2015). Although this percentage is high compared to the percentage of Ph.D. degree holders in the general population, in many cases, the majority of the users tweeting scholarly articles are probably non-researchers. On the other hand, not all researchers in the academic community use Twitter. Previous studies have found that around 10% to 15% of researchers use Twitter for work (Rowlands, Nicholas, Russell, Canty, & Watkinson, 2011; Van Noorden, 2014). However, in this dissertation research, the aim is to study the intersection of these two populations – researchers

and Twitter users. Specifically, this study started with their acts of sharing scholarly articles on Twitter and expanded this to explore how this fits into their other scholarly acts (RQ2).

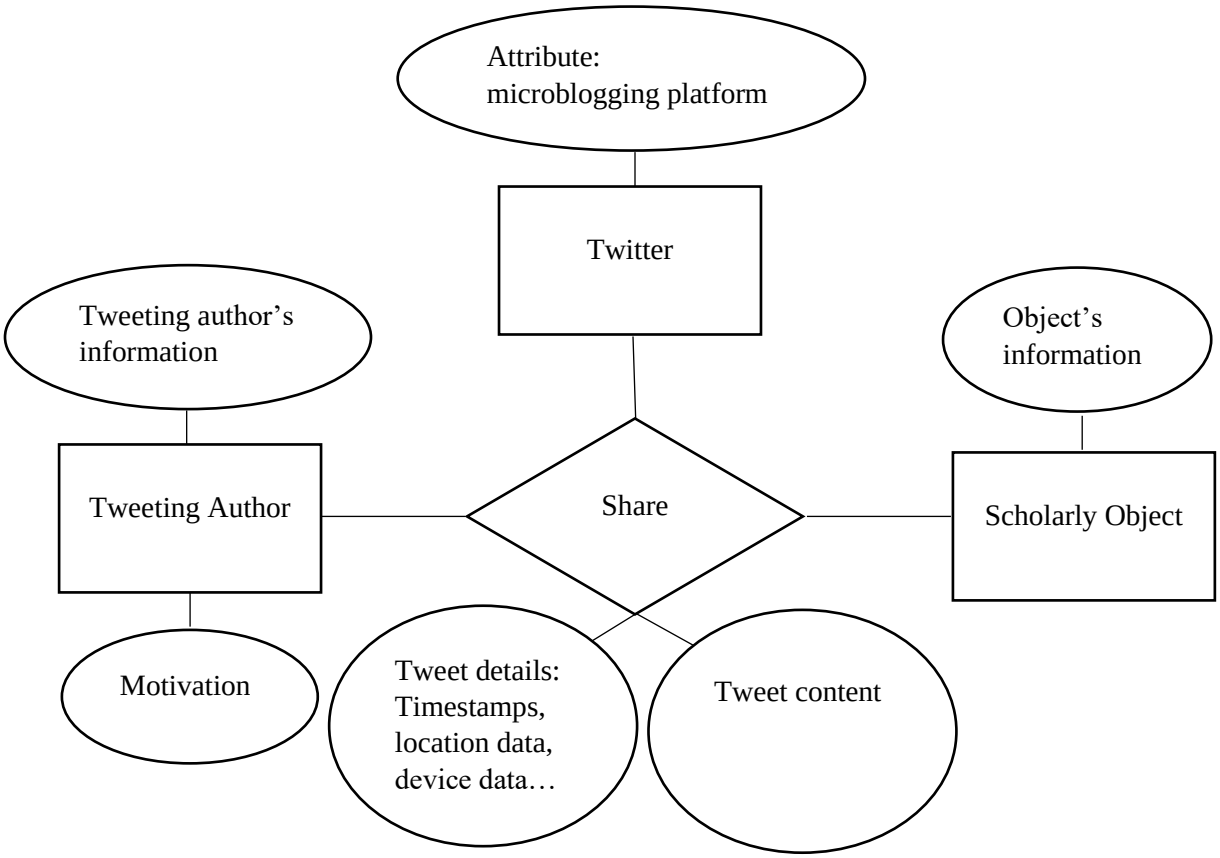

Figure 1.3 Tweet as a Digital Trace of a Scholarly Act (Sharing on Twitter)

Through the exploration of the motivations behind citations, citation theories including the normative theory (Kaplan, 1965), social constructivist theories (Gilbert, 1977), and concept symbols theory (Small, 1978) have been proposed and discussed. Similarly, a large number of the current altmetric studies were developed from an empirical perspective. However, the digital traces of the scholarly acts can only serve as a post hoc operationalization of user motivations, interests, needs, intentions, or post-act usage that led to the acts (Kurtz & Bollen, 2010). This is

similar to the idea of the semiotic citation theories (Wouters, 1999; Cronin, 2000; Wouters, 2016), which states that the sign of citation is "not a representation of reality, however distorted, but an object in the real world of knowledge making" (Wouters, 2016, pp.87). The low level of reflection on the fundaments of scholarly acts is a barrier that hinders the induction of theoretical development about the nature of these digital traces. Although currently, many types of digital traces can be collected on a large scale, inverting the traces into activities requires further understandings of the meaning of the acts, particularly the motivation of the actors. Sud and Thelwall (2014) discussed the importance of the use of creator motivation interviews or questionnaires among six methods to evaluate altmetrics. Investigating scholars' perceptions of the acts, their motivations behind the acts (RQ3), and the impact of these articles on their own works (RQ4) can help provide richer descriptions and narratives of their behaviors. Then, a fuller picture of the acts and digital traces can be mapped.

To sum up, aiming to study researchers' activities around scholarly articles on Twitter, this study selected only researchers who used Twitter as the subjects of inquiry. By conducting a large-scale survey and follow-up interviews, this study aimed to expand current altmetric research beyond the simple captures of occurrences of acts and to incorporate more contextual information about the acts into the analysis. The acts on Twitter (including tweeting, retweeting, replying, and liking) were examined in greater detail. In addition, aiming to reconstruct the sharing behaviors of the participants, this study used the Critical Incident Technique to interview participants about the stories behind their sharing activities and the articles they shared. Their motivation for sharing the articles and the impact of these articles on their own works were analyzed. An additional goal of this study was to better understand the patterns of occurrences of

cross-platform acts in the broadly defined scholarly communication process, especially those that are more likely to co-occur with the sharing activities on Twitter.

CHAPTER 2: LITERATURE REVIEW

2.1 Scholarly Communication in the Digital Age

2.1.1 Scholarly Activities and Scholarly Communication

According to Gelfand (2008), the definition of scholarly communication has only been in our standard lexicon since 1992, when Anthony Cummings and colleagues edited the report of *University Libraries and Scholarly Communications* (Cummings, 1992). The Association of Research Libraries (ARL) and the American Association of Universities (AAU) then joined forces to address and study the problems identified in the Cummings report. Scientific and technological information was one of the three major topics discussed. Later, the Association of College and Research Libraries (ACRL) Division of the American Library Association (ALA) created a scholarly communication toolkit to assist the academic library community to work with faculty to better understand the key issues, and develop strategies for change that could introduce methods and best practices in scholarly communication. The definition of scholarly communication for those purposes is:

> "Scholarly Communication is the system through which research and other scholarly writings are created, evaluated for quality, disseminated to the scholarly community, and preserved for future use." (American Library Association, 2006)

Information and Communication Technology (ICT) is playing an increasingly important role in supporting and enhancing modern research and scholarly communication. The use of the Internet, digital libraries, and computing grids has enabled a seamless flow of seeking, preserving, using, and creating information in the research process (Borgman, 2010). This allows

research practices to evolve on a larger scale, becoming richer in communication means and patterns, with fewer boundaries in space and time than before (Friedlander, 2009). In this digital age, researchers are able to "ask new questions, create new kinds of scholarly products, and reach new audiences" (Borgman, 2010, pp. xvii).

The Web 2.0 environment takes scholarly communication one step further, featuring the participation of more stakeholders (O'reilly, 2009). Extensive studies have been conducted to explore researchers' opinions and adoption of social media tools (e.g., Nicholas & Rowlands, 2010; Meyer et al., 2011; Bulger et al., 2011; Harley, Acord, Earl-Novell, Lawrence, & King, 2010). As the continuous improvement of scholarly communication infrastructures, more possibilities are emerging to study the information diffusion (e.g., De Choudhury, Lin, Sundaram, Candan, Xie, & Kelliher, 2010; Chang, 2010) and behaviors of researchers (e.g., Rhodes, Bowie, & Hergenrather, 2003; Mohammadi, Thelwall, Haustein, & Larivière, 2015).

According to Palmer, Teffeau, and Pirmann (2009), the literature on scholarly information behavior dates back at least to the reports from the 1948 Royal Society Scientific Information Conference and the 1952 Chicago School symposium on specialized information (Egan, 1954). Boyer (1990) discusses four dimensions of scholarship, which are *discovery, integration, application, and teaching*, indicating the "interdisciplinary, interpretive and integrative" nature of scholarship (Boyer, 1990, pp. 21). Specifically, the *discovery* dimension broadly refers to scholarly investigation to the unknown and to the gaps in human knowledge, which comes very close to the definition of "research" (He & Jeng, 2016); the integration dimension involves connections across scientific disciplines; the application dimension emphasizes engagement in the academia communities through being good citizens and providing services; and the teaching dimension includes both education and enticing future scholars

(Boyer, 1990). Following a similar idea, Unsworth (2000) proposes seven "scholarly primitives," including *discovering, annotating, comparing, referring, sampling, illustrating, and representing*. These primitives are basic functions "common to scholarly activity across disciplines, over time, and independent of theoretical orientation" (Unsworth, 2000, pp. 1). Building on these, Palmer and colleagues (2009) further refine the concept of "scholarly primitives" in their comprehensive review of scholarly information practices. Specifically, they frame their review around five core scholarly activities, including *searching, collecting, reading, writing, and collaborating*. In addition, they also include an additional category of "cross-cutting primitives," which encompasses monitoring, notetaking, translating, and data practices (Palmer et al., 2009, pp. 28).

In *Theories of Informetrics and Scholarly Communication: A Festschrift in Honor of Blaise Cronin* edited by Sugimoto (2016), Haustein, Bowman and Costas's chapter (2016) propose a framework of scholarly acts grouped into three categories: accessing, appraising, and applying, with an increasing level of engagement. In this framework, a wide range of scholarly acts is incorporated. According to their definition, accessing includes acts that "involve accessing and showing interest in the research object" (pp.378); appraising includes acts of mentioning the research object on "various platforms such as microblogs, in a social network, in a comment, on a Q&A site, listserv, or rating or voting platforms, as well as in a podcast or video, presentation, review, blog post, Wikipedia article, mainstream media and news, or scientific or policy document" (pp. 378); applying refers to acts that shows "actively using significant parts of, adapting, or transforming the research object" (pp.379). They provides several examples of "applying", including discussion of an article's content in a blog, the use of a scholarly document for self-study, the adaptation of the content of an article for a lecture, the modification or

improvement of a dataset or software, and so on (Haustein et al., 2016). In the same book (Sugimoto, 2016), another important chapter by Moed (2016) conceptualized altmetrics as "traces of the computerization of the research process." (pp. 362) Particularly, four aspects of the research process were distinguished: 1) the collection of research data and development of research methods; 2) scientific information processing; 3) communication and organization; and 4) research assessment. Moed (2016) built on the notions of Michael Nielsen in his monograph *Reinventing Discovery: The New Era of Networked Science* (Nielsen, 2010), and emphasized the importance of conceiving computerization in a broad sense in the digital age.

Publishing platforms and altmetrics data aggregating tools provide the usage and social media mentions data, which reflect slightly different but overall similar sets of scholarly acts. ImpactStory, one of the earliest altmetrics data aggregators, tracked views, saves, discussions, and recommendations (ImpactStory, 2012). A similar classification was proposed by Lin and Fenner (2013) for the Article-Level Metrics in the Public Library of Science (PLoS). Altmetric.com, currently one of the largest altmetrics data providers (Adie & Roe, 2013), have been tracking various sources of : Scopus and Web of Science citations, social networks (e.g., Twitter, Facebook, Google+, LinkedIn, and Pinterest), multimedia and community platforms (e.g., Youtube, Reddit, and StackOverflow), public policy documents, academic and non-academic blogs, news outlets, online reference managers, research highlights (F1000), post-publication peer review platforms (Pubpeer and Publons), Wikipedia, and the Open Syllabus Project.

Previous research has attempted to study the relationships between scholarly acts in the workflow of researchers. Mohammadi, Thelwall, and Kousha (2016) conducted a survey of 860 Mendeley users and found that most (55%) users had read or intended to read at least half of

their bookmarked publications. A work by Didegah, Alperin, and Costas (2018) investigated the path from Mendeley readership to citations. Through matching citing authors in Scopus with Mendeley users, they identified 270 users (about 5%) citing at least one of the articles they saved to their Mendeley libraries. Xu, Brown, and Hemminger (2018) interviewed researchers at two universities in the U.S. on nine groups of forty scholarly acts. In the interviews, participants talked about how much they think the acts indicate the scholarly product involved was of value to them and discussed the common flow of their scholarly acts.

2.1.2 Social Media and Scholarly Communication

Information sharing behavior on social media can be viewed as a process in which the individuals provide useful information reciprocally to all entities who may find it relevant (Gardoni, Spadoni, & Vernadat, 2000), aiming to amplify the value of information or to create new information (Deng, Lin, Liu, Chen, & Li, 2017; Van den Hooff & De Ridder, 2004). Information sharing activities are intertwined with other information practices, such as information seeking and use (Pilerot & Limberg, 2011). Online information sharing can promote innovation by contributing to the crowdsourcing of knowledge, origination transparency and openness, and the effectiveness of information technology (Fei, 2011). In the sphere of scholarly communication, a wealth of studies has been conducted to explore scientists' opinions and adoption of social media tools (Meyer et al., 2011; Bulger et al., 2011; Harley et al., 2010; Nicholas & Rowlands, 2010).

The informal communications among geographically disparate scholars in an "invisible college" is not a new concept (De Solla Price & Beaver, 1966; De Solla Price, 1965). As traditional dissemination channels are increasingly being complemented or even replaced by a variety of online communication tools, the sharing of scholarly information on relatively new

social media venues are increasingly being studied. For instance, Acord and Harley (2013) examine how the affordances of new digital technologies intersect with disciplinary conventions rooted in contemporary scholarly communication. Gruzd and colleagues (2012) employed the Unified Theory of Acceptance and Use of Technology (UTAUT), a widely adopted technology acceptance theory, to investigate how and why scholars in the field of Information Science and Technology use social media for scholarly communication. There are also studies on researchers' information behavior on social network services that are specifically targeted at the academic community, for instance, Academia.edu and ResearchGate (Nández & Borrego, 2013; Van Noorden, 2014).

According to Acord and Harley (2013), the communication of the final archival scholarly publications differs from the communication of scholarly information that has a work-in-progress nature. As scholars formulate, develop and refine their works, they are gradually more willing to share their work with a wider group of colleagues and audiences. Although social media enables a more immediate sharing of ideas, the embryonic discussion with a wider audience occurs not as often as the communication with a smaller group of targeted and trusted colleagues (Acord & Harley, 2013).

In addition to cultural drivers of academic conventions, many factors are found to affect the use of online tools for sharing scholarly information, including not only practical issues such as time, budget, access to resources, and receiving due credit, but also personal issues such as privacy, trust, and ego (Acord & Harley, 2013). The communication climate is found to positively influence knowledge donating, knowledge collecting, and affective commitment (Van den Hooff & De Ridder, 2004). Perceived information quality has a positive influence on an individual's intent to share information on social media (Qi, 2015). Popularity, interpersonal

needs, and perceived extent of social support have a significant influence on an individual's self-disclosure (Lai & Yang, 2015). The psychological ownership of content also has a positive effect on an individual's willingness to share information online (Lee, Lee, Lee, Park, & Kim, 2008).

The impact of personality traits on information sharing behavior of individuals in the online environment has been studied extensively. Factors including self-efficacy, personal outcome expectations, perceived enjoyment, individual attitudes towards knowledge sharing are found to be positively related to the motivation of information sharing (Gupta & Dhami, 2015; Lu & Hsiao, 2007; Oh & Syn, 2015; Papadopoulos, Stamati, & Nopparuch, 2013; Thatcher, Loughry, Lim, & McKnight, 2007). In addition, trust, particularly interpersonal trust, is also found to play an important role in online information sharing behavior (Liu, Rau, & Wendler, 2015; Wilson, Straus, & McEvily, 2006), considering that sharing information online entails both human-machine interaction and human-human interaction (Deng et al., 2017). Both trust and personality traits were found to have a significant impact on information sharing behavior on social media, with trust playing a mediating role between personality traits and the sharing behavior (Deng et al., 2017).

Haustein and colleagues (2016) discussed three social theories relevant to the interpretation of scholarly acts on social media. The social capital theory (Bourdieu, 1985; Coleman, 1988) assumes that actors establish and maintain relationships with other actors in the hope that they may benefit in some way from these relationships. The attention economics theory (Davenport & Beck, 2001) describes a world full of information, in which human attention is valuable as the costs to find useful information. The impression management theory (Goffman, 1959) involves presenting information about oneself in human interactions.

Some communications theories are also relevant to scholarly communication on social media. Marshall McLuhan (1964) emphasizes the important role of media and the characteristics of the media compared to the content that they carry, based on which he proposes that media is the "Extensions of Man." Lasswell (1948) proposes the "Principle of 5Ws" in communications as information transmission: "who" refers to the communicator who formulates the message; "what" is the content of message; "whom" describes either an individual recipient or the audience of mass communication; "in which channel" indicates the medium of transmission; "with what effect" is the outcome of the message. These apply in the transmission of ideas and knowledge on social media. Katz (1957) introduced the notion of opinion leaders and opinion followers and discussed the critical role of opinion leaders in the communication of information. The opinion leader theory is particularly relevant to the Diffusion of Innovation theory (Ryan & Gross, 1943; Rogers, 1962; Toews, 2003), in which adopters receive and accept innovations communicated through certain channels over time.

Also relevant are the Social Information Processing theory and social network theories. The Social Information Processing (SIP) theory was developed by Walther (1992), which described how people develop and manage relationships in a computer-mediated environment without nonverbal cues. Granovetter (1973; 2018) demonstrated the important role of weak ties because they have the potential to bring new ideas, information, and people to their own network. Given that ideas are more homogenous within strong-tie networks, people who have weak ties into other networks will have access to more information based on which they can synthesize new ideas (Burt, 2004). By connecting two networks together, they create value (Borgatti & Halgin, 2011).

Sugimoto, Work, Larivière, and Haustein (2017) provide a comprehensive review of the scholarly use of social media. Specifically, social media tools and platforms used by researchers for scholarly purposes were categorized into eight categories (Sugimoto et al., 2017):

1. social networking (e.g., Facebook, LinkedIn, Google+, ResearchGate, Academia.edu)
2. social bookmarking and reference management (e.g., Mendeley, Zotero, CiteULike, BibSonomy)
3. social data sharing (e.g., Figshare, SlideShare, GitHub, Re3data.org)
4. video (e.g., Youtube, TED Talks)
5. blogging (e.g., ResearchBlogging)
6. microblogging (e.g., Twitter, Sina Weibo, Tumblr)
7. wikis (e.g., Wikipedia)
8. social recommending, rating and referring (e.g., F1000, Pubpeer, Publons)

In addition to synthesizing the various functions of social media in the scholarly communication process, Sugimoto and colleagues (2017) also discussed the factors affecting social media use by researchers. These included age (e.g., Rowlands et al., 2011; Tenopir et al., 2013; Nicholas et al., 2014; Bowman, 2015), gender (e.g., Kovic, Lulic, & Brumini, 2008; Shema, Bar-Ilan, & Thelwall, 2012; Birkholz, Seeber, & Holmberg, 2015; Tsou et al., 2015), academic rank and status (Harley et al., 2010; Grande et al., 2014; Haustein & Larivière, 2014; Mohammadi et al., 2015), discipline (Cheverie, Boettcher, & Buschman, 2009; Acord & Harley, 2012; Collins, Bulger, & Meyer, 2012; Holmberg & Thelwall, 2014), as well as country and language (Wardle, 2010; Fausto, Machado, Bento, Iamarino, Nahas, & Munger, 2012; Alperin, 2014; Thelwall & Kousha, 2015). As pointed out by Sugimoto et al., (2017), the analyses on

these factors often generated contradictory results given the various populations of investigation and the time of the studies.

2.1.3 Twitter and Scholarly Communication

As a real-time microblogging network, Twitter has been studied extensively in various contexts, among which how scholars use Twitter is an important topic. Zhao and Rosson (2009) described Twitter as a "people-based RSS feed" (pp. 5). In Van Noorden (2014), Twitter was found to be the most "interactive" social media network among researchers. Although Twitter was only used regularly by 13% of the surveyed researchers, half of them reported that they used it to follow discussions on research-related issues, and 40% said that it is a medium for scholarly discussions (compared with 15% on ResearchGate).

There are four major types of activities on Twitter: posting a tweet (also called tweeting), reposting an existing tweet (also called retweeting), replying to a tweet, and liking a tweet. These four types of activities on Twitter are different in nature. Tweeting and retweeting are sometimes accompanied by text input as content from the users, although 80%-95% tweets of scientific articles are found to reflect no obvious opinions on the articles (Thelwall et al., 2013; Na 2015). Retweets are sometimes marked by RT ("retweet") or MT ("modified tweet"). Sometimes HT ("Heard Through" or "Hat Tip") is used to indicate that the content of this tweet is not forwarded from the Twitter platform, although it is possible that it is from a Twitter user.

Disciplinary differences have been found regarding Twitter uptake by researchers. Holmberg and Thelwall (2014) conducted a large-scale study on how researchers from ten disciplines use Twitter. Among the researchers they investigated, Twitter was used frequently for scholarly communication purposes in the fields of biochemistry, astrophysics, cheminformatics, and digital humanities. On the contrary, researchers in economics, sociology, and history of

science rarely used Twitter. In addition, by combining quantitative and qualitative methods, they observed several differences in the way researchers use Twitter: compared with researchers in the other investigated disciplines, biochemists retweeted the most; economists shared the most links; researchers in digital humanities and cognitive science used Twitter more for conversations (Holmberg & Thelwall, 2014). In another study that analyzed the thematic orientations of publications mentioned on Twitter, the fields of general medicine and social sciences showed more prominence (Costas, Zahedi, & Wouters, 2015). Overall, the general presence of altmetrics varies across different scientific disciplines (Costas et al., 2015; Haustein, Bowman, Holmberg, Peters, & Larivière, 2016; Holmberg & Thelwall, 2014).

Efforts have been made to identify scientists on Twitter (Ke et al., 2017; Costas, van Honk, & Franssen, 2017). Researchers' use of Twitter shows some distinct patterns. For instance, researchers tend to share more links and retweet more than the average Twitter users (Holmberg & Thelwall, 2014). Across personal and professional tweets, affordance use on Twitter has been shown to vary based on department, gender, academic age, age, and Twitter activity (Bowman, 2015). In a study of Twitter user profiles, it was reported that users who tweet academic articles describe themselves more factually by emphasizing their occupational expertise (Vainio & Holmberg, 2017). Most academic tweeters provide their full name and identity professionally in the profile descriptions (Bowman, 2015; Chretien, Azar, & Kind, 2011; Hadgu & Jäschke, 2014). Despite this, a large share of their activity is personal as opposed to professional (Bowman, 2015; Haustein et al., 2014; Van Noorden, 2014). When using Twitter for professional purposes, scholars discuss research-related topics and communicate with others in the field (Van Noorden, 2014). Scholarly tweets tend to contain links to both recent journal articles (Eysenbach, 2011; Holmberg & Thelwall, 2014; Priem & Costello, 2010) and blogs

(Letierce, Passant, Breslin, & Decker, 2010; Priem & Costello, 2010). However, the content of the tweets tends to be limited to the title, or part of the title of the scientific article being tweeted (Friedrich, Bowman, Stock, & Haustein, 2015; Thelwall et al., 2013).

Twitter affects the dissemination of research papers. Based on the investigation of 4166 articles from 76 Twitter users and 124 non-Twitter users, Ortega (2016) found no significant differences between the citation impact of papers authored by Twitter users and non-Twitter users. However, articles authored by Twitter users are more tweeted than those of non-Twitter users. In addition, the number of followers on Twitter was found to indirectly influence the citation impact (Ortega, 2016). Focusing on the goals, functions, and features of research, Liu and Fang (2017) investigated tweets of the top 100 papers of 2015 on Altmetric.com to explore factors that should be incorporated in using Twitter mentions to evaluate articles. In the study of Priem and Costello (2010), two main reasons for tweeting scientific articles were reported by researchers. First, it fit their workflow better. Second, it helped them get around paywalls to articles.

Twitter is widely used in academic conference settings, usually with the help of hashtags. Hashtags are often used to indicate the general topic referred to by the tweet (Letierce et al., 2010). Thus, abbreviations of conference names are often used on Twitter to indicate the relevance of tweets to the conference. Although the majority of Twitter users engaging in conference tweets at some conferences are not in-person attendees (Sopan, Rey, Butler, & Shneiderman, 2012), tweeting during conference represents a type of outreach – disseminating the conversation of a physical event to a virtual audience (Sugimoto et al., 2016). Several conferences have seen an increase in Twitter use over time (Chaudhry, Glodé, Gillman, & Miller, 2012; Hawkins, Duszak, & Rawson, 2014; Mishori, Singh, Levy, & Newport, 2014).

2.2 Citation Theories, Citer Motivation, and the Cited Works

A citation is the linkage between the citing author(s) and the cited work. Through the lens of the framework of Digital Trace of Scholarly Acts (DTSA), it is a trace created by the citing author(s) when they cite the cited work. Accordingly, it can tell us something about both the citing author(s) and the cited work. Borgman and Furner (2002) discussed two approaches to conceptualize the relationship between the citing and the cited documents: an artifact-oriented approach and a person-oriented approach. The person-oriented approach is based on the idea that the linkage can be viewed as the result of human actions. Thus, the motivations of the citer, and the situations that may potentially have an influence on the citer's "judgment and decision making" are important questions of inquiry (Borgman & Furner, 2002, pp.37).

This section reviews relevant literature on citation theories, citer motivation, and the cited works, aiming to provide a better understanding of the most thoroughly studied DTSA so far – citations.

2.2.1 Citation Theories

Blaise Cronin's book *The Citation Process* (1984) provides the first major statement on citation theory. In a more recent book *Theories of Informetrics and Scholarly Communication* edited by Sugimoto (2016), Cronin describes the "chameleon nature" of citation as follows (Cronin, 2016, pp.13):

> "Citation attracts metaphors as flame attracts moths. You will find citations described variously, though by no means exhaustively, as scholarly bricks (Price, 1963), as signposts left behind (Smith, 1981), as applause (Nelson, 1997), as gifts (Hagstrom, 1982), as forms of reward or income (Ravetz, 1971), as tools of persuasion (Gilbert, 1977), as pellets of peer recognition (Merton, 2000), as paratextual baubles (Cronin,

2014), or, verging on the poetic, as frozen footprints on the landscape of scholarly achievement (Cronin, 1981)" (Cronin, 2016, pp. 13).

Two principal opposing theories of citing behavior have been developed in past years: the Mertonian normative view and the post-modernist social constructivist view of citing behavior. In this section, these two theories and the concept symbols theory are reviewed.

2.2.1.1 The Normative Theory

The Mertonian normative view is named after the founder of the modern sociology of science, Robert K. Merton (Merton, 1973). Merton (1968) argues that referencing in research is a "moral obligation to acknowledge one's sources" (1968, pp. 622).

> "The reference serves both instrumental and symbolic functions in the transmission and enlargement of knowledge. Instrumentally, it tells us of work we may not have known before, some of which may hold further interest for us; symbolically, it registers in the enduring archives the intellectual property of the acknowledged source by providing a pellet of peer recognition of the knowledge claim, accepted or expressly rejected, that was made in that source" (Merton, 1968, pp. 622).

Citations are considered as part of the academic reward system (Merton, 1968). Merton views citation as the "pellet of peer recognition" (pp. 620), and the citing behavior as a normative constraint in science as part of the "composite cognitive and moral framework" (pp. 622). As a result, citations can be viewed as indicators of intellectual and cognitive influence, reflecting norms and values of science (Kaplan, 1965). In other words, the normative framework sees evaluative bibliometric analyses as appropriate for the assessment of scientific results.

Merton (1973) defines the *ethos of science* in terms of four basic norms: *communism, universalism, disinterestedness, and organized skepticism*. The *communism* norm refers to the

"nontechnical and extended sense of common ownership of goods" (Merton, 1973, pp. 273). *Universalism*, as defined by Merton, "finds immediate expression in the canon that truth-claims, whatever their source, are to be subjected to pre-established impersonal criteria" (Merton, 1973, pp. 210). The *disinterestedness* norm is described as "a passion for knowledge, idle curiosity, altruistic concern with the benefit to humanity, and a host of other special motives have been attributed to the scientist." (1973, pp. 276). According to the *organized skepticism* norm, scientific claims must be exposed to critical scrutiny before being accepted by the scientific community. Haustein and colleagues (2016) additionally pointed to the norm of originality (Ziman, 2000) in their review of citation theories.

Borgman and Furner (2002) point out two assumptions of the normative theory that can be tested by empirical research. First, the analysis of the motivations of the citers can reveal if they are more than professional, scholarship-serving, and rational (rather than personal, self-serving, and political). Second, it can be analyzed if the quality of a document is the most significant factor affecting its citation counts.

2.2.1.2 The Constructivist Theory

The social constructivist view is grounded in the assumption that scientific knowledge and scientific activities are socially constructed (Knorr-Cetina, 1991; Latour, 1987). Because citing is an act embedded in the social dynamics of scientific research, the motivations behind citing are influenced by socially constructed reasons and not necessarily by universalistic reasons. Specifically, these motivations might include to demonstrate their familiarity with the important literature in the field, to appeal to the readers or reviewers of the journal in which the citing document is to be published, to establish the legitimacy of the topic of the citing document, to defend their claims against attack, to advance their interests, to convince others,

and so on (Case & Higgins, 2000; Bornmann & Daniel, 2008). For instance, Gilbert (1977) described citing as an aid to persuasion:

> "A scientist who has obtained results which he believes to be true and important has to persuade the scientific community (or, more precisely, certain parts of that community) to share his opinions of the value of his work… Accordingly, authors typically show how the results of their work represent an advance on previous research; they relate their particular findings to the current literature of their field; and they provide evidence and argument to persuade their audience that their work has not been vitiated by error, that appropriate and adequate techniques and theories have been employed, and that alternative, contradictory hypotheses have been examined and rejected" (Gilbert, 1977, pp. 115-116).

Haustein and colleagues (2016) discussed four sources of distortion or biases in their review for a better understanding of this theory: persuasion hypothesis, perfunctory citations, Matthew effect, and negational citations. Because of these social influences, the constructivist theory believes that the intellectual and cognitive content of articles has little influence on how they are received (Bornmann & Daniel, 2008). It opposes the normative theory and questions the validity of evaluative citation analysis.

2.2.1.3 The Concept Symbols Theory

The concept symbols theory was proposed by Henry Small (Small, 1978). This theory considers the citation as symbolic of the idea expressed in the paper and is based on Garfield's (1964) notion of citations as descriptors in subject indexing (Haustein et al., 2016).

> "As a document is repeatedly cited, the citers engage in a dialogue on the document's significance" (Small, 1978, pp. 338).

By citing a paper, an author is associating particular ideas with the paper that they are working on. Specifically, these ideas could be concepts, statements, methodology, results, or conclusions of other studies (Small, 1978). Small's (1978) concept symbol theory was particularly discussed in the study of the "sociocognitive location" of scholars (Costas et al., 2012; Moed, 2006) and the field of scientometrics (Guns, 2013).

Drawing on Wouters (1999), Cronin (2000) views citations as signs and citing as a symbolic practice. He provides a semiotic analysis of citations and citation behavior in which the artifact-oriented approach and the person-oriented approach (Borgman & Furner, 2002) may be reconciled.

In 2016, Small (2016) revisited the debate between the normative theory and the constructivist theory, and draw the theories of cooperation and competition from evolutionary biology to explain citing behavior. He suggested using game theory and computer simulation to study cooperation and competition to arrive at a new avenue for research into citation practice and social norms in science (Small, 2016).

2.2.2 Citing Behavior and the Citer Motivation

Eugene Garfield (1962) was among the first to list and categorize citing motives:

- "Paying homage to pioneers.
- Giving credit for related work (homage to peers).
- Identifying methodology, equipment, etc.
- Providing background reading.
- Correcting one's own work.
- Correcting the work of others.
- Criticizing previous work.

- Substantiating claims.
- Alerting to forthcoming work.
- Providing leads to poorly disseminated, poorly indexed, or uncited work.
- Authenticating data and classes of fact (physical constants, etc.).
- Identifying original publications in which an idea or concept was discussed.
- Identifying original publication or other work describing an eponymic concept or term.
- Disclaiming work or ideas of others (negative claims).
- Disputing priority claims of others (negative homage)" (Garfield, 1962, pp. 85).

This list of motives is summed up based on the citations' observed location in the text, their language content, and their variations, differences, and regularities in patterns of use. Both the normative theory of citing behavior and the constructive views are reflected in this list. This study and another similar classification scheme (Lipetz, 1965) are described as "pioneer work on citing behavior" in the comprehensive review of citing behavior by Bornmann and Daniel (2008, pp.51). In the Scholarly Communication and Bibliometrics review by Borgman and Furner (2002), they comment that this list is rather "more prescriptive of 'when to cite,'" than "descriptive of the actual motivations of citers in practice" (pp. 22).

A number of subsequent empirical investigations of citing behavior have been conducted. The two major approaches are the content analysis of the citation context (Small, 1978, 1982) and surveys and interviews (Borgman & Furner, 2002).

Moravcsik and Murugesan (1975) investigated articles published in Physical Review and categorized the types of citations to five pairs of opposite characteristics: conceptual versus operational citations, organic versus perfunctory citations, evolutionary versus juxtapositional citations, confirmative versus negational citations, and valuable versus redundant citations.

These categories provided insight into the purposes and the type of connectedness of scholarly communication; they also revealed the importance of the cited work to the citing work (Bornmann & Daniel, 2008). The framework in this study was tested later by Cano (1989) by surveying researchers.

Using a similar method of content analysis, Chubin and Moitra (1975) developed six categories of citations based on research articles in physics, including four affirmative types and two negational types. They reached similar conclusions to Moravcsik and Murugesan (1975): the most frequent citations were Basic Essential, Subsidiary Essential, and Additional Supplementary, which could reflect the research impact of the cited work on the citing work. Different from Moravcsik and Murugesan (1975), they found lower percentages of Affirmative Perfunctory and Negational citations. In the categorization of Spiegel-Rösing based on citations in Science Studies publications (1977), the most frequent use of cited research was to substantiate a statement or an assumption made in the citing text or to point out further relevant information (80%). The remaining 20% of the citations could be assigned to 12 other citing categories. Krampen, Becker, Wahner, and Montada (2007) conducted a large-scale citation context analysis of articles published in scientific psychological journals. They developed a mixed categorization considering both the content and the characteristics of the citations.

As the intentions of the citing scientists are not normally available in content or context analysis (Gilbert, 1977), surveys and interviews of scientists, which are more citer-oriented, have also been widely adopted to study citer motivations (Bornmann & Daniel, 2008). Particularly, surveys and interviews for this purpose are also known as “citer motivation” or “citer behavior” studies (Borgman & Furner, 2002).

Brooks (1985; 1986) was among the first to systematically and directly ask researchers to state their particular motivations for specific citations. Interviewing researchers from a wide spectrum of departments, Brooks (1985; 1986) classified their citer motivations into three groups: 1) persuasiveness, positive credit, currency, and social consensus; 2) negative credit; and 3) reader alert and operational information. Vinkler (1987) asked chemists to assess their motivations for a total of 484 citations in their articles according to predefined categories. There were two major groups of motivations in Vinkler's categorization scheme: "Professional Motivations," which was related to the theoretical and practical content of the cited work; and "Connectional Motivations," which focused on the social relationships in the scientific community. As mentioned earlier, Cano (1989) asked researchers in the field of structural engineering to classify their citations based on the scheme developed by Moravcsik and Murugesan (1975). The results showed that the major citation category used by the scientists was perfunctory (26%), followed by organic (21%) and conceptual (19%).

Bonzi and Snyder (1991) found no significant differences between the citing motivation of self-citations and citations to other works. In Liu (1993), only a few scientists said that more than 80% of their citations were essential; a few even stated their citations were totally non-essential. Liu (1993) concluded that "more often than not, the cited documents were used in a more peripheral than critical manner" (pp. 21). Case and Higgins (2000) surveyed communication researchers on their citing motivations and found the two best predictors of citation counts were the citer's perception of the cited work as a "classic" (similar to Shadish et al. (1995)), and the citer's having a "social reason" for citing.

2.2.3 Citing Behavior and the Cited Works

Examination of the citing behavior can also provide insights into the properties or characteristics of the cited works, which are reflected by their perceived "citation worthiness" (Borgman & Furner, 2000, pp. 23).

Content or context analysis has been used to analyze the citers' attitudes towards the cited artifacts. For instance, in Moravcsik and Murugesan (1975) reviewed in Section 2.2.2, the second category (organic versus perfunctory citations) and the fourth category (confirmative versus negational citations) were related to the citers' perception of the impact of the cited works. Cole (1975) examined 123 articles that cited Robert K. Merton. The analysis shows that about half of those articles had cited Merton's work in a "ceremonial" fashion: "In fact, it is the theoretician as an authority that is being utilized rather than substantive theory" (Cole, 1975, pp. 208). Garfield (1978) conducted a content analysis of citations to a highly debated article by Arthur Jensen (1969) published in *Harvard Educational Review*. Results showed that more than half had cited it negatively or as an example of controversy. In a later study, Garfield and Welljams-Dorof (1990) focused on the publications by Steven E. Breuning, who in 1988 was convicted of scientific fraud. The citation content analysis showed that less than 10% of the citations were positive. Somewhat different results arose from a study of Kochan and Budd (1992) on John Darsee, who was discovered to have fabricated his research data. The content analysis showed that Darsee's articles were cited predominantly positively in subsequent papers.

Oppenheim and Renn (1978) investigated the citations of 23 highly-cited papers in Physics and Physical Chemistry. In a more recent study that Oppenheim coauthored (Ahmed, Johnson, Oppenheim, & Peck, 2004), they examined articles that cited the highly-cited paper by Watson and Crick (1953) that helped them won the Nobel Prize in Physiology or Medicine in

1962. Citations in both studies were categorized using the same category. The results of the second study showed that 85% of the articles cited Watson and Crick (1953) for historical reasons or background discussion (compared to 58% in the first study). In contrast, whereas in the second study only 13% of the sample were actively using Watson and Crick's (1953) information (4%), methods (5%), or theory (4%), a greater proportion (28%) of the citations in the first study were made for this purpose (information=1%, methods=11%, theory=16%). Tabatabaei (2013) developed a coding scheme for assessing the contribution of information science to other disciplines, as reflected by the functions of highly-cited *Journal of the Association for Information Science and Technology* (JASIST) papers in their citing articles. A coding scheme with five categories, including "applied," "contrastive," "supportive," "reviewed," and "perfunctory" (pp.153).

Interviews were also utilized to explore the properties of the cited works. For instance, White and Wang (1997) interviewed agricultural economics researchers and categorized the contributions of the cited articles are as follows: 1) Analogies/Contrasts/Comparisons; 2) Corroboration; 3) Data; 4) Identification of Originator; 5) Justification; 6) Methodology; 7) Tangential/Ceremonial; and 8) Theory, Concepts, Definitions. Overall, the topicality and contents of the cited document were two of the most commonly used criteria on which citation decisions were based (White & Wang, 1997). They noted that their scheme of categories was similar to other schemes derived rationally rather than empirically, for instance, the eight categories of citation roles proposed in Peritz (1983): 1) setting the stage for the present study; 2) background information; 3) methodological (including citations referring to both the design of the study and methods of analysis); 4) comparative; 5) argumental, speculative, hypothetical; 6) documentary; 7) historical; 8) casual.

Shadish, Ragsdale, Glaser, and Montgomery (1995) elicited citers' opinions about their own citing activity, based on which they conducted a factor analysis and a multiple regression analysis to test the relationship between the degree of citedness and citing authors' perceptions of the cited works. They found that highly-cited papers were perceived by citers as classics and as less creative. To explain the somewhat counter-intuitive lower creativity of highly-cited papers, the authors stated "those articles that are creative in a way that does not fit into existing conceptual frameworks or into accepted social norms for scholarship in an area. Or they may be so creative that they rapidly become part of the accepted canon, and henceforward are rarely specifically cited." (Shadish et al.,1995, pp. 485). Case and Higgins (1995) found that while less-cited publications were cited more frequently to establish the legitimacy of the citer's topic, highly-cited works were more frequently cited in order to review prior work in the area. Additionally, only highly-cited documents were cited because the cited work was authored by a recognized authority in the field; none less-cited document was cited due to this reason. Three factors in predicting citation counts were detected: 1) the perception that the cited work is novel, well known, and represents a genre of studies; 2) the judgment of the citing scientist that citing a prestigious work will promote the cognitive authority of his or her own work; and 3) the perception that a cited item serves criticism – which could establish the citer as an authoritative, critical thinker (Case and Higgins, 2000).

2.3 Critical Incident Technique

The Critical Incident Technique (CIT) was first developed by Flanagan (1954). It is defined as a procedure "for gathering certain important facts concerning behavior in defined situations" (Flanagan. 1954, pp. 9). In the evaluation of pilot performance, Flanagan (1954) applied the CIT method to produce a list of components critical for task performance, which

proved to be more helpful than the vague descriptions previously used for pilot selection and training. Another important definition is provided by Chell (1998), particularly in regard to the objective of CIT – to "gain understanding of the incident from the perspective of the individual, taking into account cognitive, affective, and behavioral elements" (Chell, 1998, pp. 56). The factual accounts of respondents' behavior collected using this technique can provide unequivocal understandings regarding their behavior (Flanagan, 1954; Chell, 1998).

The CIT approach has been applied in a wide range of fields, for instance, market research (Grove & Fisk, 1997; Wong & Sohal, 2003; Gremler, 2004), healthcare (Kemppainen, 2000; Bradley, 1992; Arora, Johnson, Lovinger, Humphrey, & Meltzer, 2005), and information seeking behavior research (Auster & Choo, 1994; Wilkinson; 2001; Zach, 2005). Particularly, Tenopir, King, & Bush (2004) employed the CIT method to study the use of scholarly journals by medical faculty.

In the CIT approach, data are normally collected as words through interviewing the subjects to discuss their perspectives about specific incidents that happened to them (Creswell, 1998). Therefore, rich details of firsthand experiences can be collected (Bitner, Booms, and Mohr, 1994), which can be used to provide evidence relevant to the subject matter as an empirical starting point. Based on these factual accounts of participants' behavior, it is possible to employ an "interpretive, naturalistic approach" to the subject matter, which is aligned with the overall goal of qualitative research (Denzin & Lincoln, 1994, pp. 2). Edvardsson (1992) has suggested that the CIT technique is inductive in nature.

During a CIT interview, typically, respondents are asked to use their own language to describe the events (Stauss & Weinlich 1997). This allows them to fully develop the context from their own perspective (Edvardsson 1992; Chell 1998). Due to the specificity of the events,

respondents have the opportunity to better recall and provide a detailed account of their experiences (Stauss & Weinlich 1997). Thus, more concrete information regarding the events can be collected compared to a general inquiry on their opinion and behavior.

In the data analysis process, the purpose is to create a categorization scheme that summarizes and describes the data while at the same time 'sacrificing as little as possible of their comprehensiveness, specificity, and validity' (Flanagan, 1954, pp. 344). The incidents represented complex activities that often contained more than one intention. As a result, it was recommended that categories should not be considered exclusive (Flanagan, 1954).

The CIT technique relies on events being remembered accurately by respondents. Due to the naturally retrospective nature of the interview, the CIT method has been criticized for the possibility to be flawed by recall bias based on respondents' different retrospective capabilities (Michel 2001). Inaccurate memories might lead the participant to reinterpret the past event when describing and discussing it (Johnston 1995). Therefore, it is critical to evaluate the quality of their descriptions and discussions about the event. If the details are full and precise, the information can be taken as accurate; whereas if the reports are vague, some of the data may be incorrect (Flanagan, 1954).

The reliability and validity issues of the CIT method have been studied and discussed since the early years. Andersson and Nilsson (1964) evaluated various reliability and validity aspects of CIT, including the reliability of data collection and analysis procedures, as well as the overall saturation and comprehensiveness in terms of how well the critical incidents represented the content domain. Ronan and Latham (1974) examined three reliability measures and four validity measures in their paper. They found satisfactory inter-judge reliability and intra-observer

reliability, although the inter-observer reliability was low. Meanwhile, they obtained satisfactory content validity, construct validity, concurrent validity, and relevance in content.

Based on the strengths and weaknesses of CIT, researchers have suggested using CIT for specific purposes of research. According to Gremler (2004), the CIT technique is especially useful in three scenarios:

1. when the topic being researched has been sparingly documented (Grove and Fisk 1997),
2. as an exploratory method to increase knowledge about a little-known phenomenon, and,
3. when a thorough understanding is needed when describing or explaining a phenomenon (Bitner, Booms, & Tetreault 1990).

Walker and Truly (1992) argue that CIT can be particularly effective when used in developing the conceptual structure to be used and tested in subsequent research. Kolbe and Burnett (1991) suggested using CIT as a companion research method in multimethod studies.

CHAPTER 3: RESEARCH QUESTIONS

The overarching research aim of this dissertation is to gain a more comprehensive understanding of researchers' activities around scholarly articles on Twitter. Specifically, the following four research questions drove this study:

RQ1: What opinions do researchers have on the scholarly articles they interact with on Twitter? In this research question, the Twitter interactions investigated included tweeting, retweeting, replying, and liking on Twitter. These four acts reflect a comprehensive picture of the researchers' sentiment of opinions in their interactions with scholarly articles on Twitter.

RQ2: How does sharing (tweeting and retweeting) scholarly articles on Twitter fit into researchers' workflows? In this research question, the scholarly acts workflow refers to the common scholarly acts that researchers would conduct around scholarly articles, including 1) skim the article to gain a very basic idea of it; 2) read the article in depth (examining at least some sections/figures/tables in the article very carefully); 3) look at online discussions of the article; 4) search for information about the author(s) of the article; 5) save the article to their computer or reference manager tools; 6) organize the article (such as renaming the article file or categorizing it into a folder); and 7) cite the article (in their working research papers or teaching materials).

RQ3: What are the motivations behind researchers' sharing of scholarly articles on Twitter? The Critical Incident Technique was applied in the interviews to explore the motivations behind the sharing of specific scholarly articles by the researchers. The stories

behind the researchers' examples of tweets containing scholarly articles were discussed in depth in the interviews.

RQ4: Do the scholarly articles shared by researchers on Twitter have an impact on their own work? This question explored two facets of the impact of the articles that researchers shared on Twitter. First, were the shared articles relevant to the researchers' research, teaching, and creative activities and thus impacted their work? Second, how did sharing the articles on Twitter had an effect on their work? Similar to RQ3, the Critical Incident Technique was employed to study this research question.

CHAPTER 4: METHODS

This dissertation research employed a sequential mixed-method approach. This included a large-scale survey and twenty follow-up interviews. In the interviews, questions were designed to not only follow up with the participants on their responses in the survey but also discuss specific examples of scholarly tweets created by the participants earlier. Overall, this study proceeded in three phases.

Phase I: The goal of the first phase was to identify the survey audience of this study.

Phase II: In the second phase, an online survey was conducted. Respondents of the survey were asked if they would like to participant in a follow-up interview. Then, interview participants were identified.

Phase III: The third phase consisted of twenty follow-up interviews with selected survey respondents.

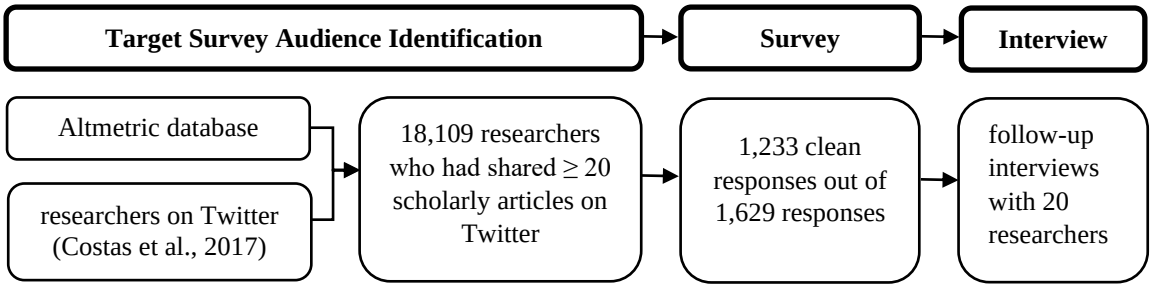

Figure 4.1 Brief Overview of Study Procedure

4.1 Target Survey Audience Identification

Altmetric.com provided their full dataset of article-level metrics from October 2011 to February 2017 for this dissertation study. This was a snapshot of the Altmetric database containing over 8.1 million records in the .JSON format. Each record represented one scholarly artifact (for instance, a research article) and encompassed various types of altmetrics data about this artifact. Specifically, the mentions of research outputs on Twitter, Facebook, Blog, Wikipedia, News, Google Plus, Policy, Reddit, F1000, Weibo, Peer Reviews, Video, and Q&A platforms were captured by matching and tracking scholarly identifiers including PubMed ID, arXiv ID, ADS ID, SSRN ID, RePEC id, Handle.net identifiers, URN (Uniform Resource Name) identifiers, ISBNs, and DOIs (Digital Object Identifier) (Altmetric, 2019). Specifically, in this study, the data related to Twitter were extracted.

Costas, van Honk and Franssen (2017) adopted a combination of matching algorithms to match bibliometric data from Web of Science and Twitter users identified by Altmetric.com. Although the matching process found duplicates, to guarantee precision over recall, only Twitter-author matches that were unique were selected. They were able to identify a large set of researchers matched with Twitter users, which was the largest set of researchers who were also Twitter users at that moment. The initial step of the survey audience identification in this dissertation was based on this work (Costas et al., 2017).

In the second step of survey audience identification, a database was constructed using a Python script, matching the dataset of researchers and the Twitter related data in the Altmetric.com dataset. The tweets and retweets posted by these researchers that contained links to scholarly articles were extracted and organized.

Based on the counts of these tweets and retweets, all researchers who had posted or reposted 20 tweets containing scholarly articles or more were identified as the target survey audience. The rationale behind this was to exclude users that were relatively inactive in posting or reposting scholarly articles in the time span of 65 months. This step also laid the foundation for the selection of the critical incidents of sharing scholarly articles by these researchers, which were used in the interview described in Section 4.3.

As a result, 18,109 researchers (26.1%) were identified out of 69,459 researchers. These researchers had published at least one scholarly article indexed in Web of Science; meanwhile, they had posted or reposted 20 scholarly articles with a Digital Object Identifier (DOI) during the period of October 2011 to February 2017. The representativeness of the survey respondents is discussed at the end of Section 5.1.1.

4.2 Survey

4.2.1 Survey Design

Following a comprehensive literature review and incorporating feedback from my doctoral committee members, a structured survey was designed. The survey consisted of four sections. The content of the survey is attached in Appendix I.

The first section contained three questions about the respondents' general use of Twitter for professional purposes. The scope of "use" here was not only limited to sharing activities on Twitter; it also encompassed behaviors like browsing, following, and interacting with others. The purpose of this section was to collect some descriptive background information regarding how the respondents normally use Twitter.

The goal of the second section was to understand respondents' sentiment of opinions (positive, neutral, or negative) about the articles that they tweeted, retweeted, replied to, and liked.

Questions in the third section asked whether other scholarly acts would co-occur with tweeting and retweeting scholarly articles, including both before and after tweeting and retweeting. These acts included: 1) skim the article to gain a very basic idea of it; 2) read the article in depth (examining at least some sections/figures/tables in the article very carefully); 3) look at online discussions of the article; 4) search for information about the author(s) of the article; 5) save the article to their computer or reference manager tools; 6) organize the article (such as renaming the article file or categorizing it into a folder); and 7) cite the article (in their working research papers or teaching materials). These acts were identified based on existing literature and had been explored in two of my previous studies exploring researchers' information behavior (Xu & Hemminger, work in progress; Xu, Brown, & Hemminger, work in progress).

The last section collected demographic information of respondents, including age, gender, country of living, level and type of highest degree earned, current primary position, and primary academic discipline.

To improve the accuracy of respondents' memories, the survey asked the respondents to recall a typical month of using Twitter and provided this past May as an example for them. In designing the response anchors, a larger number of options on a rating scale would permit the respondents to express their point of view more clearly. However, there might be a risk that it would exceed the discriminative capacity of the respondents (Lozano, García-Cueto, & Muñiz,

2008). Therefore, five-point Likert rating scales were used in all the survey questions about frequency, with “1” being never and “5” being always.

The survey was first pilot-tested on two Twitter user researchers. After the survey was improved according to the feedback from my committee members, two more pilot studies were conducted. The cognitive interviewing (Willis, 2004) technique was applied in the pilot studies. As both think-aloud and retrospective probing are recommended for self-administered questionnaires (Redline, Smiley, Lee, & DeMaio, 1998), the first two pilot studies were concurrent using the think-aloud technique as the participants went through the questions in the survey. The third and fourth pilot studies were retrospective, during which pilot participants completed the survey in their naturalistic settings. After these participants completed the survey, I asked them questions (see Appendix III) to assess their understanding of the questions. Feedback was gathered regarding the wording of questions, the use of technical terms, as well as whether there were vague questions, biasing questions, and questions that were generally too lengthy to answer. In addition, the usability aspects were also probed. The third retrospective test was conducted on a laptop interface; the fourth retrospective test was conducted on a cellphone interface.

4.2.2 Survey Data Collection

An online survey (Appendix I) was created using Qualtrics through a campus-wide site license at the University of North Carolina at Chapel Hill. The survey consent form was attached on the first page of the survey link.

In the distribution of the survey, emails were sent off from Qualtrics in batches, in order to avoid being automatically categorized into the spam folder of scholars’ inboxes. The survey was distributed from early-June to mid-July. In the first phase, the recruiting email was sent to

18,109 researchers identified in Section 4.1. In the second phase, a reminder email was sent to the potential participants who did not answer the survey in the first fifteen days.

In total, 1629 responses were collected. The response rate was 9.0%. The data cleaning process is reported in Appendix IV. After data cleaning, 1233 responses were used in the following analyses.

4.2.3 Survey Data Analysis

In the survey, three questions in the demographics section provided a text entry box to allow respondents to enter their responses if they found none of the answer options provided could best describe their answers. Therefore, the first step of survey data analysis was to code the responses to these three questions in the demographics section: primary discipline, primary position, and gender.

The categorization of disciplines adopted in this study was based on the CWTS Leiden Classifications of discipline (https://www.leidenranking.com/information/fields). Based on this classification, Social Sciences and Humanities were separated into two categories. In total, this study used six categories of disciplines: Biomedical and Health Sciences, Life and Earth Sciences, Mathematics and Computer Science, Physical Sciences and Engineering, Social Sciences, and Humanities. The additional responses provided by the survey respondents were coded in these six categories. The coding scheme is attached in Appendix V. In total, 73 responses were manually categorized and checked by a second coder. Complete agreement was reached.

In the survey, two questions asked “Who do you follow on Twitter for professional uses?” and “Who do you interact with the most on Twitter for professional uses?”. In addition to a list of answers to choose from, a text entry box was also provided in the survey. The second

step in the survey data analysis was to code the responses respondents provided in these two questions. Specifically, for the "follow" question, 7 responses of "students", 4 responses of "politicians", 7 responses of "activists", 4 responses of "research participants or lived experience experts relevant to research", and 1 response of "high school teachers" were classified into the existing "Other individuals" category. Four responses of "labs," although being a small unit, were categorized into the existing "Research institutions and universities" category. In addition, two responses of "research projects" were categorized into the existing "Professional organizations and conferences" category. For the "interact with" question, similarly, 3 responses of "activists," 1 response of "politicians," 1 response of "research participants or lived experience experts relevant to research," and 3 response of "students" were categorized into the "Other individuals" category. Similar to the coding of disciplines, a second coder also checked my categorizations of these two questions; after discussions on two cases, complete agreement was reached.

In the following subsections, I describe the methods and techniques used in the quantitative analysis of the survey data. All the analyses were performed in Python, with the help of the packages of Numpy (Oliphant, 2006; Van Der Walt, Colbert, & Varoquaux, 2011), Matplotlib (Hunter, 2007), Pandas (McKinney, 2010), and additional ones mentioned in the corresponding sections below.

4.2.3.1 Kruskal-Wallis Test

The Kruskal-Wallis test is a rank-based nonparametric test that can be used to determine if there are statistically significant differences between multiple groups of variables (Kruskal & Wallis, 1952). It is a non-parametric alternative to the one-way analysis of variance (ANOVA). Different from ANOVA, which calculates the ratio of the treatment sum of squares to the

residual sum of squares, the Kruskal-Wallis test uses the ranks of the data instead of the raw data in this process. Therefore, the Kruskal-Wallis test is widely adopted in analyzing ordinal data.

The posthoc test to the Kruskal-Wallis test used in this study was the Mann-Whitney tests with Bonferroni correction (Mann & Whitney, 1947). The Mann-Whitney U test is also known as the Wilcoxon rank-sum test (Wilcoxon, 1945). It is also a non-parametric test that can be used to determine if there are statistically significant differences between two independent variables. Therefore, following the Kruskal-Wallis test, the Mann-Whitney U test was used to perform pair-wise comparisons between different pairs of variables.

In this study, the Kruskal-Wallis test and Mann-Whitney U test with Bonferroni correction were used to compare researchers' sentiment of opinions on articles associated with their tweeting, retweeting, replying, and liking acts. Additionally, it was also employed to compare researchers' other scholarly acts that co-occurred with their tweeting and retweeting of scholarly articles. The comparisons were conducted across researchers in groups of different age, gender, country, education background, position, and discipline.

The SciPy library in Python, which is an open-source Python library widely used for scientific computing, was used in this part of data analysis (Jones et al., 2001). Specifically, the scipy.stats module was used. The scikit-posthoc package in Python was used for the posthoc comparisons between variables (Terpilowski, 2019).

4.2.3.2 t-Distributed Stochastic Neighbor Embedding (t-SNE)

The dimensionality reduction method adopted in this study, t-Distributed Stochastic Neighbor Embedding (t-SNE), is a non-linear technique widely used in data exploration and visualization. Different from Stochastic Neighbor Embedding (SNE), t-SNE uses a Student-t distribution instead of a Gaussian distribution to compute the similarity between two points in

the low-dimensional space (Van Der Maatan & Hinton, 2008). t-SNE is capable of capturing both the local and the global structure of the high-dimensional data. In the process of dimensionality reduction, the t-SNE algorithm converts similarities between data points to joint probabilities. Based on the joint probabilities, it reduces the dimensionality of the data by minimizing the Kullback-Leibler divergence between the low-dimensional embedding and the high-dimensional data.

One of the critical tuning parameters in the t-SNE technique is perplexity, which is relevant to the number of nearest neighbors used in other manifold learning algorithms (Van Der Maaten & Hinton, 2008). The Python package used in this analysis was Scikit-learn (Pedregosa et al., 2011), in which the default setting of the perplexity value was 30. This default value was adopted in our analysis to cluster researchers based on their sentiment of opinions on the articles they tweeted, retweeted, replied to, and liked.

4.2.3.3 k-means Clustering

The k-means clustering technique is one of the most widely adopted unsupervised machine learning techniques to classify a given dataset into a certain number(k) of clusters (MacQueen, 1967). Starting with a first group of randomly selected centroids, k-means uses iterative calculations to optimize the positions of the centroids by minimizing the within-cluster variances. After dimensionality reduction, the k-means algorithm was employed to cluster researchers based on their sentiment of opinions on the articles they tweeted, retweeted, replied to, and liked. The Scikit-learn package in Python was used in this part of the analysis (Pedregosa et al., 2011).

To determine the optimal number of clusters (k), the elbow method (Thorndike, 1953) was used as a reference. The elbow technique calculates and plots the various values of “cost”

with the change of the k value. As the value of k increases, the average distortion will decrease as the number of elements decreases. In this plot, the point where the distortion declines the most drastically is considered the elbow point. Considering that the elbow method is in essence a heuristic approach, I combined visual examination and sensemaking of the data to determine the number of clusters.

4.2.3.4 Spearman Correlation Analysis

Spearman correlation is a rank-based non-parametric method that can be used to measure the strength of the relationship between two variables (Spearman, 1906). In this study, the frequencies of scholarly acts before and after tweeting and retweeting were collected from the survey as ordinal data. The relationships between the scholarly acts before and after tweeting, and that before and after retweeting was assessed respectively, using the Spearman correlation coefficient. Two correlation coefficients matrix was constructed. The coefficients were interpreted based on the rule of thumb in Table 4.1 below.

Table 4.1 Rule of Thumb for Interpreting the Size of a Correlation Coefficient

(Hinkle, Wiersma, & Jurs, 2003)

Size of Correlation	Interpretation
0.90 to 1.00 (-1.00 to -0.90)	Very high positive (negative) correlation
0.70 to 0.90 (-0 90 to -0.70)	High positive (negative) correlation
0.50 to 0.70 (-0.70 to -0.50)	Moderate positive (negative) correlation
0.30 to 0.50 (-0.50 to -0.30)	Low positive (negative) correlation
0.00 to 0.30 (-3.00 to -0.00)	Negligible positive (negative) correlation

This part of the analysis was performed using the scipy.stats module in the SciPy library in Python (Jones et al., 2001).

4.2.3.5 Wilcoxon Signed Rank Test

Different from the Wilcoxon rank-sum test (Wilcoxon, 1945) mentioned above, the Wilcoxon signed-rank test is used to compare two related samples or repeated measurements on a single sample. This method was proposed in the same paper (Wilcoxon, 1945). However, using a paired test when the data are paired provides more power to detect the differences. Therefore, the Wilcoxon Signed Rank test was used to compare the acts of researchers before and after sharing the article on Twitter, to see if there were differences in terms of preferences of conducting the acts before or after sharing them. Similarly, it was used to compare the acts of researchers before tweeting and retweeting an article, as well as after tweeting and retweeting an article, to explore whether there was a difference in the acts associated with tweeting and retweeting. This part of the analysis was performed using the scipy.stats module in the SciPy library in Python (Jones et al., 2001).

4.3 Interview

4.3.1 Interview Design

The purpose of the interview was twofold. First, based on the responses provided by the respondents in the survey, I followed up with the interview participants to better understand the context behind their behaviors. Secondly, employing the Critical Incident Technique (CIT) (Flanagan, 1954) to help facilitate our discussion and improve participants' recall of events, I explored their motivations behind sharing articles on Twitter, as well as the impact of the shared articles to these researchers. The interview was designed to be semi-structural to allow the pursuit of unanticipated lines of inquiry. The interview guide is attached in Appendix II. This guide is organized with both specific questions serving as topic anchors and probes as potential follow-up questions used to gather additional detail and clarify responses when needed.

In the first section of the interview, the main goal was to follow up with questions from Section II of the survey – to ask about the reasons for having the different sentiment of opinions on the article they tweeted, retweeted, replied to, and liked. The questions in this section aimed to elicit the ways these researchers come to understand, account for, and take actions on Twitter in their naturalistic settings.

In the second section of the interview, the participants were presented with ten of their tweets and retweets. Each of the tweets and retweets contained a link to a scholarly article. In other words, each of the tweets and retweets were related to an incident of sharing a scholarly article on Twitter. Questions were asked specifically relevant to the articles in these tweets and retweets identified. The major goals were to discuss in more depth their motivations behind sharing these articles and the impact of these articles on them.

For the critical incidents, I also asked participants about the occurrences of other scholarly activities associated with the specifically identified articles. The answers to this question were compared to the answers provided by the participants in Section III of the survey, which was their general memory and perception of how sharing fit in their research process. The discussions about these comparisons are included in the Reflections on the Methods section.

To evaluate and improve the interview questions and procedures, three pilot studies were conducted via Zoom (see Appendix III) on an iterative basis. Both the content and instrumental aspects of the interview were improved according to the pilot participants' reactions and answers, as well as feedback provided in the cognitive interviewing after the interview.

4.3.2 Interview Data Collection

The first step in the interview data collection was to identify interview participants. Based on the survey responses, I created a pool of potential interview participants. To account for the

variety of demographics and characteristics that might affect their use of Twitter, I used quota sampling and selected participants from different ages, genders, regions, education backgrounds, positions, and disciplines. In this selection process, their activeness on Twitter (using the counts of tweets of scholarly articles they had posted or reposted on Twitter during the period of October 2011 to February 2017) was also taken into consideration. This ongoing selection accompanied the recruiting process in order to ensure a reasonable spread of participants across all demographics and characteristics mentioned above.

The second step was to identify ten tweets or retweets that contained a link to a scholarly article for each of the participants to use in Section II of the interview. In Priem and Costello (2010), this was defined as a "first order Twitter citation" (pp. 2). The guidelines in selecting these tweets and retweets were as follows:

1. For each participant, the number of original tweets was no less than seven; the number of retweets was no more than three.
2. There were diverse types of tweets: they were of various lengths; there were diverse patterns of Twitter affordances uses; they were associated with different sentiments; they seemed to be associated with different purposes of sharing.

To be able to select tweets that seemed to be associated with different purposes of sharing, a preliminary content analysis of the tweet text was conducted. This was assisted by my content analysis experiences in two of my previous studies investigating the motivations behind sharing scholarly articles on microblogging platforms (Xu, Yu, Hemminger, & Dong, 2018; Yu, Xu, Xiao, Hemminger, & Yang, 2017). For each participant, I reviewed 20-100 tweets or retweets of theirs and selected ten for each of them.

These tweets were displayed in a ten-page .pdf file generated from PowerPoint slides. On each page, the link of the tweet or retweet is located at the top of the page. The screenshot of the tweet or retweet is located in the middle of the page. By clicking on the link of a tweet or retweet, the participants could further explore the tweet content, including the links, mentions, and hashtags included in them. Before the interview, participants were asked to spend a few minutes to examine these tweets.

All interviews were conducted via Zoom. Consent forms were signed either digitally or print-sign-scanned. For each participant, I sent out a Zoom link to them before the interview. Two participants joined the meeting on the phone; eighteen participants joined the meeting via the Internet. All conversations were recorded via the recoding functionality of Zoom. The interviews were conducted from the beginning of August to the end of August, except for one in early September.

4.3.3 Interview Data Analysis

The interviews were initially transcribed using the Google Speech-to-Text tool. In this process, I chose to opt-out of their data logging program to protect the privacy of the participant's interviews. This would prevent Google from having access to the study data for the purpose of improving their algorithms. Then, I manually transcribed the interviews based on the transcriptions obtained in the initial step.

The coding process started from open coding to focused coding. In the pre-coding phase, the in vivo coding technique was used in the first reading of the data (Saldaña, 2008). This approach emphasized the voice of the participants, which could better express participants' opinions and feelings in their own language. Then, the official coding process began with descriptive coding by inductive reasoning. In this process, codes were developed and constantly

compared to one another to describe relevant concepts and their dimensions and properties (Davies, 2008; Stake, 2010).

A second coder helped in the coding of 50% of the data. First, two coders independently coded 25% of the data. After initial codes and tentative categories were formed, we had a discussion about our coding process, the meaning and boundaries of codes, as well as the level of specificity. We refined our codes and categories by adding, subtracting, combining or splitting the codes, and reached a reasonable agreement after this discussion. In the second round of coding, we recoded the first 25% of the data and continued to code another 25% of the data. We compared our coding results again after the second round of coding. A high level of agreement was reached after this discussion. There was not an established criterion of the reliability of the coding of critical incidents, but according to Andersson and Nilsson (1964), an acceptable agreement level was if independent raters could correctly classify 75% to 85% of the incidents into the categories and 60% to 70% into the sub-categories. In our coding of the 100 critical incidents, we reached an agreement on 97 (97%) incidents in the sub-categories of motivations behind sharing; and the agreement on the category level was 99%. We reached an agreement on 93 (93%) incidents in the subcategories of impact of the articles on the researchers; and the agreement on the category level was 98%. The codebooks are attached in Appendix VI and VII.

Therefore, based on our agreement, I continued to code the remaining 50% of the data. Then, I had another discussion with the second coder about a few extracts where I had uncertainty in coding, as well as one minor addition and one minor revision to the sub-categories. The second coder agreed on these two changes. At last, I re-examined the codes carefully to ensure they were coded in a systematic and consistent fashion across the entire dataset.

4.4 Discussions on the Methods

This study tested the use of an online survey to collect a large number of cross-platform behaviors of researchers around scholarly articles, which was not previously available on any single platform or any aggregated data provider. Although this method had limitations, this study attempted to experiment and evaluate the feasibility of applying this method to further previous works conducted on particular information behaviors (such as seeking, reading, saving, or citing) of researchers.

Using the Critical Incident Technique (CIT) (Flanagan, 1954) in the interviews to ask researchers about the stories behind them combined the strengths of content analysis and in-depth interviews. In two previous studies of mine (Xu et al., 2018; Yu et al., 2017) exploring researchers' motivation behind sharing scholarly articles online, we had used content analysis to analyze the text of tweets and Weibo posts. However, in many cases, we were not able to understand the motivation due to the simplicity of the text. This limitation existed in the studies that mainly used the method of content analysis to analyze the citation context as well. What made things more difficult was that the majority of the tweets and retweets of scholarly articles were posted without additional engagement reflected in the content (Thelwall et al., 2013; Tsou, 2015; Haustein et al., 2016).

In this dissertation study, using specific examples of tweets posted by the researchers to facilitate the interviews improved the recall of the participants and the accuracy of their answers. In addition, due to the privacy protection in this study, some participants also discussed motivations that they would prefer to not reveal in a public setting. Compared to using observation-based methods, this method ameliorated a potential Hawthorne effect (Parsons,

1974), a phenomenon that participants might change their behavior when they knew they were being studied.

CHAPTER 5: RESULTS

5.1 Research Participants Demographics

5.1.1 Survey Participants Demographics

In this section, I present the demographics information of the survey participants. Depending on the age, gender, country, education, position, and discipline of the participants, I present both a table and a figure to describe this sample.

Table 5.1 presents the distribution of age. Overall, 40-49 years old was the largest category of survey respondents. Meanwhile, 30-39 years old and 50-59 years old were the second and third largest categories. In total, these three categories constituted nearly 90% of the total number of survey participants.

Table 5.1 Distribution of Researchers by Age

Age	n	%
20-29 years old	23	1.9
30-39 years old	377	30.6
40-49 years old	470	38.1
50-59 years old	256	20.8
60-69 years old	93	7.5
70 years or older	14	1.1
Total	1233	100.0

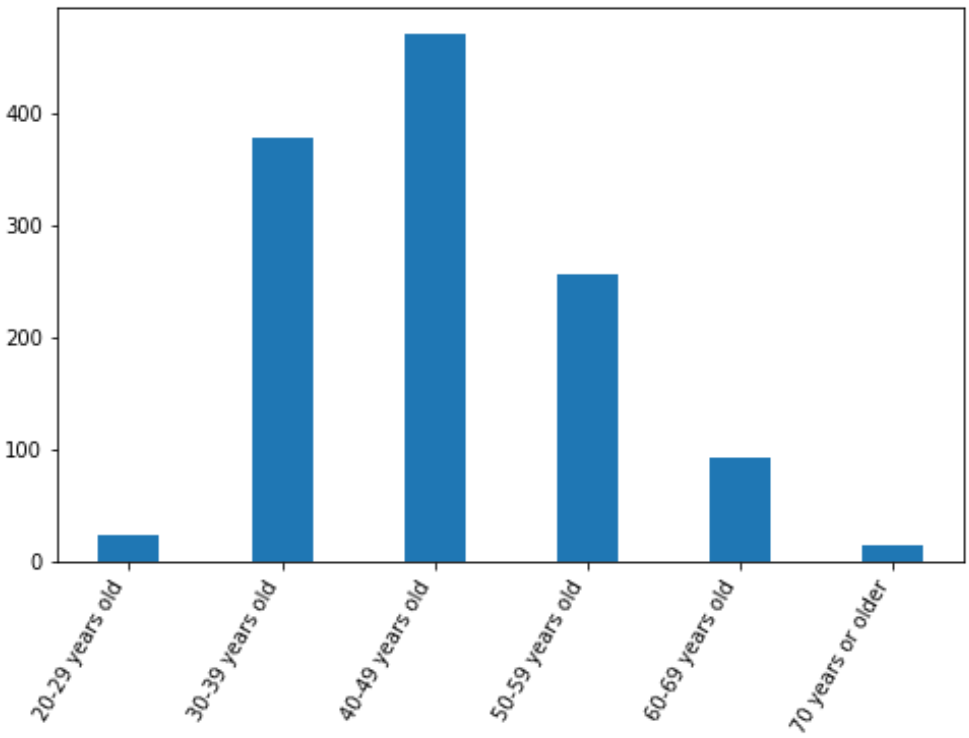

Figure 5.1 Distribution of Researchers by Age

In terms of gender, male researchers constituted the majority of the total researchers investigated. Slightly over one-third of the participants were female researchers.

Table 5.2 Distribution of Researchers by Gender

Gender	n	%
Female	432	35.0
Male	777	63.0
Transgender male	1	0.1
Gender variant/non-conforming	7	0.6
Not listed	2	0.2
Prefer not to answer	14	1.1
Total	1233	100.0

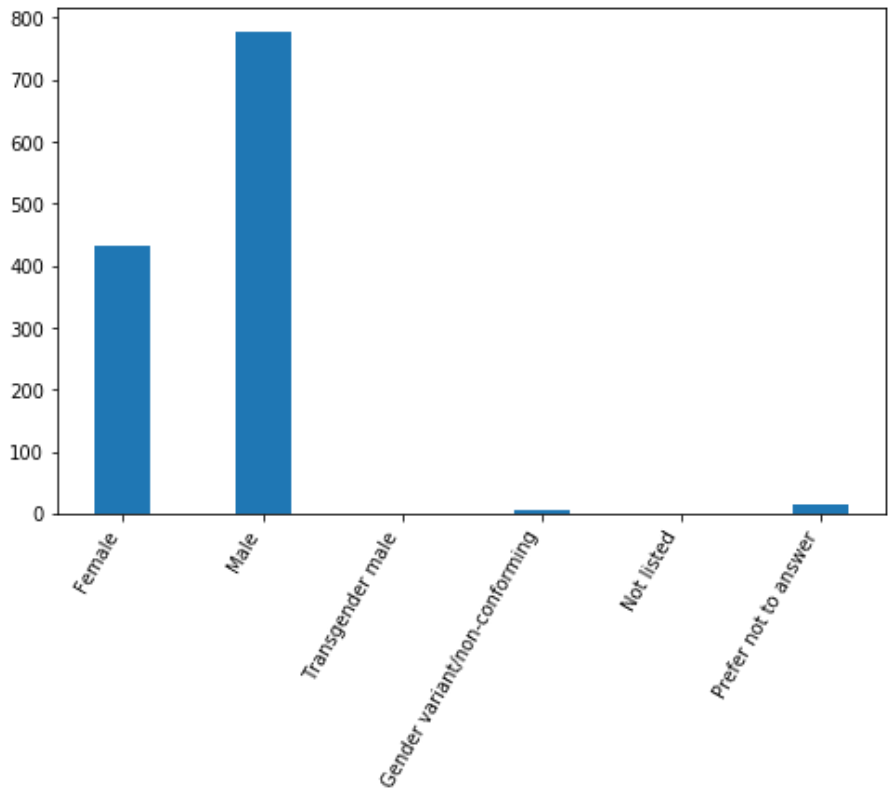

Figure 5.2 Distribution of Researchers by Gender

Respondents of the survey came from 48 countries distributed across six continents of the world: Africa (1 country), Asia (10 countries), Europe (24 countries), North America (5 countries), Oceania (2 countries), and South America (6 countries).

Researchers from the United States were the largest group. They accounted for almost two-fifths of the sample. Meanwhile, there were less than five participants in 27 countries out of these 48 countries. The distribution in terms of countries was highly skewed towards English-speaking countries, with the top four countries being the United States (38.0%), the United Kingdom (15.5.0%), Canada (10.0%), and Australia (7.4%).

Table 5.3 Distribution of Researchers by Country

Country	n	%	Country	n	%
Australia	91	7.4	Japan	4	0.3
Argentina	2	0.2	Luxembourg	1	0.1
Belgium	13	1.1	Mexico	4	0.3
Brazil	9	0.7	Netherlands	38	3.1
Canada	123	10.0	New Zealand	17	1.4
Chile	7	0.6	Norway	16	1.3
China	2	0.2	Oman	1	0.1
Colombia	3	0.2	Panama	1	0.1
Croatia	1	0.1	Peru	3	0.2
Czech Republic	1	0.1	Philippines	1	0.1
Denmark	9	0.7	Poland	1	0.1
Ecuador	1	0.1	Portugal	3	0.2
Finland	14	1.1	Qatar	1	0.1
France	34	2.8	Romania	1	0.1
Germany	20	1.6	Serbia	1	0.1
Greece	3	0.2	Singapore	1	0.1
Thailand	1	0.1	Slovenia	2	0.2
Iceland	1	0.1	South Africa	8	0.6
India	5	0.4	Spain	52	4.2
Indonesia	1	0.1	Sweden	23	1.9
Ireland	11	0.9	Switzerland	10	0.8
Israel	3	0.2	Turkey	4	0.3
Italy	25	2.0	United Kingdom	191	15.5
Jamaica	1	0.1	United States	468	38.0
Total					100.0

Almost half of the survey participants were from North America. Only less than 1% of them were from Africa. Less than 2% of them were from Asia.

Table 5.4 Distribution of Researchers by Continent

Continent	n	%
Africa	8	0.6
Asia	20	1.6
Europe	475	38.5
North America	597	48.4
Oceania	108	8.8
South America	25	2.0
Total	1233	100.0

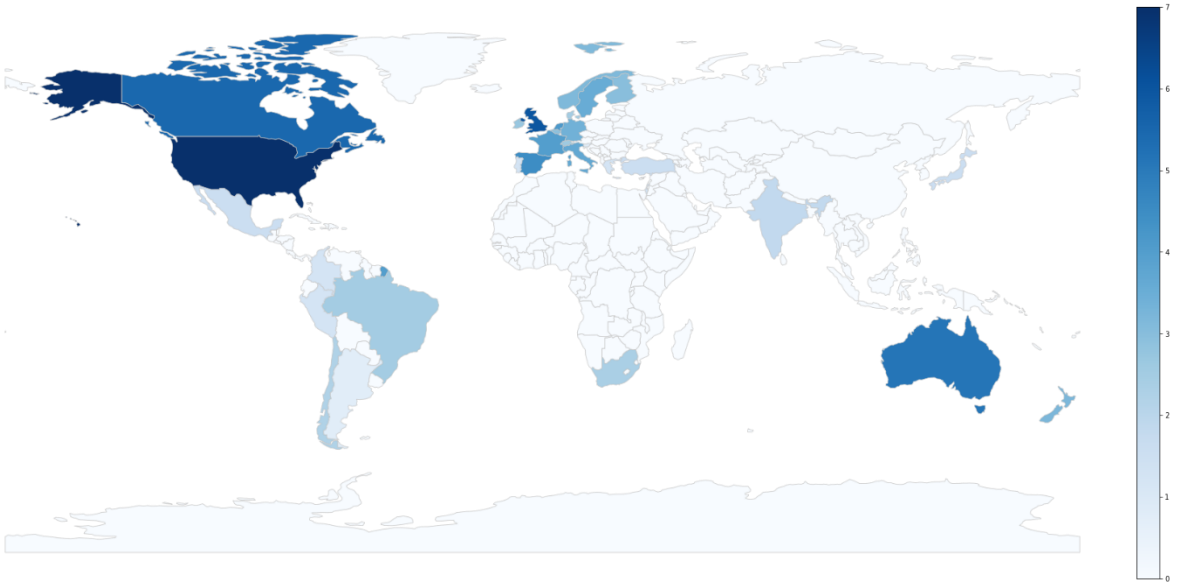

Figure 5.3 Distribution of Researchers by Country (log data)

The education level was highly skewed in this sample, with 94.3% of respondents holding a Doctoral degree or a professional degree (MD, JD, etc.). This aligned with the targeted survey audience of this study.

Table 5.5 Distribution of Researchers by Education

Highest Degree Received	n	%
Bachelor's degree	10	0.8
Master's degree	61	5.0
Doctoral degree	1071	86.9
Professional degree (MD, JD, etc.)	91	7.4
Total	1233	100.0

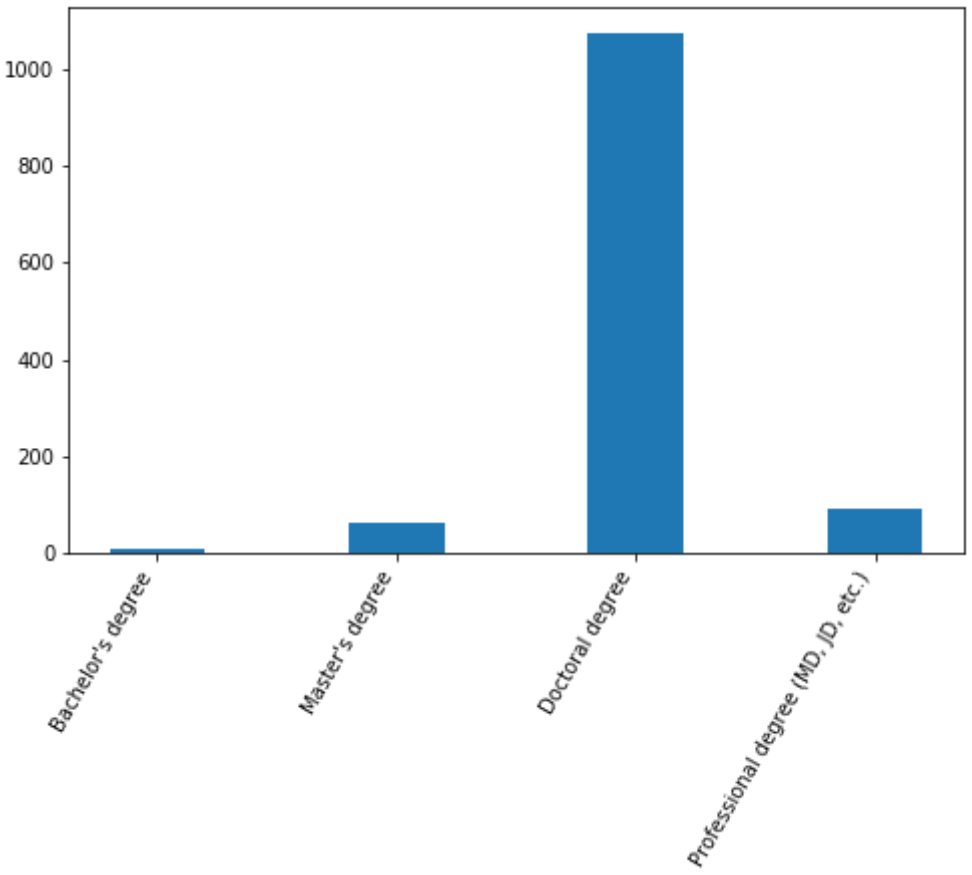

Figure 5.4 Distribution of Researchers by Education

Table 5.6 shows the distribution of respondents' current primary positions. As described in Appendix IV, eight categories were manually created from coding the responses provided in the "Others" category: "academic researcher", "academic researcher with an administrative role", "non-profit or non-government organization researcher", "industry researcher", "government researcher", "clinical researcher or physician", "Adjunct Professor", and "retired professor".

The largest category in this sample was Professor, which accounts for almost 30% of the total researchers investigated. If Professor and Associate Professor were defined as tenured researchers, more than half of the researchers in this sample were tenured researchers.

Table 5.6 Distribution of Researchers by Position

Current Primary Position	n	%
Professor	369	29.9
Associate Professor	288	23.4
Assistant Professor	149	12.1
Senior Lecturer	64	5.2
Lecturer	35	2.8
Academic researcher	45	3.6
Academic researcher with an administrative role	23	1.9
Adjunct Professor	4	0.3
Retired professor	7	0.6
Non-profit or Non-government organization researcher	31	2.5
Industry researcher	37	3.0
Government researcher	14	1.1
Clinical researcher or physician	27	2.2
Research Librarian	11	0.9
Post-Doctoral researcher	103	8.4
PhD student	24	1.9
Masters student	2	0.2
Total	1233	100.0

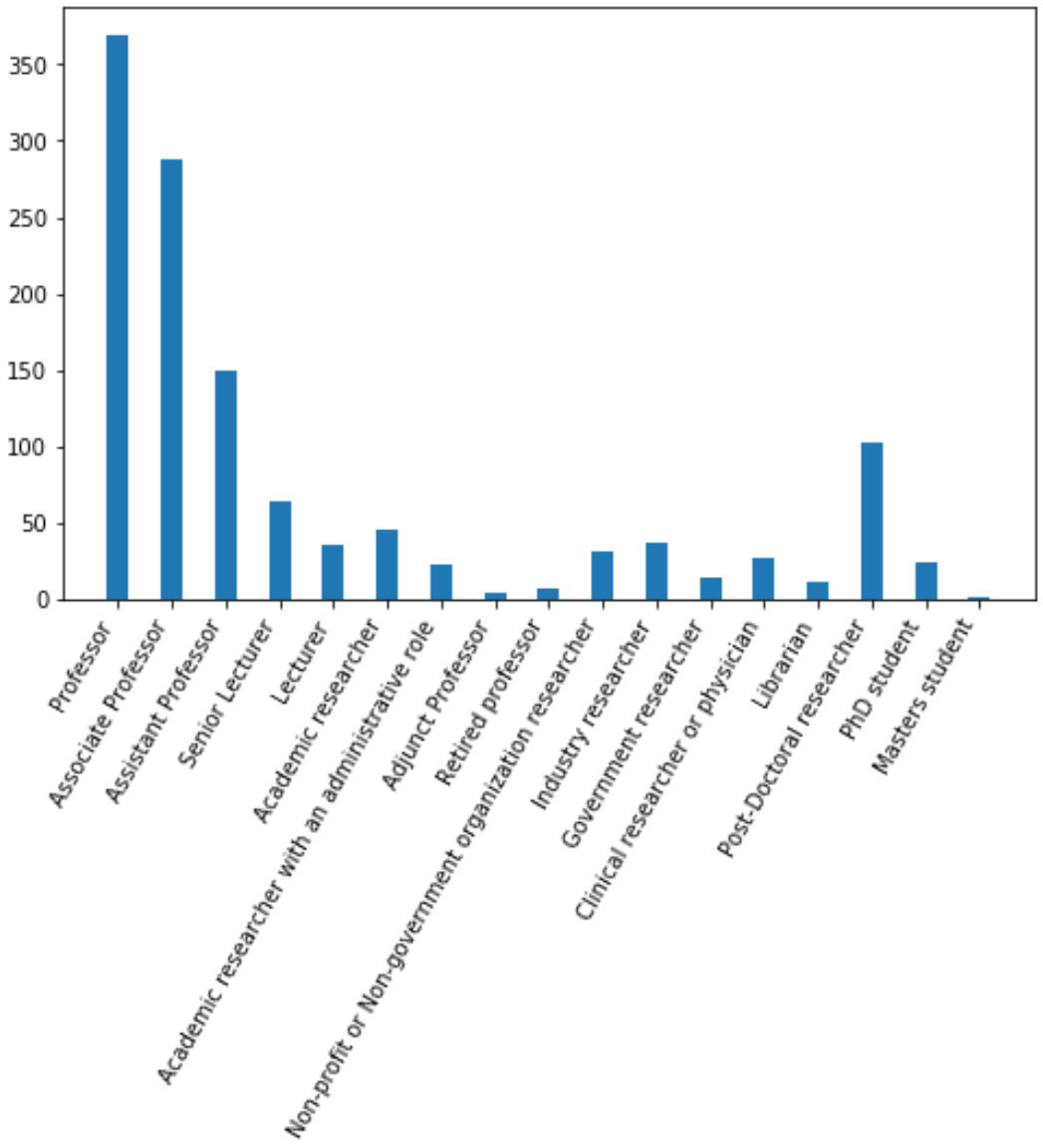

Figure 5.5 Distribution of Researchers by Position

Table 5.7 presents the distribution of disciplines of the survey respondents. Overall, Biomedical & Health Sciences, Social Sciences, and Life & Earth Sciences were the largest categories in our sample of researchers. They constituted almost 85% of the entire sample.

Table 5.7 Distribution of Researchers by Discipline

Discipline	n	%
Biomedical & Health Sciences	405	32.9
Humanities	43	3.5
Life & Earth Sciences	275	22.3
Mathematics & Computer Science	37	3.0
Physical Sciences & Engineering	109	8.8
Social Sciences	364	29.5
Total	1233	100.0

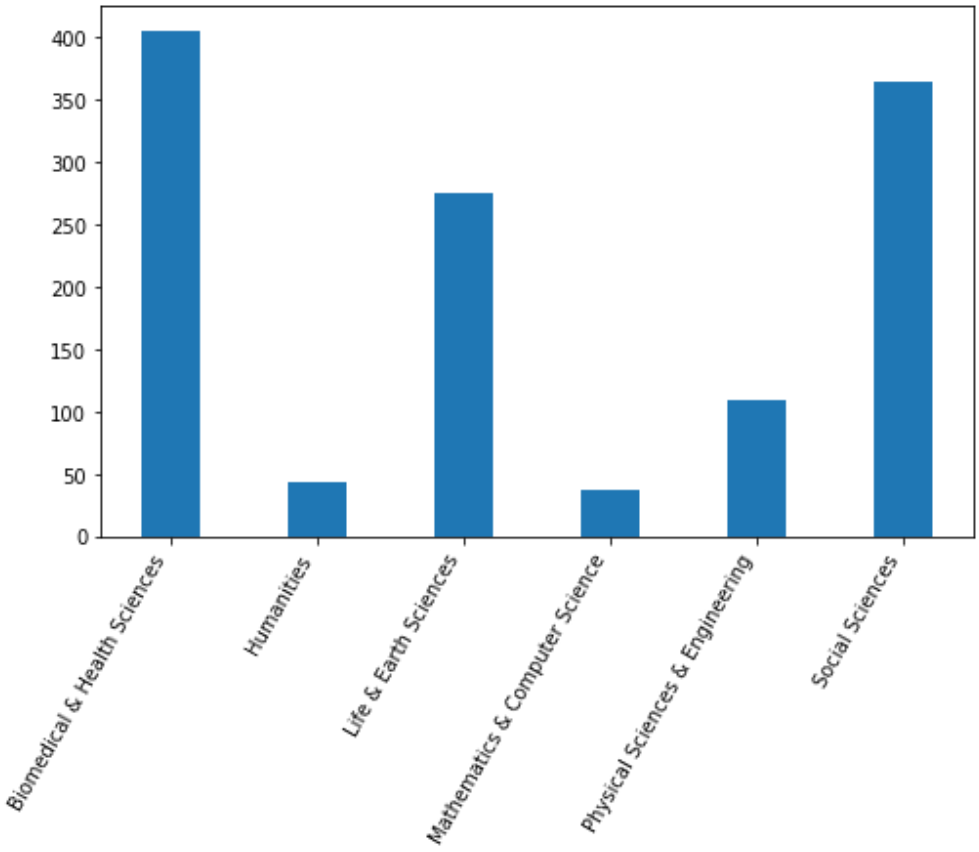

Figure 5.6 Distribution of Researchers by Discipline

The representativeness of this sample could be better understood in terms of the gender and discipline of the researchers. In another systematic identification of scholars on Twitter (Ke et al., 2017), out of the 32,964 researchers on Twitter that they were able to identify the gender,

38.6% were female, and 61.4% were male. This was similar to the composition of our sample. Costas et al. (2017) discussed in their paper that in this sample of researchers, a strong presence of researchers in the Social Sciences and the Humanities was found. On the contrary, Natural Sciences researchers were underrepresented the most on Twitter. More specifically, approximately 2% of researchers from all disciplines were found on Twitter. Scholars with Twitter accounts were prominent in "Social and Behavioral Sciences (slight over 5%) and "Law, Arts, and Humanities" (almost 4%). The share of researchers in the "Medical and Life Sciences" were slightly over 2%. The share of researchers in "Natural Sciences" was slightly above 1%. In Ke et al. (2017), which did not rely on any bibliographic databases in the identification of researchers, it was found that social scientists were overrepresented on Twitter and that mathematicians were particularly underrepresented. This was also similar to the composition of the sample in this study.

5.1.2 Interview Participants Demographics

I conducted twenty interviews with participants from eleven countries. There was a wide range of diversities in terms of age, gender, country, education, position, and discipline among the interview participants (Table 5.8). There were researchers not only in higher education universities but also in other sectors, including non-profit research institutes and the industry. Their frequency of Twitter uses ranged from several times a day to several times a month. These data were based on self-report in the surveys and later were verified according to both their information online and conversations in the interviews.

Using a quota sampling strategy, the aim was to account for the variety of demographics and characteristics that might affect their use of Twitter. Researchers that were 30-39 years old were overrepresented in this sample compared to the survey sample. Meanwhile, female

researchers were overrepresented. Researchers in some underrepresented countries were also overrepresented in this sample.

Table 5.8 Interview Participant Characteristics

Characteristic	n	%
Age		
30-39 years old	10	50
40-49 years old	7	35
50-59 years old	2	10
70 years or older	1	5
Gender		
Female	10	50
Male	10	50
Country		
Australia	1	5
Brazil	1	5
Canada	2	10
Finland	1	5
France	1	5
Ireland	1	5
Japan	1	5
Mexico	1	5
South Africa	1	5
United Kingdom	3	15
United States of America	7	35
Highest Degree Received		
Doctor of Philosophy (Ph.D.)	19	95
Doctor of Medicine (M.D.)	1	5
Position		
Professor	5	25
Associate Professor	5	25
Assistant Professor	3	15
Academic researcher	2	10
Academic researcher with an administrative role (Assistant Dean, Research)	1	5
Non-profit research institute researcher	1	5
Industry researcher	1	5
Post-Doctoral researcher	1	5
Retired professor	1	5

Discipline		
Biomedical & Health Sciences	4	20
Humanities	3	15
Life & Earth Sciences	4	20
Mathematics & Computer Science	2	10
Physical Sciences & Engineering	2	10
Social Sciences	5	25
Frequency of Twitter User for Professional Purposes		
Several times a day	11	55
About once a day	4	20
Several times a week	3	15
About once a week	1	5
Several times a month	1	5

5.2 Use of Twitter for Professional Purposes

This section discusses the researchers' use of Twitter for professional purposes, including how often they used Twitter, what types of Twitter accounts they followed and interacted with for professional reasons.

Among the survey participants, more than 70% used Twitter on a daily basis professionally. Particularly, about half of all researchers used Twitter for professional purposes several times a day. There was a decreasing trend in the professional use of Twitter from the most frequent ("Several times a day") to the least frequent ("Fewer than once a month") category.

Table 5.9 Frequency of Twitter Use for Professional Purposes

Frequency	n	%
Several times a day	606	49.1
About once a day	288	23.4
Several times a week	203	16.5
About once a week	60	4.9
Several times a month	41	3.3
About once a month	19	1.5
Fewer than once a month	16	1.3
Total	1233	100

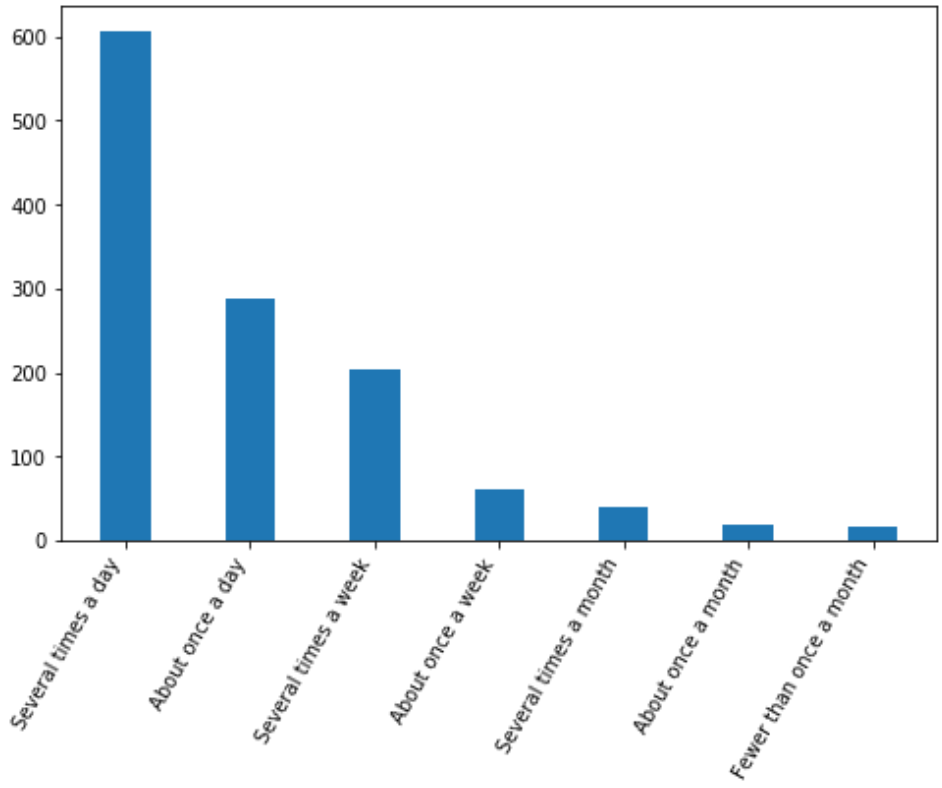

Figure 5.7 Frequency of Twitter Use for Professional Purposes

5.2.1 Accounts Researchers Follow on Twitter

In the survey, researchers were asked about who they followed on Twitter for professional purposes. Twelve categories were provided in the survey allowing for multi-select. As described in Appendix IV, 62 responses were provided in the "Others" category and were manually coded by myself and a second coder. Specifically, students, politicians, activists, research participants, lived experience experts relevant to research, and high school teachers were categorized into the "Other individuals" category. Labs, despite being smaller research unites than research institutes and departments, were categorized into the "Research institutions

and universities" category. "Research projects" was put in the "Professional organizations and conferences" category. "Journals" was put into the "Academic publishers" category.

The largest category in this sample was individual scholars; 97.2% of the researcher surveyed followed other individual scholars on Twitter for professional reasons. The other three large categories, which were followed by more than 80% of the researchers, included individual scientific communicators/journalists, research institutions and universities, and professional organizations and conferences. Except for businesses, all of the other eleven categories of Twitter accounts were followed by more than half of the researchers in our survey.

Table 5.10 Categories of Twitter Accounts Followed by Researchers

Frequency	n	%
Individual scholars	1199	97.2
Individual professionals	837	67.9
Individual scientific communicators/journalists	1092	88.6
Other individuals	726	58.9
Research institutions and universities	1035	83.9
Funding organizations	759	61.6
Professional organizations and conferences	998	80.9
Civil society organizations	628	50.9
Academic publishers	736	59.7
News media	667	54.1
Public authorities	619	50.2
Businesses	283	23.0

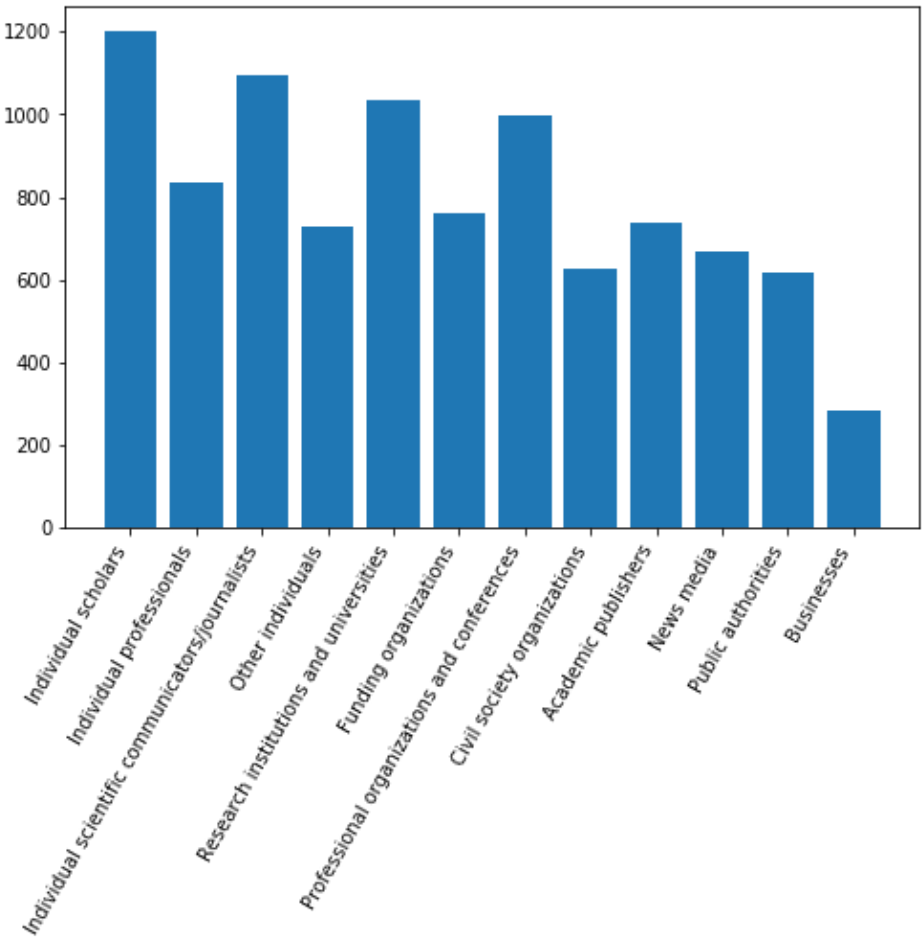

Figure 5.8 Categories of Twitter Accounts Followed by Researchers

5.2.2 Accounts with Which Researchers Interact on Twitter

The accounts with which researchers interacted are shown in Table 5.11 below. Similar to the Twitter accounts followed by researchers for professional reasons, four top categories were individual professionals, individual scientific communicators/journalists, research institutions and universities, and professional organizations and conferences. Compared to the accounts followed by these researchers the most, individual professionals, which was the fifth-largest category, was a category that researchers interacted with relatively frequently. On the other hand,

the researchers rarely interacted with funding organizations (6.1%) and public authorities (6.9%), despite that more than half of the researchers followed them.

Table 5.11 Categories of Twitter Accounts with Which Researchers Interact

Frequency	n	%
Individual scholars	1151	93.3
Individual professionals	563	45.7
Individual scientific communicators/journalists	540	43.8
Other individuals	339	27.5
Research institutions and universities	363	29.4
Funding organizations	75	6.1
Professional organizations and conferences	350	28.4
Civil society organizations	131	10.6
Academic publishers	173	14.0
News media	155	12.6
Public authorities	85	6.9
Businesses	13	1.1

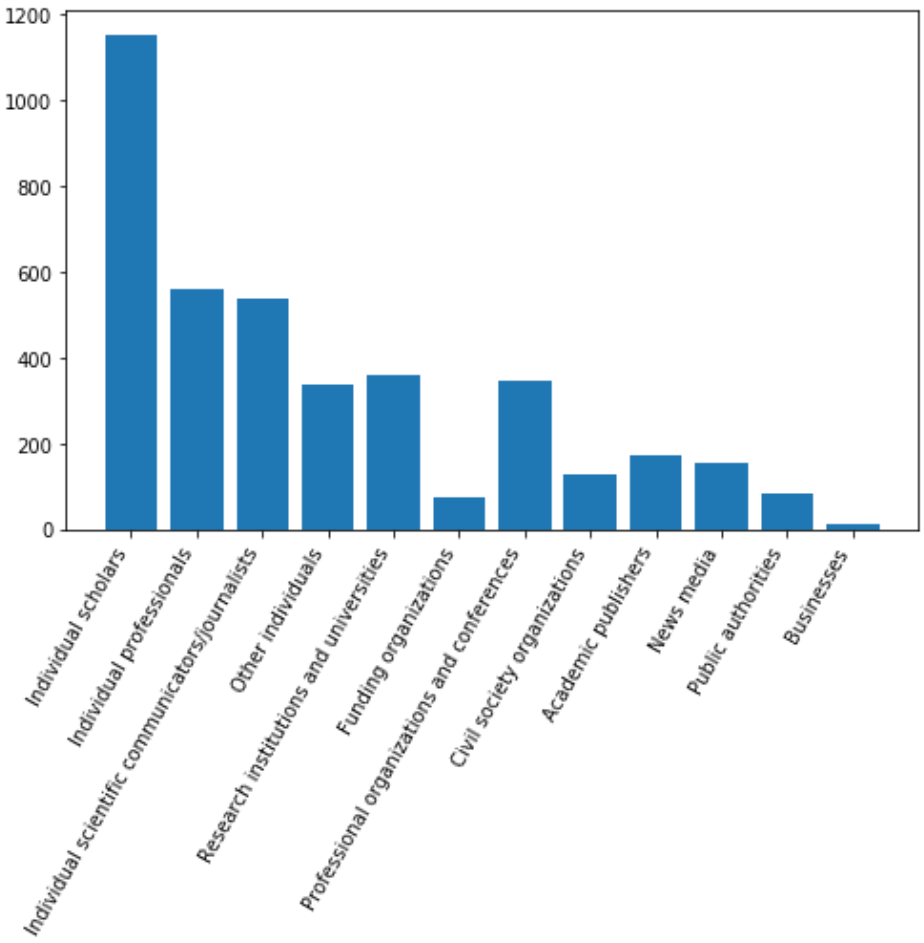

Figure 5.9 Categories of Twitter Accounts with Which Researchers Interact

To test the differences of professional use of Twitter across different groups of researchers, the Kruskal-Wallis test and post hoc Mann-Whitney U test with Bonferroni Correction were performed on researchers among different age, gender, country, education, position, and discipline groups. The results of the comparisons are presented in Section 5.2.3.

5.2.3 Twitter Use for Professional Purposes

5.2.3.1 Twitter Use for Professional Purposes by Age

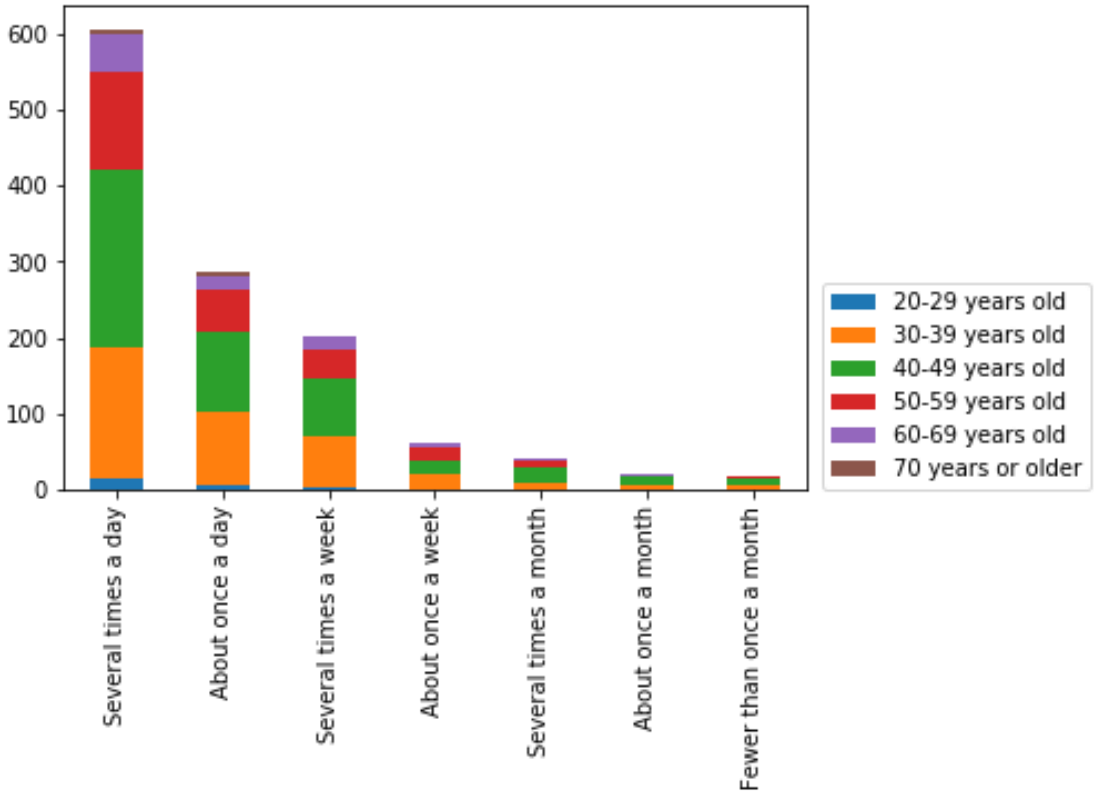

Figure 5.10 Twitter Use for Professional Purposes by Age

The Kruskal-Wallis test showed no statistically significant difference among the frequency of Twitter use for professional purposes by researchers in different age groups ($H = 3.54$, $p = 0.62$).

5.2.3.2 Twitter Use for Professional Purposes by Gender

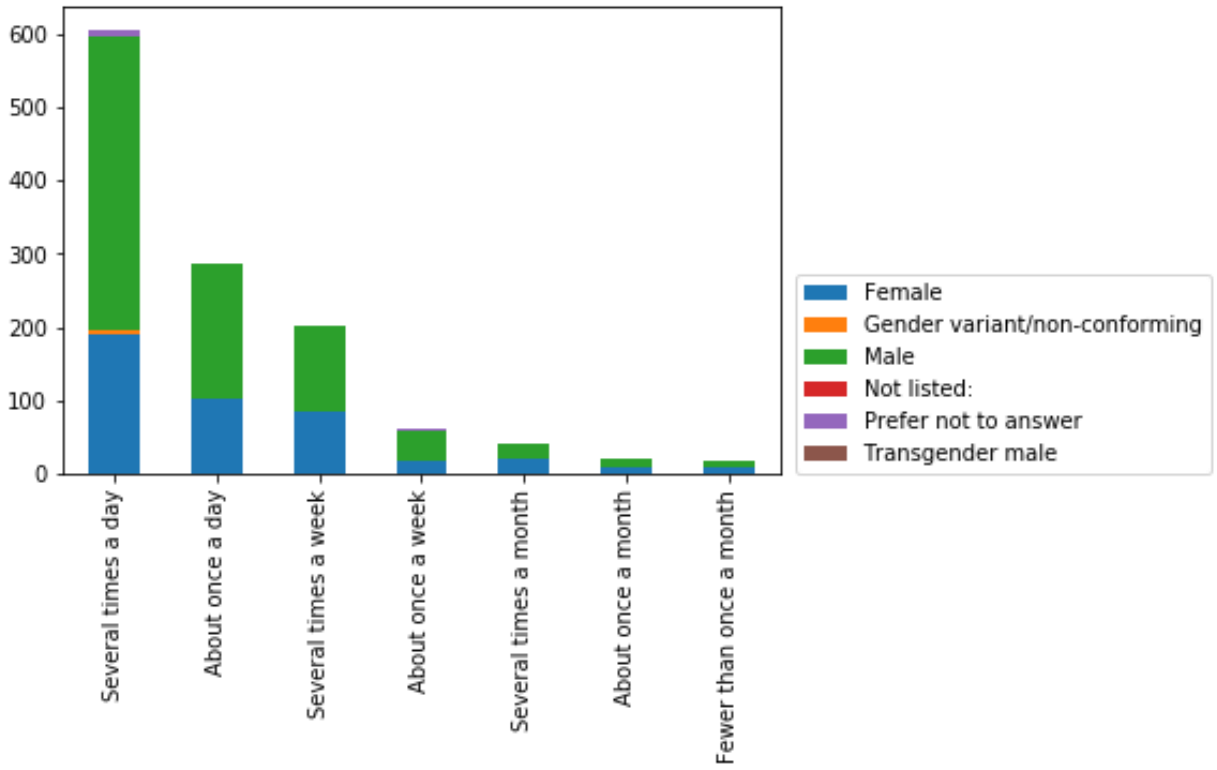

Figure 5.11 Twitter Use for Professional Purposes by Gender

Considering the small number of observations in the other groups (“Gender variant/non-conforming” category (n = 7, % = 0.57), “Transgender male” category (n = 1, % = 0.08), and the “Not listed” category (n =2, % = 0.16)), only Female and Male researchers were compared on the frequency of professional Twitter use. According to the Kruskal-Wallis test, there was a statistical difference between female and male researchers (H = 9.63, p = 0.00). On a 7-point Likert scale, female researchers (median = “About once a day”) used Twitter less frequently than male researchers (median = “Several times a day”) did.

5.2.3.3 Twitter Use for Professional Purposes by Continent

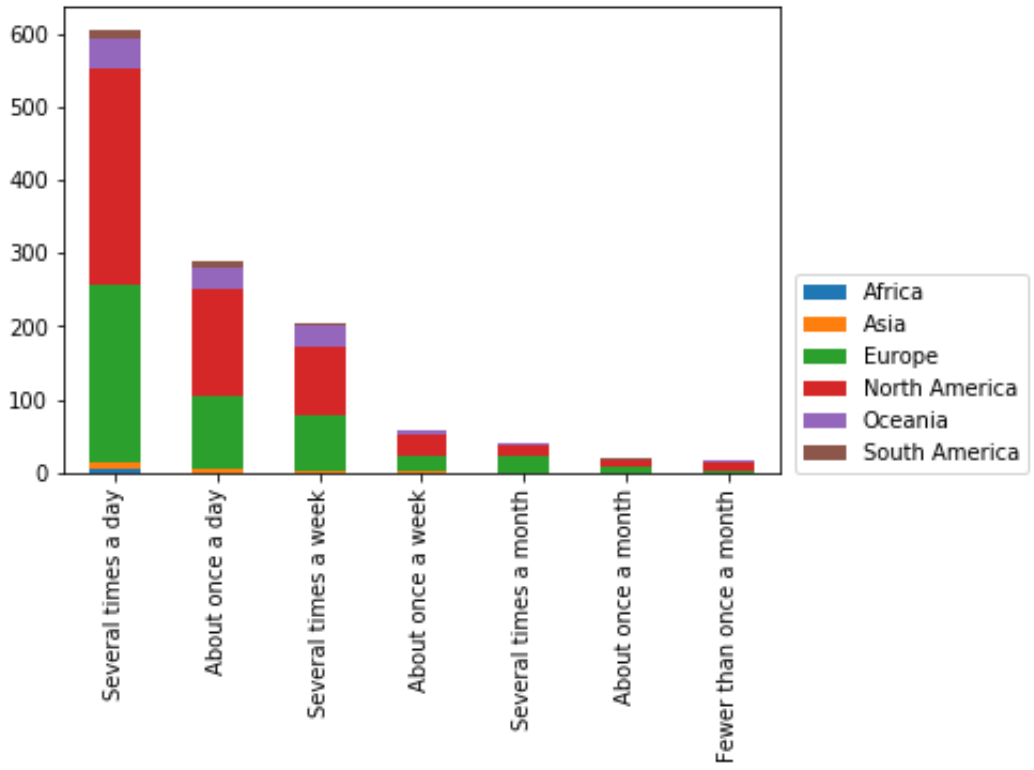

Figure 5.12 Twitter Use for Professional Purposes by Continent

To compare the Twitter use for professional purposes by researchers from different parts of the world, data of the 48 countries were aggregated into six continents. The Kruskal-Wallis test showed no statistically significant difference among researchers from different continents of the world ($H = 4.63$, $p = 0.46$).

5.2.3.4 Twitter Use for Professional Purposes by Education

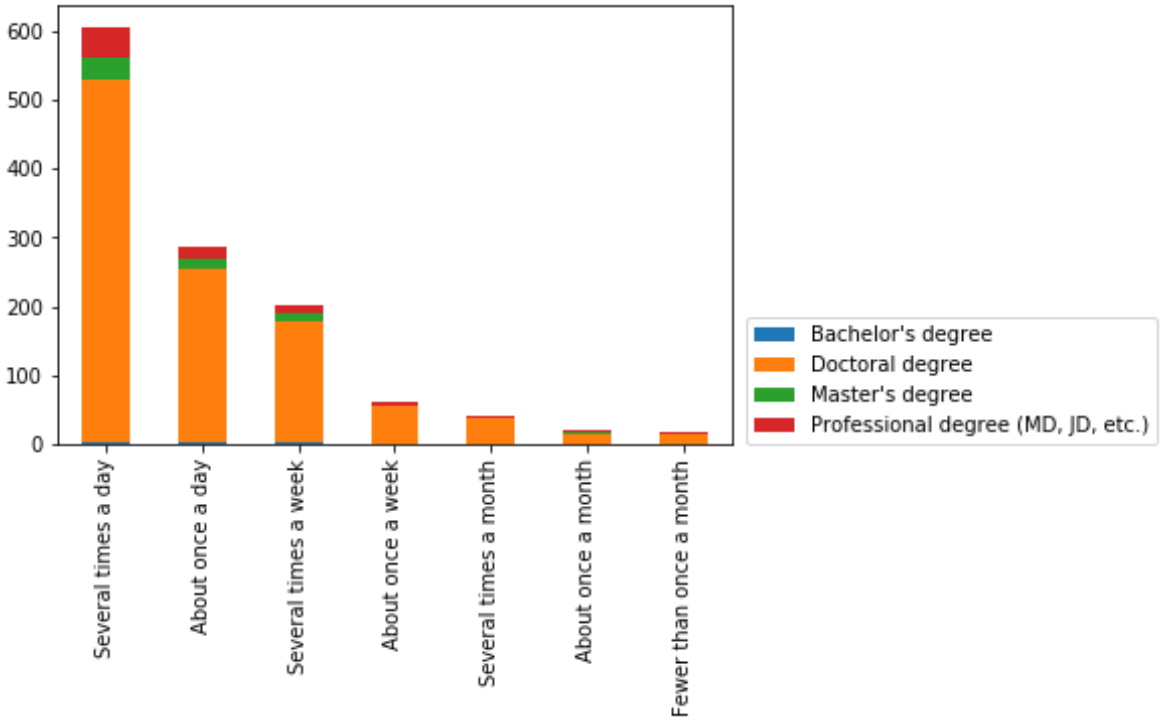

Figure 5.13 Twitter Use for Professional Purposes by Education

Comparing the different educational levels and types, the Kruskal-Wallis test showed no statistically significant difference in the frequency of researchers' professional Twitter use ($H = 3.38$, $p = 0.34$).

5.2.3.5 Twitter Use for Professional Purposes by Position

For the purpose of comparison, I integrated the finer-grained categories of positions collected from the survey into larger categories of positions. Specifically, "Professor" and "Associate Professor" were merged into "Tenured researcher"; "Assistant Professor" was renamed as "Pre-tenured researcher"; "Post-Doctoral researcher", "PhD student", and "Masters student" were categorized as "Early-career researcher"; "Senior Lecturer" and "Lecturer" were merged as "Lecturer". In addition, "Clinical researcher or physician," "Government researcher,"

"Industry researcher," and "Non-profit or Non-government organization researcher" were categorized into "Other researcher." "Academic researcher" (n = 45, % = 3.6) and "Academic researcher with an administrative role" (n = 23, % = 1.9%) were not included in the Kruskal-Wallis analysis because of the difficulty to assign them into a category.

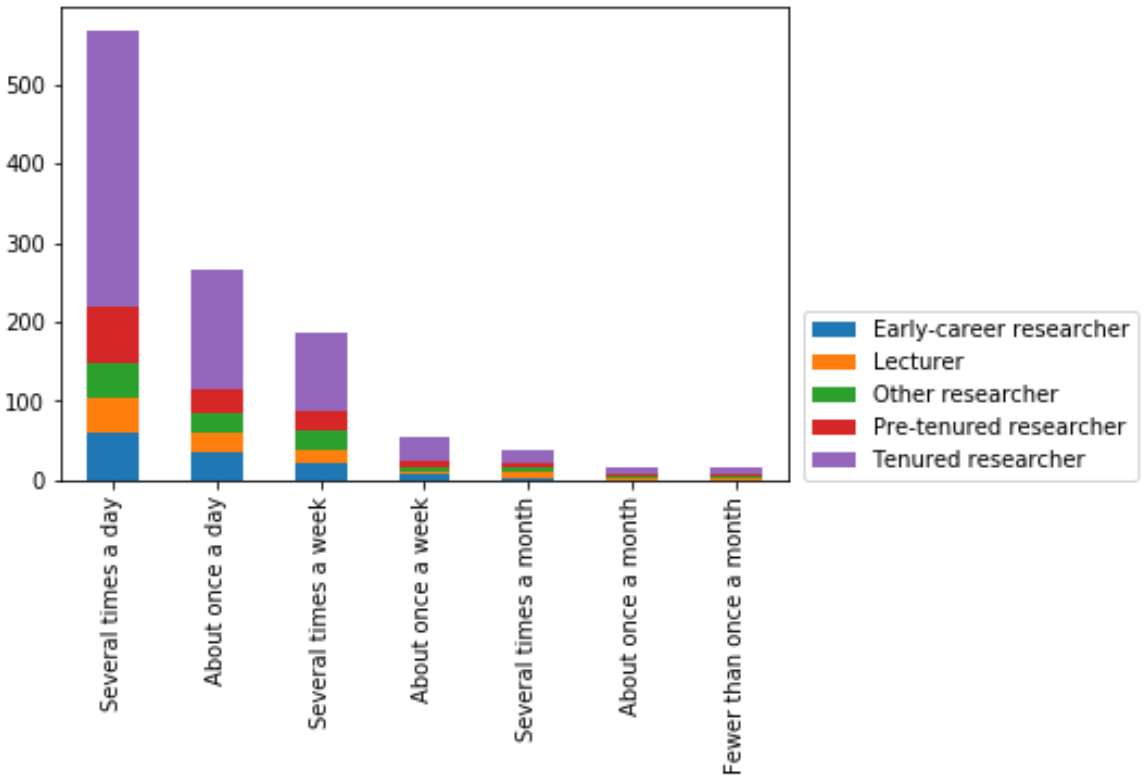

Figure 5.14 Twitter Use for Professional Purposes by Position

According to the Kruskal-Wallis test, there were statistically significant differences among the frequency of professional Twitter use by researchers in different positions (H = 11.97, p = 0.02). Specifically, tenured researchers used Twitter for professional purposes the most frequently, followed by early-career researchers, lectures, and pre-tenured researchers. Researchers in other sectors, including clinical researchers or physicians, government

researchers, industry researchers, and non-profit or non-government organization researchers, used Twitter for professional purposes the least frequently.

To further understand if there existed statistically significant differences among the groups, Mann-Whitney U tests with Bonferroni correction were applied. On a 7-point Likert scale, tenured researchers (median = “Several times a day”) used Twitter for professional purposes more frequently than researchers in other sectors did (median = “About once a day”) ($p = 0.00$). Similarly, tenured researchers also used twitter more frequently than lecturers (median = “About once a day”) did for professional purposes ($p = 0.04$).

5.2.3.6 Twitter Use for Professional Purposes by Discipline

The Kruskal-Wallis test showed statistically significant differences among the frequency of professional Twitter use by researchers in different disciplines ($H = 17.83$, $p = 0.00$).

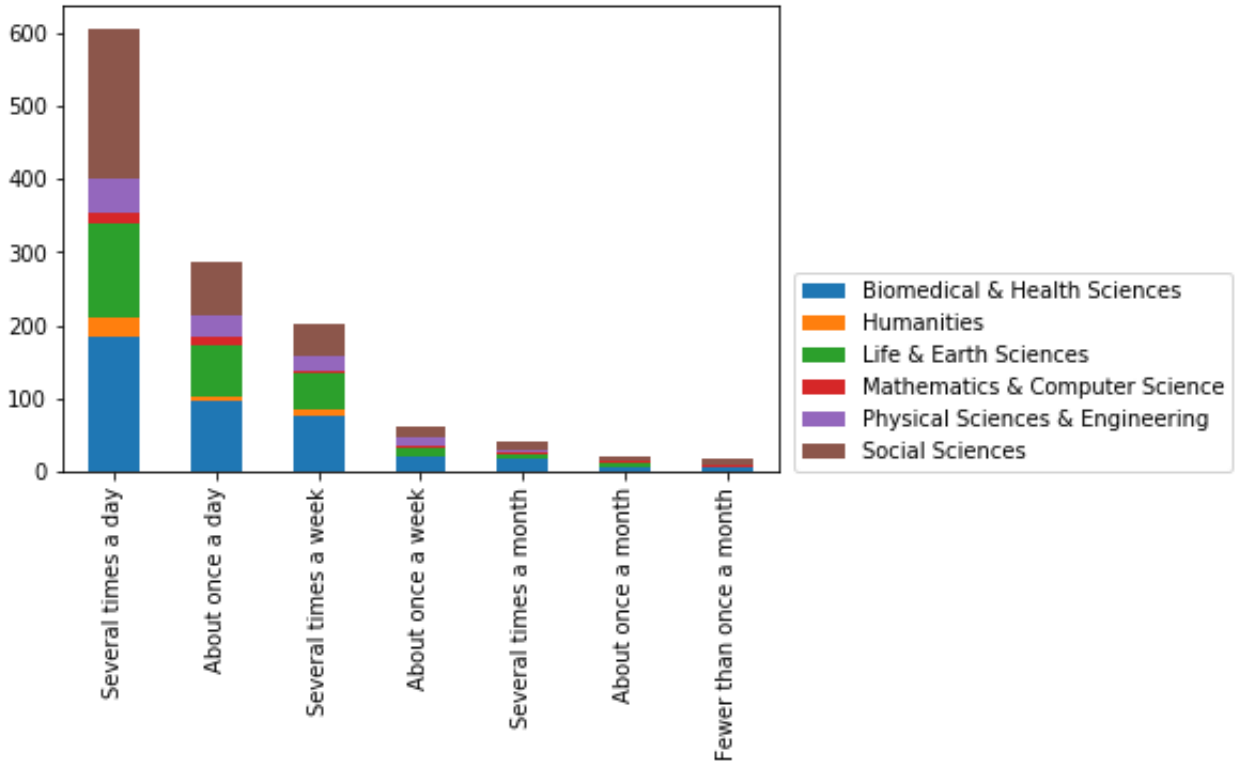

Figure 5.15 Twitter Use for Professional Purposes by Discipline

Researchers in the Humanities used Twitter for professional purposes the most frequently, followed by those in Social Sciences, Life & Earth Sciences, Biomedical & Health Science, and Physical Sciences & Engineering. Mathematics & Computer Science researchers used Twitter for professional purposes the least frequently.

Mann-Whitney U tests with Bonferroni correction were applied to investigate if there existed statistically significant differences among the groups. Biomedical & Health Sciences researchers (median = "About once a day") used Twitter for professional purposes statistically less frequently than both Social Sciences (median = "Several times a day") ($p = 0.00$) and Humanities researchers (median = "Several times a day") ($p = 0.02$). Meanwhile, Social Sciences researchers' professional use of Twitter was also more frequent than researchers in the field of Physical Sciences & Engineering (median = "About once a day") ($p = 0.01$). In addition, researchers in the Humanities used Twitter for professional purposes more frequently than researchers in both Physical Sciences & Engineering ($p = 0.04$) and Mathematics & Computer Science (median = "About once a day") ($p = 0.01$).

5.3 Twitter Acts and Sentiment of Opinions on Articles

This section focuses on researchers' Twitter acts that are associated with scholarly articles instead of their general use of Twitter for professional purposes.

In the survey, researchers were asked about their opinion on the scholarly articles contained in the tweet they posted (tweeted), reposted (retweeted), replied to, and liked. Regarding each of these four activities, researchers were asked: "When you posted/retweeted/replied to/liked tweets regarding scholarly articles, how often did you have a positive/neutral/negative opinion on the articles?" In Section 5.3.1, I present the analyses of researchers' sentiment of opinions on the articles associated with their activities. Similar to in

Section 5.2, first, I discuss how researchers in different groups have different opinions on the articles they tweeted, retweeted, replied to, and liked. In order to perform these analyses, researchers were divided into different groups by age, gender, continent, education, position, and discipline.

In addition, researchers were clustered based on their sentiment of opinions on the scholarly articles associated with these Twitter acts. The clusters of researchers are presented and discussed in Section 5.3.2.

In Section 5.3.3, the interview data were analyzed to discuss the researchers' perception of these Twitter acts and the reasons for having the different sentiment of opinions on the articles associated with these acts.

5.3.1 Sentiment of Opinions on the Scholarly Articles

5.3.1.1 Sentiment of Opinions on the Scholarly Articles by Age

Table 5.12 shows the results of the Kruskal-Wallis tests. Similar to what has been reported in Section 5.3, the H-statistic and p-value are reported for each of the tests. "Chi-square" is the H-statistic. A p-value of 0.05 or less indicates a statistical difference among the groups.

When liking tweets that contained a link to a scholarly article, researchers in different age groups had different patterns regarding the neutral and negative opinions. Specifically, further comparisons using Mann-Whitney U Test with Bonferroni Correction showed that researchers that were 29-39 years old tended to have a neutral opinion on the scholarly articles they liked in more cases than researchers that were 30-39 years old ($p = 0.00$), 40-49 years old ($p = 0.00$), 50-59 years old ($p = 0.00$), and 60-69 years old ($p = 0.00$). In other words, when researchers liked a tweet containing a scholarly article, researchers in their 20s more frequently indicated a neutral opinion on the article.

Table 5.12 Kruskal-Wallis Test Results of Opinions by Age

Act	Opinion	H	p
Tweeting	Positive	1.35	0.93
	Neutral	3.07	0.69
	Negative	5.34	0.38
Retweeting	Positive	1.96	0.85
	Neutral	6.60	0.25
	Negative	5.77	0.33
Replying	Positive	5.42	0.37
	Neutral	1.00	0.96
	Negative	4.93	0.42
Liking	Positive	6.75	0.24
	Neutral	14.61	0.01**
	Negative	13.54	0.02**

Meanwhile, when liking tweets containing scholarly articles, researchers who were 60-69 years old had a negative opinion on the articles in fewer cases compared to researchers in several younger groups, including 30-39 years old ($p = 0.01$), 40-49 years old ($p = 0.02$), and 50-59 years old ($p = 0.02$).

5.3.1.2 Sentiment of Opinions on the Scholarly Articles by Gender

Overall, female researchers had a relatively more positive opinion in their actions related to scholarly articles on Twitter. When tweeting ($p = 0.00$), retweeting ($p = 0.01$), replying to ($p = 0.00$), and liking ($p = 0.00$) tweets that contained scholarly articles, female researchers more frequently had a positive opinion on the articles compared to male researchers. On the contrary, male researchers had a negative opinion on the articles in the tweets that they tweeted ($p = 0.01$), retweeted ($p = 0.01$), replied to ($p = 0.00$), and liked ($p = 0.01$) in more cases than female researchers did. In addition, when replying to tweets that contained a link to a scholarly article, male researchers more frequently had a neutral opinion on the article compared to female researchers ($p = 0.01$).

Table 5.13 Kruskal-Wallis Test Results of Opinions by Gender

Act	Opinion	H	p
Tweeting	Positive	9.29	0.00**
	Neutral	2.42	0.12
	Negative	7.87	0.01**
Retweeting	Positive	6.47	0.01**
	Neutral	0.42	0.51
	Negative	5.96	0.01**
Replying	Positive	15.86	0.00**
	Neutral	6.71	0.01**
	Negative	10.26	0.00**
Liking	Positive	10.73	0.00**
	Neutral	0.00	0.98
	Negative	7.77	0.01**

5.3.1.3 Sentiment of Opinions on the Scholarly Articles by Continent

Examined geospatially at the continent level, when tweeting and replying to tweets that contained scholarly articles, researchers' opinions on the articles differed on both the positive and the negative sides in different continents. Meanwhile, in terms of retweeting and liking, researchers in different continents had positive opinions on the articles differently.

When tweeting scholarly articles, researchers in Oceania had a positive opinion on the articles the most frequently, followed by those in North America, Asia, Africa, Europe, and South America. Statistical differences were found between the first and the last two groups. Specifically, researchers in South America less frequently had positive opinions on the articles tweeted compared to North America ($p = 0.05$) and Oceania scholars ($p = 0.02$). Similarly, researchers in Europe also had positive opinions on the articles in fewer cases than North America ($p = 0.02$) and Oceania scholars ($p = 0.01$).

Table 5.14 Kruskal-Wallis Test Results of Opinions by Continent

Act	Opinion	H	p
Tweeting	Positive	12.47	0.03**
	Neutral	9.75	0.08
	Negative	13.13	0.02**
Retweeting	Positive	24.19	0.00**
	Neutral	7.78	0.17
	Negative	5.85	0.32
Replying	Positive	23.68	0.00**
	Neutral	4.63	0.46
	Negative	21.63	0.00**
Liking	Positive	16.56	0.01**
	Neutral	3.14	0.68
	Negative	8.39	0.14

The patterns of researchers' opinions on articles that they retweeted were similar to which they retweeted. Researchers in Europe and South America had positive opinions on the articles they retweeted less frequently than researchers in North America ($p = 0.00$, $p = 0.00$, respectively) and Oceania ($p = 0.00$, $p = 0.00$, respectively) did.

In regards to replying to tweets containing scholarly articles, researchers in Africa had a positive opinion on them the most frequently, followed by those in Oceania, North America, Asia, Europe, and South America. Specifically, researchers in South America had positive opinions on the articles contained in the tweets they replied to statistically less frequently compared to researchers in Africa ($p = 0.05$), North America ($p = 0.01$), and Oceania ($p = 0.00$). At the same time, researchers in Oceania statistically more frequently had positive opinions on the articles contained in the tweets they replied to compared to Europe ($p = 0.00$). The difference between those in North America and Europe was also statistically significant ($p = 0.01$)

Finally, in terms of liking a tweet containing a scholarly article, researchers in North America had a positive opinion on the article they liked the most frequently, while those in South America had a positive opinion on the article they liked the least frequently. Specifically,

researchers in South America tended to less frequently have a positive opinion on the articles contained in a tweet they liked compared to researchers in Europe ($p = 0.05$), North America ($p = 0.00$), and Oceania ($p = 0.01$). Meanwhile, it was also less frequent for European researchers to have a positive opinion on the articles contained in a tweet they liked compared to North American researchers ($p = 0.00$).

In terms of having a negative opinion on the articles tweeted, researchers in Asia tended to have a negative opinion on the articles the most frequently. The differences between Asian researchers and researchers in Europe ($p = 0.03$), North America ($p = 0.02$), Oceania ($p = 0.00$), and South America ($p = 0.03$) were all statistically significant. On the contrary, researchers in Oceania were the least frequent to have a negative opinion on the articles tweeted. They did that statistically less frequently than European ($p = 0.01$) and North American ($p = 0.04$) researchers.

Replying to a tweet containing a scholarly article to which researchers had a negative opinion on displayed a similar pattern. Researchers in Oceania did this statistically less compared to researchers in Asian ($p = 0.02$), Europe ($p = 0.00$), North America ($p = 0.00$), and South America ($p = 0.02$).

5.3.1.4 Sentiment of Opinions on the Scholarly Articles by Education

When grouped by education background, differences were found in having a positive opinion on tweeted articles. There were also differences in having a negative opinion on the articles contained in tweets and replies.

From the results of the posthoc Mann-Whitney U tests with Bonferroni Correction, it was more frequent for researchers holding a doctoral degree to have a positive opinion on the article they tweeted than for researchers with a professional degree ($p = 0.00$). On the contrary, results also showed that researchers holding a professional degree had a negative opinion on the article

they tweeted about more frequently compared with researchers with a doctoral degree (0 = 0.00). In addition, these two groups of researchers also differed in the frequency of having a negative opinion on an article contained in a tweet they replied to. Similar to tweeting, researchers holding a professional degree also more frequently had a negative opinion on the scholarly articles they replied to (p = 0.00).

Table 5.15 Kruskal-Wallis Test Results of Opinions by Education

Act	Opinion	H	p
Tweeting	Positive	9.75	0.02**
	Neutral	1.50	0.68
	Negative	15.58	0.00**
Retweeting	Positive	1.49	0.69
	Neutral	2.57	0.46
	Negative	3.49	0.32
Replying	Positive	6.56	0.09
	Neutral	4.87	0.18
	Negative	10.02	0.02**
Liking	Positive	2.77	0.43
	Neutral	0.56	0.91
	Negative	3.29	0.35

Overall, researchers holding a doctoral degree were found to be relatively more positive compared to those holding a professional degree in their tweeting and replying acts related to scholarly articles.

5.3.1.5 Sentiment of Opinions on the Scholarly Articles by Position

In regards to different positions, the only statistically significant difference found was in researchers having neutral opinions on the articles being retweeted. Specifically, early-career researchers had a neutral opinion on the articles they retweeted statistically more frequently than all the other groups, including tenured researchers (p = 0.00), pre-tenure researchers (p = 0.00),

lecturers (p = 0.02), and researchers working in government, industry, clinical, and non-profit or non-government settings (p = 0.01).

Table 5.16 Kruskal-Wallis Test Results of Opinions by Position

Act	Opinion	H	p
Tweeting	Positive	6.70	0.15
	Neutral	4.13	0.39
	Negative	6.50	0.16
Retweeting	Positive	7.19	0.13
	Neutral	13.19	0.01**
	Negative	2.81	0.59
Replying	Positive	2.38	0.67
	Neutral	6.40	0.17
	Negative	2.66	0.62
Liking	Positive	2.18	0.70
	Neutral	4.75	0.31
	Negative	5.85	0.21

5.3.1.6 Sentiment of Opinions on the Scholarly Articles by Discipline

For researchers in different disciplines, they mainly differed in having negative opinions on the articles they tweeted, retweeted, and replied to. There was no statistical difference in the act of liking.

When tweeting articles, researchers in Biomedical & Health Sciences had a negative on the articles the most frequently, followed by those in Humanities, Social Sciences, Mathematics & Computer Science, Life & Earth Sciences, and Physical Sciences & Engineering.

Specifically, the difference between Biomedical & Health Sciences and Life & Earth Sciences was statistically significant (p = 0.00). Meanwhile, researchers in both Biomedical & Health Sciences researchers (p = 0.01) and Social Sciences (p = 0.00) more frequently had a negative opinion on the articles compared to Physical Sciences & Engineering researchers.

Table 5.17 Kruskal-Wallis Test Results of Opinions by Education

Act	Opinion	H	p
Tweeting	Positive	9.19	0.10
	Neutral	8.04	0.15
	Negative	28.35	0.00**
Retweeting	Positive	2.20	0.82
	Neutral	3.62	0.61
	Negative	16.56	0.01**
Replying	Positive	6.94	0.22
	Neutral	10.24	0.07
	Negative	13.14	0.02**
Liking	Positive	3.32	0.65
	Neutral	9.84	0.08
	Negative	4.61	0.47

In terms of negative opinions associated with the act of retweeting, researchers in Biomedical & Health Sciences and Social Sciences seemed to be the most critical. Specifically, it was more frequent for Biomedical & Health Sciences researchers to have a negative opinion on the articles they retweeted than Life & Earth Sciences ($p = 0.00$) and Physical Sciences & Engineering ($p = 0.01$) researchers. Similarly, researchers in Social Sciences also had a statistically higher frequency of having a negative opinion compared to researchers in Life & Earth Sciences ($p = 0.01$) and Physical Sciences & Engineering ($p = 0.01$).

Lastly, researchers in Biomedical & Health Sciences ($p = 0.00$) and Social Sciences ($p = 0.03$) also replied to articles they had negative opinions on more frequently than researchers in Life & Earth Sciences did. At the same time, researchers in Biomedical & Health Sciences also had negative opinions on articles they replied to more frequently compared to researchers in Physical Sciences & Engineering ($p = 0.03$).

Overall, researchers in Biomedical & Health Sciences and Social Sciences tended to have a critical opinion on the articles they communicated on Twitter more frequently, while in Life &

Earth Sciences and Physical Sciences & Engineering related fields, researchers tended to have a positive opinion on the articles they communicated more frequently.

5.3.2 Clusters of Researchers

After dimension reduction using the t-SNE technique, the researchers who participated in the survey were clustered using the k-means method with respect to each of the four acts. In this section, the clusters of researchers who use Twitter to tweet, retweet, reply to, and like scholarly articles in different patterns are identified and visualized. Figure 5.16, Figure 5.18, Figure 5.20, and Figure 5.22 are the two-dimensional representation of the data after dimension reduction. They demonstrate clear partitioning by behaviors; however, they do not have meaningful axes. For meaningful interpretation, they should be examined in conjunction with the attributes of researchers in different clusters displayed in the following tables (Table 5.19, Table 5.21, Table 5.23, and Table 5.25). Given the ordinal nature of the data collected from the survey questions, the median and mode of the data were used as measures of central tendency.

In Figure 5.17, Figure 5.19, Figure 5.21, and Figure 5.23, three-dimensional radar maps are used to better visualize the overall tendency of the sentiment of the clusters, with the negative sentiment on the left side, positive sentiment on the right side, and neutral sentiment in the middle. In these figures, mode was used to represent a group. Specifically, 5 indicates “Always,” 4 indicate “Most of the time,” 3 indicates “Sometimes,” 2 indicates “Rarely,” and 1 indicates “Never.”

5.3.2.1 Tweeting

Table 5.18 Sentiment of Opinions on Articles in Tweeting

	Always	Most of the time	Sometimes	Rarely	Never	Total
Positive	357	739	120	8	9	1233
Neutral	6	54	518	330	325	1233
Negative	0	11	198	518	506	1233

Overall, when tweeting scholarly articles, researchers tended to have a positive opinion on the articles. Except for 11 researchers who had a negative opinion on the articles they tweeted in most of the cases, the act of tweeting indicated a positive to neutral opinion on the researchers towards the articles.

Breaking down by clusters, it can be seen that overall, the sentiment of opinions associated with the tweeted articles leaned towards the positive side. This trend is also visualized in Figure 5.17, in which the left side is the negative side while the right side is the positive side.

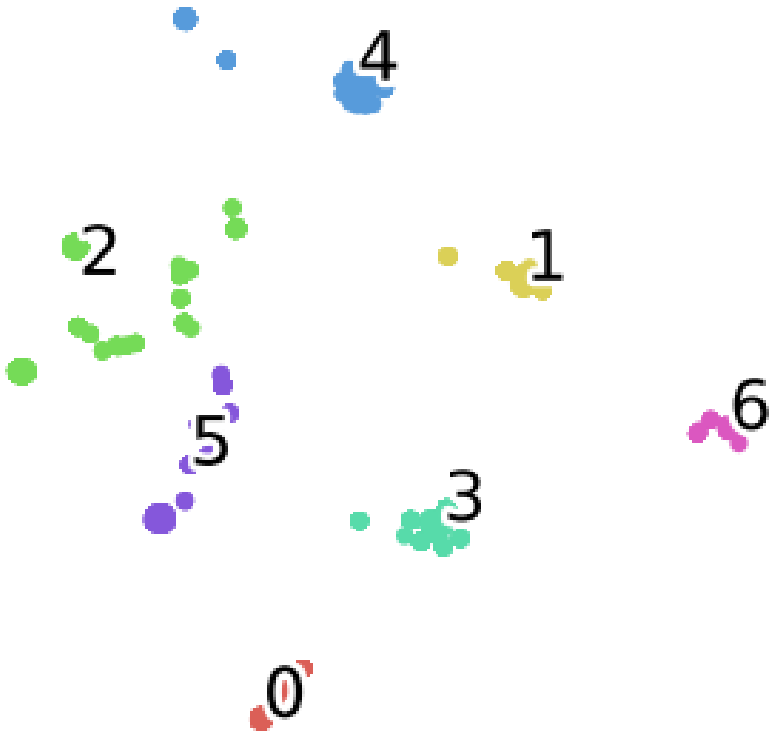

Figure 5.16 t-SNE Clustering Results (Tweeting)

Table 5.19 Descriptive Statistics of t-SNE Clustering Results (Tweeting)

	n	%	Positive		Neutral		Negative	
			mdn	mode	mdn	mode	mdn	mode
Cluster 0	81	6.6	5	5	3	3	1	1
Custer 1	205	16.6	5	5	1	1	1	1
Cluster 2	269	21.8	4	4	2	2	1	1
Cluster 3	253	20.5	4	4	3	3	2	2
Cluster 4	181	14.7	4	4	2	2	2	2
Cluster 5	175	14.2	3	3	3	3	1	1
Cluster 6	69	5.6	4	4	3	3	3	3

Note: 5 indicates "Always," 4 indicate "Most of the time," 3 indicates "Sometimes," 2 indicates "Rarely," and 1 indicates "Never."

Cluster 2 was the largest cluster among all. Researchers in Cluster 2 (n = 269, % = 21.8) had a positive opinion on the article they tweeted in most of the cases, and they additionally occasionally tweeted articles on which they had neutral opinions. However, they never tweeted articles on which they had negative opinions. A similar pattern was found in Cluster 0 (n = 81, % = 6.6). The difference was that in Cluster 0, researchers had a positive opinion on all ("Always") instead of most of the articles they tweeted, and they additionally sometimes had a neutral opinion on the articles they tweeted. They never had a negative opinion on an article they tweeted, which was the same case as those in Cluster 2. The overuse of "Always" will be further discussed in the Discussions section.

In Cluster 3 (n = 253, % = 20.5), Cluster 4 (n = 181, % = 14.7), and Cluster 6 (n = 69, % = 5.6), researchers displayed similar sentiment involved with the articles they tweeted as in the two clusters described above. They mainly tweeted when they felt positive, and sometimes or occasionally when neutral. The difference was that instead of never tweeting an article for which

they felt negative, researchers in Cluster 3 and Cluster 4 would occasionally tweet them; those in Cluster 6 would sometimes tweet them.

Different from researchers in the clusters described above, those in Cluster 1 (n = 205, % = 16.6) only shared articles on which they had a positive opinion on Twitter. If they had a neutral or negative opinion on the article, they tended to not tweet it at all.

A typical researcher in Cluster 5 (n = 175, % = 14.2) sometimes had a positive opinion on the articles they tweet, sometimes had a neutral opinion on them. Different from those in previous clusters, researchers in this cluster did not have an obvious tendency towards the positive side compared to the neutral side. However, they never tweeted articles on which they had negative opinions.

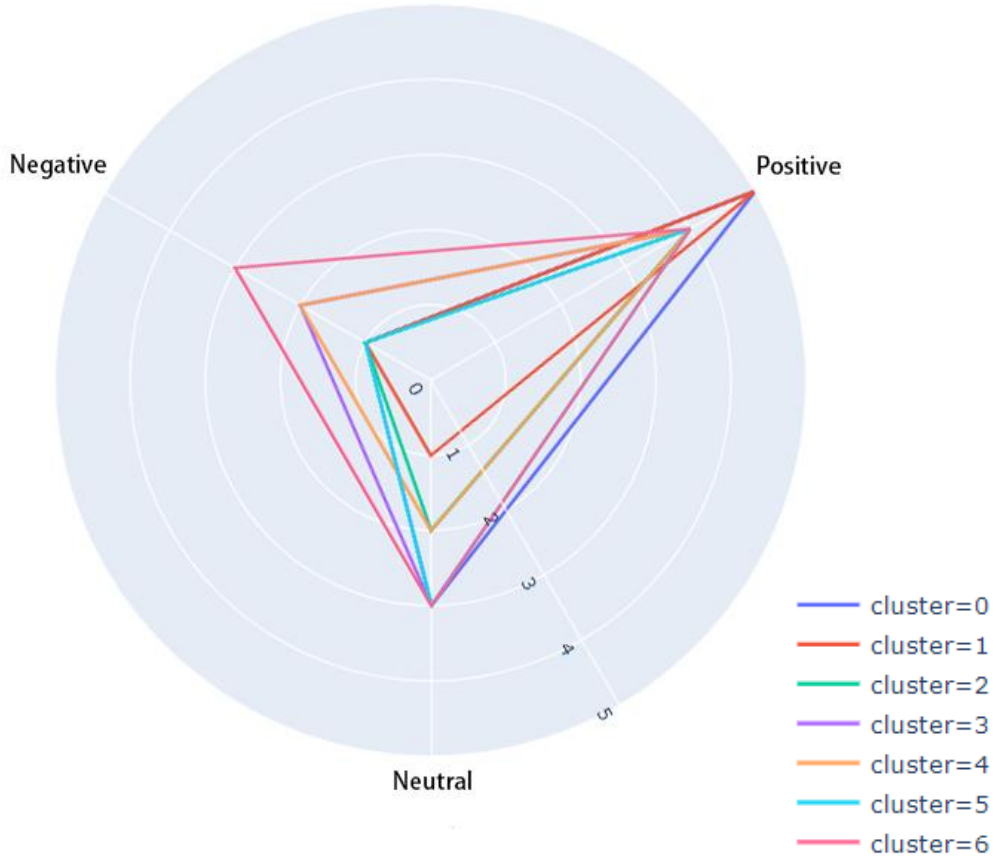

Figure 5.17 t-SNE Clusters Radar Chart (Tweeting)

To sum up, besides the overall tendency towards the positive side, in some clusters, there was a difference between neutral and negative opinions. Particularly, the frequencies of neutral opinions were higher than those of the negative ones (e.g., Cluster 0, Cluster 2, and Cluster 3). While in others, neutral and negative opinions occurred on a similar frequency (e.g., Cluster 1, Cluster 4, and Cluster 6).

In cluster 5, researchers never tweeted articles on which they had a negative opinion. Meanwhile, the frequencies of positive and neutral opinions were similar – the sentiment of their opinions on the articles they tweeted was sometimes positive and sometimes neutral.

5.3.2.2 Retweeting

A similar overall positive tendency was observed in the opinions associated with retweeted scholarly articles. Overall, when retweeting scholarly articles, researchers tended to have a positive opinion on the articles except for 12 researchers who had a negative opinion on the articles they tweeted in most of the cases. Descriptions of the clusters are provided below.

Table 5.20 Sentiment of Opinions on Articles in Retweeting

	Always	Most of the time	Sometimes	Rarely	Never	Total
Positive	309	745	145	20	14	1233
Neutral	8	59	479	375	312	1233
Negative	0	12	199	495	527	1233

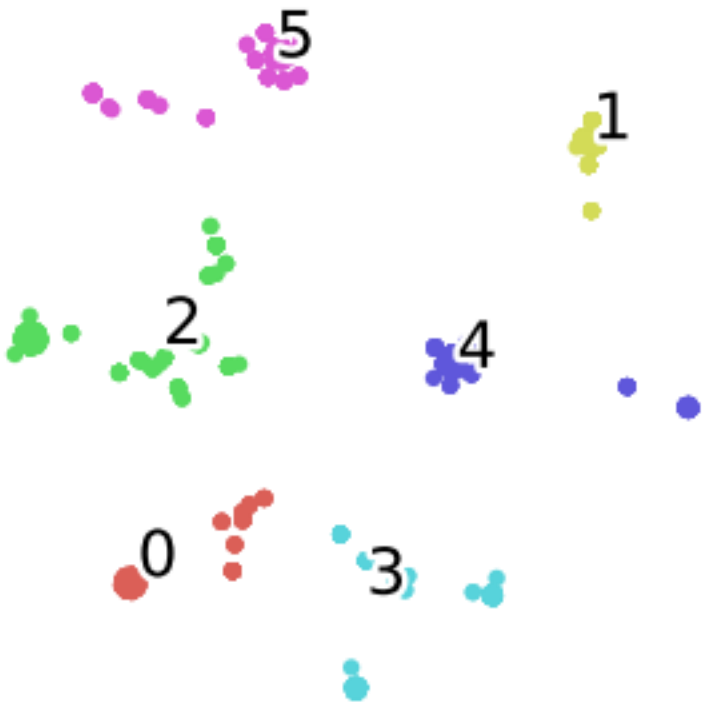

Figure 5.18 t-SNE Clustering Results (Retweeting)

Table 5.21 Descriptive Statistics of t-SNE Clustering Results (Retweeting)

	n	%	Positive		Neutral		Negative	
			mdn	mode	mdn	mode	mdn	mode
Cluster 0	148	12.0	4	4	2	2	1	1
Custer 1	179	14.5	5	5	1	1	1	1
Cluster 2	258	20.9	4	4	3	3	1	1
Cluster 3	163	13.2	4	4	1	1	3	3
Cluster 4	197	16.0	4	4	2	2	2	2
Cluster 5	288	23.4	4	4	3	3	2	2

Note: 5 indicates “Always,” 4 indicate “Most of the time,” 3 indicates “Sometimes,” 2 indicates “Rarely,” and 1 indicates “Never.”

In Cluster 1 (n = 179, % = 14.5), researchers tended to be the most positive in terms of their sentiment of opinions on the articles they retweeted on Twitter. They always had a positive

opinion on them. Never would they retweet an article if their opinion on it was neutral or negative.

Similarly, researchers in Cluster 0 (n = 148, % = 12.0) and Cluster 2 (n = 258, % = 20.9) never retweeted an article if they had a negative opinion on it. Different from researchers in Cluster 1, in these two clusters, researchers would sometimes or occasionally retweet an article if their opinion on the article was neutral.

Cluster 4 (n = 197, % = 16.0) and Cluster 5 (n = 288, % = 23.4) contained researchers who would most of the time have a positive opinion on the articles they retweeted, and they would additionally sometimes or occasionally have a neutral opinion on the articles. However, different from those in the three clusters described above who would never retweet an article on which they had a negative opinion, these researchers would occasionally have a neutral or negative opinion on the articles they retweeted.

A typical researcher in Cluster 3 (n = 163, % = 13.2) never retweeted an article if they had a neutral opinion on it. They would only retweet an article if they had either a positive or negative opinion on it. Specifically, when a typical researcher in this cluster retweeted an article, they had a positive opinion on it in most of the cases and a negative opinion on it in some cases.

In summary, these six clusters created according to researchers' opinions on the articles they retweeted revealed similar but slightly different patterns compared to those based on tweeting. What was similar was that in most cases, the majority of researchers would retweet articles for which they felt positive. There were slight gradations of difference between clusters in terms of neutral and negative opinions.

Nevertheless, different from the patterns of opinions observed in tweeting, researchers in one cluster (Cluster 3) would never retweet an article if they had a neutral opinion on it. They

tended to only retweet an article if they have either positive or negative opinions on it. What was also different was the absence of a cluster containing researchers whose main opinions on their retweeted article were equally shared by both the positive and neutral categories instead of being dominated by the positive category.

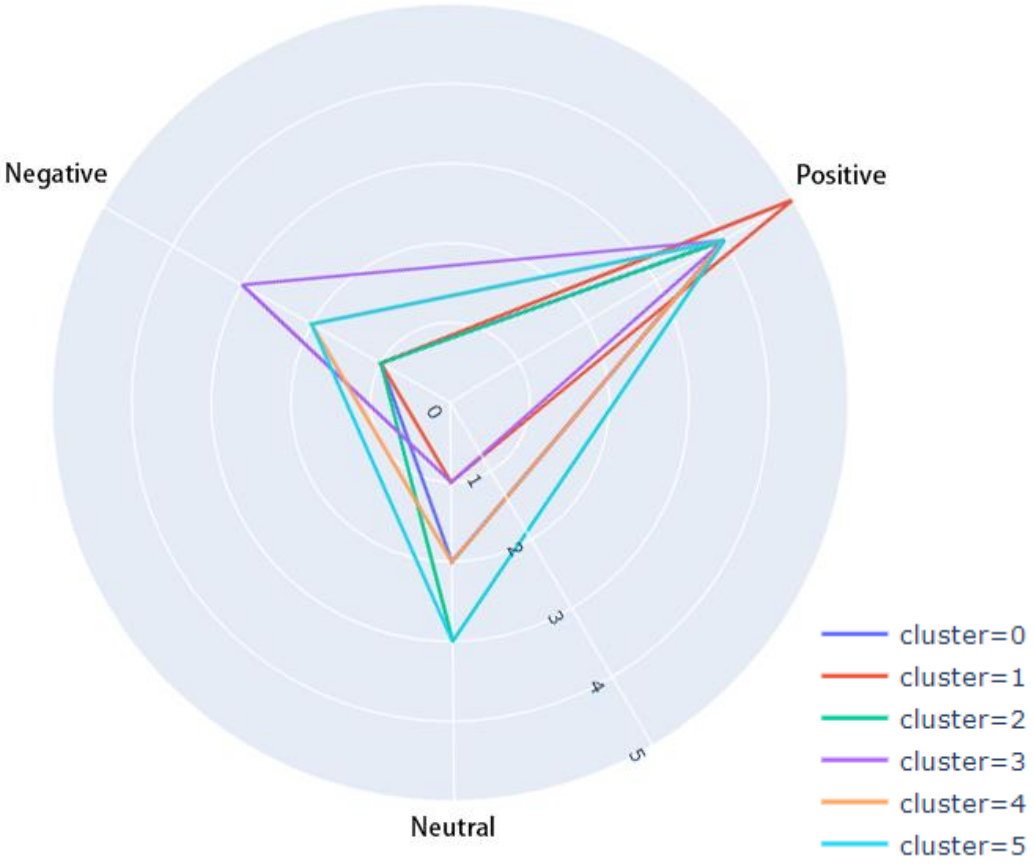

Figure 5.19 t-SNE Clusters Radar Chart (Retweeting)

5.3.2.3 Replying

Based on the researchers' opinions on the articles contained in the tweets they replied to, researchers were clustered using the same techniques. When replying to tweets that contained

scholarly articles, relatively more (32) researchers mainly had a negative opinion on the articles compared to tweeting and retweeting. Nevertheless, the percentage (2.6%) was still relatively low compared to the positive category (67.5%). Descriptions of the clusters are provided below.

Table 5.22 Sentiment of Opinions on Articles in Replying

	Always	Most of the time	Sometimes	Rarely	Never	Total
Positive	186	646	316	49	36	1233
Neutral	4	56	475	377	321	1233
Negative	2	30	403	428	370	1233

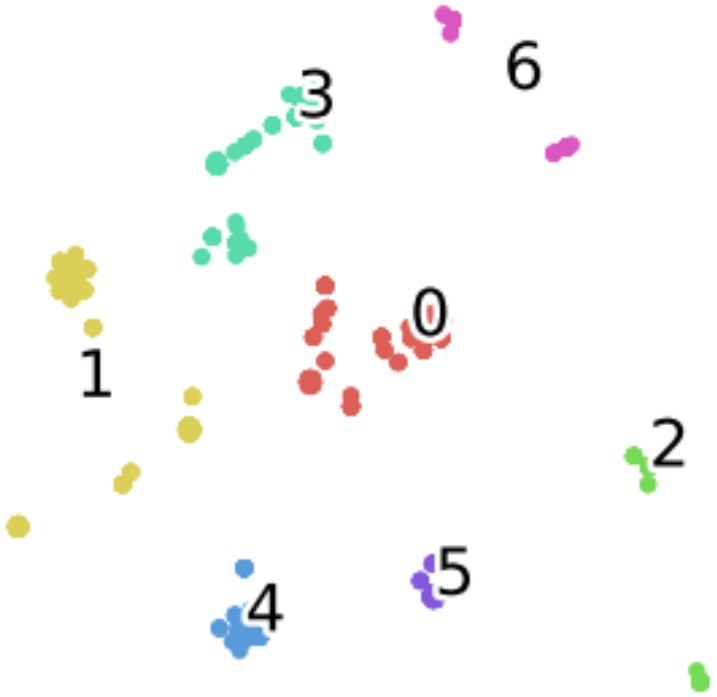

Figure 5.20 t-SNE Clustering Results (Replying)

Table 5.23 Descriptive Statistics of t-SNE Clustering Results (Replying)

	n	%	Positive		Neutral		Negative	
			mdn	mode	mdn	mode	mdn	mode
Cluster 0	289	23.4	4	4	3	3	2	2
Custer 1	288	23.4	4	4	2	2	2	2
Cluster 2	92	7.5	4	4	2	2	3	3
Cluster 3	273	22.1	3	3	3	3	3	3
Cluster 4	140	11.4	5	5	1	1	1	1
Cluster 5	77	6.2	4	4	3	3	3	3
Cluster 6	74	6.0	2	3	1	1	2	1

Note: 5 indicates “Always,” 4 indicate “Most of the time,” 3 indicates “Sometimes,” 2 indicates “Rarely,” and 1 indicates “Never.”

Cluster 4 (n = 140, % = 11.4) and Cluster 6 (n = 74, % = 6.0) were the only two clusters in which the majority of researchers never had a negative opinion on the articles they replied to. However, these two clusters differed in the occurrences of positive opinions. In Cluster 4, the researchers always had a positive opinion on the articles they replied to, while those in Cluster 6 only sometimes (according to the mode) or occasionally (according to the median) had a positive opinion on these articles. The overuse of “Rarely” in the case of replies will be discussed further in the Discussions section.

In Clusters 0, 1, 2, and 5, researchers replied to articles on which they had a positive opinion most of the time, and additionally, they sometimes or occasionally had a neutral opinion on the articles. However, the frequency of the occurrences of a negative opinion differed. In Clusters 0 (n = 289, % = 23.4) and Cluster 1 (n = 288, % = 23.4), which were the two largest clusters among all, researchers only occasionally had a negative opinion on the articles they replied to, while for those in Clusters 2 (n = 92, % = 7.5) and Cluster 5 (n = 77, % = 6.2), the frequency of having a negative opinion was slightly higher (“Sometimes”).

When researchers in Cluster 3 (n = 273, % = 22.1) were replying to a tweet containing a scholarly article, they sometimes had a positive opinion, sometimes had a neutral opinion, and sometimes had a negative opinion on the article.

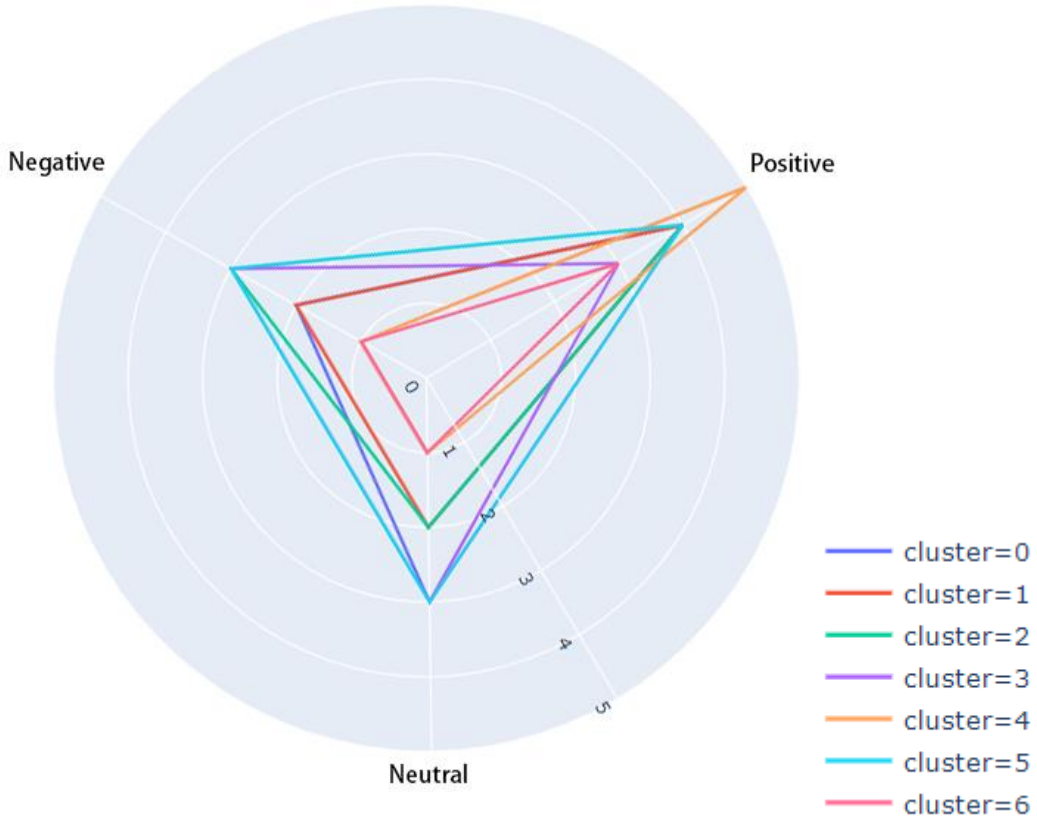

Figure 5.21 t-SNE Clusters Radar Chart (Replying)

To sum up, in addition to the overall positive tendency observed, a new pattern emerged in regards to the sentiment of researchers' opinions on the articles contained in tweets which they would reply to. Specifically, in one cluster (Cluster 3), the opinions of the researchers were equally shared among all the three sentiment categories. In addition, in both Clusters 2 and 6,

researchers never had a neutral opinion on the articles they replied to. In other words, they would not reply to a tweet containing a scholarly article if they had a neutral opinion on the article.

5.3.2.4 Liking

Lastly, researchers were clustered based on their opinions on the articles contained in tweets they liked. Compared to tweeting, retweeting, and replying, the highest percentage of researchers (84.8%) were found to have a positive opinion on the articles they liked on Twitter. More descriptions of the clusters are provided below.

Table 5.24 Sentiment of Opinions on Articles in Liking

	Always	Most of the time	Sometimes	Rarely	Never	Total
Positive	434	611	137	21	30	1233
Neutral	8	62	399	347	417	1233
Negative	2	11	168	378	674	1233

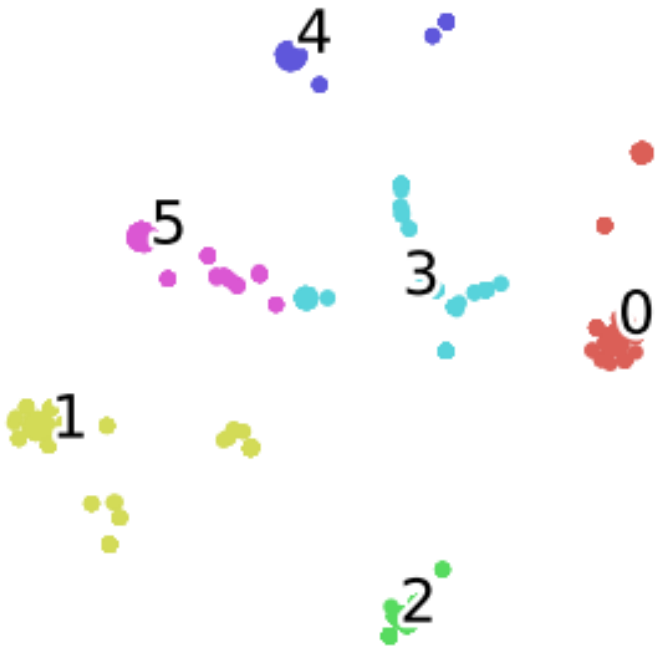

Figure 5.22 t-SNE Clustering Results (Liking)

Table 5.25 Descriptive Statistics of t-SNE Clustering Results (Liking)

	n	%	Positive		Neutral		Negative	
			mdn	mode	mdn	mode	mdn	mode
Cluster 0	204	16.5	4	4	2	2	2	2
Custer 1	261	21.2	4	4	3	3	2	2
Cluster 2	301	24.4	5	5	1	1	1	1
Cluster 3	192	15.6	3	3	2	1	3	3
Cluster 4	128	10.4	4	4	2	2	1	1
Cluster 5	147	11.9	4	4	3	3	1	1

Note: 5 indicates "Always," 4 indicate "Most of the time," 3 indicates "Sometimes," 2 indicates "Rarely," and 1 indicates "Never."

The largest cluster, Cluster 2 (n = 301, % = 24.4), contained researchers who always had a positive opinion on the articles contained in tweets that they liked on Twitter. They never had a neutral or negative opinion on the articles they liked.

Similarly, researchers in Cluster 4 (n = 128, % = 10.4) and Cluster 5 (n = 147, % = 11.9) also never had a negative opinion on the articles they liked. Different from researchers in Cluster 2, however, researchers in these two clusters sometimes or occasionally had a neutral opinion on the articles they liked.

When a typical researcher in Cluster 0 (n = 204, % = 16.5) or Cluster 1 (n = 261, % = 21.2) liked a tweet containing a scholarly article, they had a positive opinion on this article in most of the cases, and additionally they rarely had a negative opinion on the article. They sometimes or occasionally felt neutral about the article included in the tweets they liked.

In Cluster 3 (n = 192, % = 15.6), researchers sometimes had a positive but sometimes had a negative opinion on the article contained in a tweet they liked. They rarely (according to the median) or never (according to the mode) had a neutral opinion on the article. This pattern similar to Cluster 6 in the replying clusters will be further discussed in both Section 5.3.3 and the Discussions section.

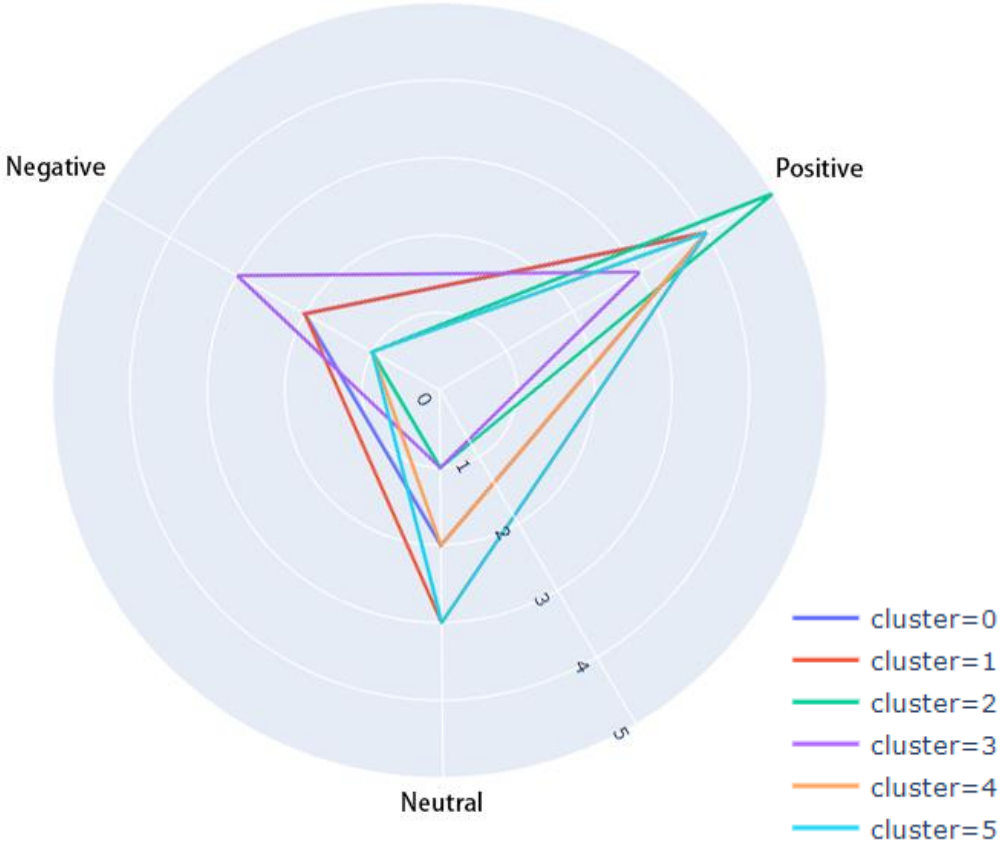

Figure 5.23 t-SNE Clusters Radar Chart (Liking)

To sum up, in five out of six clusters, researchers would rarely or never like a tweet if they had a negative opinion on the article. However, in one cluster (Cluster 3), researchers would still sometimes like a tweet even if they had a negative opinion on the article in the tweet. In other words, despite the seemingly positive meaning of the word "like" (compared to the relatively neutral meaning of the other acts), not all researchers had overwhelmingly positive opinions on the articles contained in the tweets they had liked.

5.3.3 Stories behind Twitter Acts and Sentiment of Opinions on Articles

In the survey, participants provided their frequencies of having a positive/neutral/negative opinion on the articles they tweeted, retweeted, replied to, and liked. For each interview participant, I followed up on their reasons for the different sentiment of opinions associated with the articles. The major theme that emerged from their discussions was their perception of the different acts.

The exact prevalence of codes and categories was not reported in this section due to the qualitative nature of this part of the study. The sample of researchers interviewed was not necessarily representative of all researchers who used Twitter. As a result, this study intended to avoid making inferences that might appear to be generalizable claims. However, in order to provide a sense of how common a behavior or thought was from the data, consistent conventions of "a few" (0-4; 0-20%), "some" (5-9; 25%-45%), "many"(10-14; 50%-70%), "almost all" (15-19; 75%-95%), and "all" (20; 100%) were used, as was suggested in previous research (Braun & Clark, 2006; Chen, 2018).

5.3.3.1 Tweeting

For almost all participants, tweeting a scholarly article normally originated from reading articles from the "table of content" subscriptions of journals in emails. A few participants mentioned tweeting articles recommended by colleagues via email or in person. A few researchers mentioned tweeting while searching for literature for research projects. A few researchers would tweet articles mentioned in conference presentations for the audience who were not able to attend the conferences. Last but not least, a few researchers mentioned tweeting articles in only remotely relevant fields or out of personal interests while reading as leisure. These articles were mostly from popular science magazines.

All of the researchers I interviewed had a positive or neutral opinion on the vast majority of the articles they tweeted. In other words, in most of the cases, all of these researchers would tweet articles they have a positive or neutral opinion on. Some researchers deliberately refrained from expressing critical opinions on scholarly articles on Twitter. For instance, P20 commented, "I didn't want to stick my neck out on Twitter because I don't have time to deal with potential conflicts that might cause."

Researchers I interviewed had mixed opinions regarding whether tweeting equaled to endorsement. On the one hand, some researchers tried to maintain the responsible use of social media all the time. They believed that their audience, among which a lot were "early-career researchers, students, practitioners, and the lay audience" (P13), would trust researchers on Twitter regarding their opinions on science. They believed being responsible for their tweets were part of the responsibility of being a researcher. For instance,

> P8: "In all cases, tweeting an article does signify that I'm supporting the article. If I wanted to convey that I don't agree with it, I'd definitely add something to the tweet, like 'I don't agree with this article, for the following reasons…'".
>
> P9: "What I have a problem with is retweeting without reading the article. I look at my metrics sometimes. When you tweeted something, you can look at how many people have retweeted you, and how many people have clicked on the links, how many people have enlarged the image, etc. And I'm also stunned when the number of retweets is greater than the number of people that have clicked on the link. I think misinformation can get perpetuated that way. So sometimes when I retweeted with a comment, it may be a plea to actually read the article or an additional perspective that somebody who tweeted the article may not have added."

On the other hand, some researchers disagreed. They tweeted articles more for the purpose of disseminating information to the potentially relevant audience. For instance,

> P5: "I'm more like not saying anything. I would say "Good article!" if it is a REALLY good article. In other cases, I was just getting it out there, wanting more people to be able to see it in case they were interested."

Relevant to endorsing, researchers also had different opinions on tweeting for promotional purposes. Although many researchers believed that tweeting to promote a researcher reflected their positive opinion on that article and researcher, a few of them believed that tweeting a researchers' work for promoting purposes was more of neutral sentiment. The latter type hoped to disseminate the work rather than recommend the works by tweeting them. One researcher (P12) liked to promote early-career researchers. In some cases, he would promote researchers whose work he knew well. In some cases, he would promote the works of researchers who came from the same country, without fulling knowing their works. In this specific case, this was because he believed that researchers in his country were underrepresented in the world, and their research needed to be seen by researchers from other parts of the world. P5 commented that he would be "slightly positive, but not enthusiastic" when he tweeted to promote his colleagues' works just because they worked in the same institution with him, which he described as "for institutional reasons." P15 used "positive to neutral" to describe her sentiment regarding promoting because she could not decide if it was mostly positive or neutral.

5.3.3.2 Retweeting

Different from tweeting, retweeting originated from content on Twitter. Some researchers would directly retweet from their Twitter feed. Some researchers mentioned retweeting from their Twitter alerts. These alerts were mostly tweets that many accounts they followed had

retweeted or liked. A few researchers mentioned using hashtags to find tweets to retweet during academic conferences.

Similar to tweeting, all researchers had a positive or neutral opinion on most of the articles they retweeted. Compared to tweeting, more researchers had a neutral opinion on the articles they retweeted. Some participants reported not reading the articles before retweeting compared to tweeting. A few participants insisted on reading all the articles before retweeting them. They would retweet an article with their comments when they believed an additional perspective was needed. P11, particularly, commented that different from tweeting, she would feel more comfortable to express her critical opinions if someone else had started a critical discussion.

> P11: "Usually, I don't want to try to be the first one to post an article I don't like, but if it is part of a discussion, I'd be more like, more willing to express my opinions."

The researchers who did not always read the article before retweeting all noted that their retweets did not indicate endorsement of the articles. They had less of a feeling of responsibility towards the content they retweeted. However, a few researchers believed that retweeting should also equal to endorsement.

Instead of taking their judgment of the articles as a criterion in deciding to retweet an article, many participants talked about the importance of the tweeters of the article. If the person who tweeted this article was someone who they "trusted" (P7, P10, P16, P17), or someone who "did good work/research" (P2, P3, P9, P13), or someone who was "well respected in the field" (P4), or their "hero" (P1), they tended to trust the tweeters' opinion on the articles.

This discussion prompted some researchers to discuss and highlight the fuzzy criterion when it came to the decision making of retweeting. A few researchers noted that sometimes they

probably had less of a consistent criterion in deciding to retweet scholarly articles compared to tweeting scholarly articles.

> P1: "When tweeting, I feel like I'm vouching for the article in some way, but when retweeting, I feel like I'm just passing it on. I don't feel the responsibility. So in many cases, when I'm retweeting, I would you know, just do it."
>
> P10: "When I'm tweeting, I usually have read at least some sections of the article in depth, but when retweeting, I think I only skim the abstract of the article in about 75% of the cases."

Compared to tweeting, relatively more researchers reported retweeting for promotional purposes. Similarly, it included promoting the scholarly works, researchers, institutes, journals, research projects, and research fields. Some researchers interviewed mentioned promoting underrepresented researchers. This included cases where the tweeting researchers themselves were a member of the same underrepresented groups and cases where they were not. Women in science early career researchers were the most mentioned in these cases. For instance, P15, a Professor, commented that even if she didn't have a strong positive opinion on the paper from an early-career researcher, she would retweet it to "help them get some exposure."

5.3.3.3 Replying

A few researchers considered replying as a stronger "liking," which was always associated with positive sentiment in the comment text but not necessarily a positive opinion on the articles included. Three major scenarios were identified. The first scenario was the participants saying congratulations, expressing a compliment, or providing encouragement to researchers who tweeted their own works. In many cases of this scenario, they had not read the article before replying and did not have an opinion on the article. However, they had a positive

opinion on the authors. The second scenario was the participants expressing gratitude to researchers who tweeted articles that they found useful. In this scenario, the participants usually had a positive opinion on the articles. The third scenario was the participants expressing gratitude to researchers who tweeted the participants' own works.

However, replying to a tweet containing a scholarly article was the most associated with a potentially negative or critical opinion among all four acts. A few researchers reported criticizing the articles in their replies. A few researchers talked about initiating a discussion about the article by asking a critical question regarding the article.

> P9: "I just can't help myself when things are off. Sometimes when people are all gung-ho about a certain, you know, new lab test for a certain new drug, but if you actually read the article and look at the statistics it may not look that good or maybe it only applies to a very small population… I realize that all through med school I wasn't trained to read studies critically and so I would sort of take it like you know, you read the abstract and you read the conclusions and yet you know a little bit about things, and you can put it together but I realize I was misled so often by that because the study design would actually be really bad or the population is so limited, so I just can't help myself when somebody tweets out an article and thinks maybe it's practice-changing or uses it to support something that really it shouldn't be used to support."

Some participants compared replying to retweeting. They noted the importance of their awareness of the audience when deciding to retweet or to reply. According to these researchers, they would usually retweet an article only if they think it was worth disseminating to the majority of their audience. Or, they would reply instead of retweet. If they wanted to inform

specific user or users, they would mention the user(s) in their replies without retweeting the tweet.

> P15: "My research area is an extremely interdisciplinary one. So I have a few different groups of followers. I have practitioners in my followers. I also have industry partners. They wouldn't be interested in the same kind of content. So in a lot of cases, I would be careful what to pull to my Twitter timeline, which might be noises in some of my followers' Twitter feed."

> P1: "I might at (mention) people in the replies if I think they might be interested in the article, but I wouldn't retweet the article on my Twitter feed."

> P9: "When I'm replying to correct something, and if I wanted to amply my point, I would retweet it instead of replying to this specific person only."

A few researchers commented that usually, they would not reply to a tweet containing a scholarly article unless they were mentioned in the tweet.

5.3.3.4 Liking

For many researchers, liking a tweet containing a scholarly article was the most common activity among the four acts. They tended to like others' tweets on the most frequent basis.

> P11: "I'm very generous with my likes. Partly because it is so easy to do. It costs nothing to make people feel better. Why not do that? My likes are not endorsement of good science; My likes are more like, 'Woo-hoo'!"

> P16: "I rarely use my phone to write when I'm using Twitter. I rarely use my phone to write in general. When I'm tweeting or replying to others, I usually use my computer. However, I browse Twitter on my phone or my iPad a lot. It is very convenient to like

others' tweets while browsing on the phone because you only needed to click on one button."

There were different opinions regarding whether the act of liking reflected their positive opinion on the articles. Different motivations of liking a tweet containing a scholarly article were reported. The three scenarios discussed in Section 5.3.3.3 were all mentioned in the act of liking. In addition to these scenarios, a few researchers mentioned liking the articles just to acknowledge that they were aware of them, as a means to "interact without actually commenting" (P4). P17 commented that liking to her sometimes meant "I acknowledge your point, even if I don't agree."

In addition, liking, in particular, was also used by some researchers to curate articles – in their words, "bookmark" articles (P2, P5, P6, P10, P13, P15, P20). In most of the cases when they did this, they found the articles relevant and might be of potential use to themselves in the future. When they liked a tweet containing a scholarly article, they saved it on their list of likes. A few researchers commented that they would use the like mechanism to curate articles that were relatively peripheral to their own research; one participant used "different or bizarre" (P10) to describe his bookmarked research.

The use of the liked content differed among these researchers. P5, for instance, never reviewed this list in the past eight years of using Twitter, although he knew that there was "good content" in the list. Differently, P20, a Humanities researcher, would read the articles she liked on approximately a biweekly basis on a "reading day" (which she defined as to be saved completely for reading) to review what was in the articles that she had bookmarked in the past two weeks. P6 bookmarked articles with the expectation that he would review the articles on a regular basis, but was not able to do that anymore after a few months. However, he provided an

example when he successfully found an article from the list when he was working on a research project and remembered that one article he had bookmarked previously was relevant.

A few researchers were relatively more conservative in terms of liking. P7, in particular, believed that her liking was equal to endorsement.

Different from one cluster of researchers (Cluster 3 in "Liking") found in the survey, no researcher in this sample of interview participants would like a tweet if they had a negative opinion on the articles in it.

5.4 Scholarly Acts, Tweeting, and Retweeting

Similar to Section 5.3, this section also focuses on researchers' Twitter acts that are associated with scholarly articles instead of their general use of Twitter for professional purposes.

In the survey, researchers were asked about how sharing research on Twitter fit in their scholarly acts workflow. Section 5.4.1-5.4.2 presents the analyses of the survey results based on age, gender, continent, education, position, and discipline.

Section 5.4.3 presents the findings regarding the relationships among these acts, including the correlations and comparisons results.

Considering the limitations of collecting data on people's general behavior, or their perception of their general behavior (see more in the Discussions section), 200 specific instances of tweets and retweets of interview participants were provided to help them better recall their actions before and after they tweeted or retweeted these specific articles. The contextual information associated with these recalled Critical Incidents are reported in Section 5.4.4.

5.4.1 Scholarly Acts and Tweeting

Table 5.26 presents the number of respondents who would: 1) skim the article to gain a very basic idea of it; 2) read the article in depth (examining at least some sections/figures/tables in the article very carefully); 3) look at online discussions of the article; 4) search for information about the author(s) of the article; 5) save the article to their computer or reference manager tools; 6) organize the article (such as renaming the article file or categorizing it into a folder); and 7) cite the article (in their working research papers or teaching materials) before tweeting a scholarly article.

Table 5.26 Acts Before Tweeting a Scholarly Article

	In all cases	In most of the cases	In half of the cases	In rare cases	Never
Skim article	535	418	154	94	32
Read article in depth	92	342	430	330	39
Look at online discussions of article	6	134	243	561	289
Search for information about authors of article	19	131	264	573	246
Save article	113	316	365	321	118
Organize article	72	168	227	367	399
Cite article	6	46	292	670	219

Table 5.27 Acts After Tweeting a Scholarly Article

	In all cases	In most of the cases	In half of the cases	In rare cases	Never
Skim article	150	176	174	401	332
Read article in depth	53	221	411	393	155
Look at online discussions of article	21	155	265	517	275
Search for information about authors of article	12	96	257	618	250
Save article	63	174	301	475	220
Organize article	46	122	207	482	376
Cite article	14	74	371	663	111

Table 5.27 presents the number of respondents who would conduct these acts after tweeting a scholarly article.

5.4.1.1 Scholarly Acts and Tweeting by Age

Table 5.28 Kruskal-Wallis Test Results of Acts Before and After Tweeting by Age

	Act	H	P
Before Tweeting	Skim article	1.46	0.92
	Read article in depth	1.93	0.86
	Look at online discussions of article	3.01	0.70
	Search for information about authors of article	9.27	0.10
	Save article	6.38	0.27
	Organize article	7.59	0.18
	Cite article	10.23	0.07
After Tweeting	Skim article	16.45	0.01**
	Read article in depth	8.84	0.12
	Look at online discussions of article	6.36	0.27
	Search for information about authors of article	11.09	0.05**
	Save article	6.76	0.24
	Organize article	6.31	0.28
	Cite article	10.84	0.05**

Researchers in different age groups differed in three acts after tweeting the articles, including skimming the articles, searching for information about the authors of articles, and citing the articles.

Specifically, researchers in the age group of 20-29 years old and 30-39 years old both skimmed the article after retweeting in statistically more cases compared to researchers in the age group of 50-59 years old ($p = 0.01$, $p = 0.00$, respectively) and 60-69 years old ($p = 0.02$, $p = 0.03$, respectively).

Meanwhile, after tweeting the scholarly articles, researchers who were 30-39 years old searched for information about the authors of the articles in more cases compared to researchers in the age groups of 40-49 years old ($p = 0.00$) and 50-59 years old ($p = 0.00$).

Lastly, researchers who were 30-39 years old tended to cite the articles after tweeting in more cases compared with researchers who were 40-49 years old ($p = 0.04$), 60-69 years old ($p = 0.04$), and 70 years or older ($p = 0.02$).

5.4.1.2 Scholarly Acts and Tweeting by Gender

Table 5.29 Kruskal-Wallis Test Results of Acts Before and After Tweeting by Gender

	Act	H	P
Before Tweeting	Skim article	7.66	0.01**
	Read article in depth	3.24	0.07
	Look at online discussions of article	0.60	0.44
	Search for information about authors of article	1.19	0.27
	Save article	3.69	0.05**
	Organize article	2.23	0.14
	Cite article	2.97	0.09
After Tweeting	Skim article	3.86	0.05**
	Read article in depth	0.52	0.47
	Look at online discussions of article	0.00	0.96
	Search for information about authors of article	0.00	0.98
	Save article	0.57	0.45
	Organize article	0.54	0.46
	Cite article	1.50	0.22

Before tweeting an article, female researchers tended to skim the article in more cases compared to male researchers ($p = 0.01$). They also saved the articles in more cases compared to male researchers ($p = 0.05$). However, there were more male researchers than female researchers who skimmed the articles after tweeting it ($p = 0.05$).

5.4.1.3 Scholarly Acts and Tweeting by Continent

Statistically significant differences were found among researchers from different continents in terms of looking at online discussions of an article both before and after tweeting it. Meanwhile, there were also differences in the frequency of citing an article after tweeting it.

Before tweeting an article, compared to researchers in North America, researchers in Europe ($p = 0.00$), and South America ($p = 0.03$) looked at the online discussions of the article in

more cases before they tweeted them. Meanwhile, after tweeting, researchers in South America looked at the online discussions of articles in more cases compared to researchers in Africa ($p = 0.02$), Asian ($p = 0.03$), North America ($p = 0.03$), and Oceania ($p = 0.03$).

In addition, researchers in Asia and South America tended to cite the articles after tweeting in more cases compared to researchers in Europe ($p = 0.02$, $p = 0.00$, respectively), North America ($p = 0.02$, $p = 0.00$, respectively), and Oceania ($p = 0.01$, $p = 0.00$, respectively).

Table 5.30 Kruskal-Wallis Test Results of Acts Before and After Tweeting by Continent

	Act	H	P
Before Tweeting	Skim article	2.93	0.71
	Read article in depth	1.04	0.96
	Look at online discussions of article	14.02	0.02**
	Search for information about authors of article	9.40	0.09
	Save article	3.57	0.61
	Organize article	3.74	0.59
	Cite article	10.17	0.07
After Tweeting	Skim article	4.09	0.54
	Read article in depth	2.18	0.82
	Look at online discussions of article	11.2	0.05**
	Search for information about authors of article	4.47	0.48
	Save article	6.00	0.31
	Organize article	6.00	0.31
	Cite article	19.65	0.00**

5.4.1.4 Scholarly Acts and Tweeting by Education

Among researchers with different educational backgrounds, differences mainly existed in looking at online discussions about the article and saving it, both before and after tweeting an article.

Before tweeting a scholarly article, researchers holding a doctoral degree looked at the online discussions of the article in fewer cases compared to researchers holding a professional degree ($p = 0.01$) or a master's degree ($p = 0.00$). Similarly, after tweeting a scholarly article,

researchers holding a doctoral degree looked at the online discussions of the article in fewer cases compared to researchers holding a professional degree ($p = 0.03$) or a master's degree ($p = 0.03$). This pattern was the same as before tweeting an article. It seemed that including before and after-tweeting, doctoral degree holders tended to look at online discussions of articles in fewer cases than professional degree holders or master degree holders.

Table 5.31 Kruskal-Wallis Test Results of Acts Before and After Tweeting by Education

	Act	H	P
Before Tweeting	Skim article	1.74	0.63
	Read article in depth	7.11	0.07
	Look at online discussions of article	19.39	0.00**
	Search for information about authors of article	5.71	0.13
	Save article	9.52	0.02**
	Organize article	1.30	0.73
	Cite article	0.42	0.94
After Tweeting	Skim article	7.10	0.07
	Read article in depth	3.58	0.31
	Look at online discussions of article	11.08	0.01**
	Search for information about authors of article	2.67	0.44
	Save article	8.31	0.04**
	Organize article	3.38	0.34
	Cite article	2.87	0.41

Before tweeting, there were more cases for researchers holding a doctoral degree to had saved the article compared to researchers holding a professional degree ($p = 0.02$). In addition, after tweeting, researchers holding a doctoral degree tended to save the article in more cases compared to researchers holding a master's degree ($p = 0.03$).

5.4.1.5 Scholarly Acts and Tweeting by Position

Researchers in different positions differed in whether they would cite an article before tweeting it. Besides this, they differed in all seven acts after tweeting, including skimming,

reading, looking at online discussions, searching about authors, saving and organizing, as well as citing the article.

Tenured researchers (p = 0.00) and lecturers (p = 0.01) tended to cite an article in their working research papers or teaching materials before tweeting in more cases compared to researchers in other sectors.

Table 5.32 Kruskal-Wallis Test Results of Acts Before and After Tweeting by Position

	Act	H	P
Before Tweeting	Skim article	2.86	0.58
	Read article in depth	4.27	0.37
	Look at online discussions of article	8.33	0.08
	Search for information about authors of article	5.38	0.25
	Save article	8.90	0.06
	Organize article	3.85	0.43
	Cite article	12.58	0.01**
After Tweeting	Skim article	12.06	0.02**
	Read article in depth	17.20	0.00**
	Look at online discussions of article	9.33	0.05**
	Search for information about authors of article	25.83	0.00**
	Save article	14.33	0.01**
	Organize article	13.06	0.01**
	Cite article	17.32	0.00**

After tweeting a scholarly article, early-career researchers tended to skim the article in statistically more cases compared to tenured researchers (p = 0.00), lecturers (p = 0.04), and other researchers (p = 0.01). In addition, both pre-tenured researchers and early-career researchers read the articles in depth in statistically more cases than tenured researchers (p = 0.01, p = 0.01, respectively) and other researchers (p = 0.00, p = 0.00, respectively). Meanwhile, early-career researchers looked at the online discussions of the articles after retweeting them in more cases than tenured researchers (p = 0.01).

After tweeting an article, pre-tenured researchers would, in more cases, search for information about the authors of it compared to tenured researchers ($p = 0.03$) and other researchers ($p = 0.01$). For early-career researchers, it was a similar case, except that they tended to search for information about the authors in more cases than not only tenured researchers ($p = 0.00$) and other researchers ($p = 0.00$) but also lecturers ($p = 0.03$).

Saving an article after tweeting was less of the case for other researchers compared to tenured researchers ($p = 0.05$), pre-tenure researchers ($p = 0.00$), lecturers ($p = 0.01$), as well as early-career researchers ($p = 0.00$). Meanwhile, it occurred less frequently in tenured researchers than pre-tenured researchers ($p = 0.05$). The pattern of organizing an article after tweeting it was similar to saving in that other researchers tended to do this in statistically fewer cases compared to tenured researchers ($p = 0.04$), pre-tenure researchers ($p = 0.00$), lecturers ($p = 0.03$), as well as early-career researchers ($p = 0.00$). What was also similar was that pre-tenure researchers did it more frequently than tenured researchers ($p = 0.04$).

Lastly, other researchers also tended to cite an article after tweeting it in statistically less cases compared to tenured researchers ($p = 0.00$), pre-tenure researchers ($p = 0.00$), lecturers ($p = 0.00$), as well as early-career researchers ($p = 0.01$).

5.4.1.6 Scholarly Acts and Tweeting by Discipline

Researchers in different disciplines had different patterns in multiple acts both before and after tweeting an article.

Before tweeting a scholarly article, researchers in Biomedical & Health Sciences tended to have read it in depth in statistically more cases than researchers in Social Sciences ($p = 0.00$) and Life & Earth Sciences ($p = 0.00$).

Researchers in Physical Sciences & Engineering in fewer cases would look at the online discussions of an article before tweeting it compared to researchers in Biomedical & Health Sciences ($p = 0.00$), Social Sciences ($p = 0.00$), Life & Earth Sciences ($p = 0.00$), as well as Humanities ($p = 0.05$). In addition, statistically significant differences between researchers in Biomedical & Health Sciences and Social Sciences were detected, with Biomedical & Health Sciences being the biggest discipline in reading online discussions of articles before tweeting them. Similarly, after tweeting, there were also more cases for researchers in Biomedical & Health Sciences to look at the online discussions of articles compared to researchers in Social Sciences ($p = 0.01$) and Physical Sciences & Engineering ($p = 0.01$).

Researchers in Biomedical & Health Sciences searched for information about the authors before tweeting an article the least frequently. Specifically, they did this in statistically fewer cases than those in Social Sciences ($p = 0.03$) and Mathematics & Computer Science ($p = 0.01$). Similarly, after tweeting, researchers in Biomedical & Health Sciences searched for information about the authors of the articles in fewer cases than researchers in four other disciplines: Social Sciences ($p = 0.05$), Life & Earth Sciences ($p = 0.05$), Mathematics & Computer Science ($p = 0.05$), and Humanities ($p = 0.01$).

Before tweeting an article, researchers in Life & Earth Sciences ($p = 0.00$) and Physical Sciences & Engineering ($p = 0.01$) tended to save it in more cases than in Biomedical & Health Sciences. In addition, Life & Earth Sciences researchers also saved before retweeting in more cases than Social Sciences researchers ($p = 0.01$). However, no significant difference was found in the behavior of saving after tweeting.

Table 5.33 Kruskal-Wallis Test Results of Acts Before and After Tweeting by Position

	Act	H	P
Before Tweeting	Skim article	10.10	0.07
	Read article in depth	15.57	0.01**
	Look at online discussions of article	21.50	0.00**
	Search for information about authors of article	12.72	0.03**
	Save article	15.20	0.01**
	Organize article	9.64	0.09
	Cite article	4.41	0.49
After Tweeting	Skim article	17.62	0.00**
	Read article in depth	4.44	0.49
	Look at online discussions of article	10.95	0.05**
	Search for information about authors of article	12.31	0.03**
	Save article	9.71	0.08
	Organize article	10.89	0.05**
	Cite article	5.29	0.38

Although no difference was detected for organizing an article before tweeting it, it was found that Life & Earth Sciences researchers organized the articles after tweeting in more cases than those in Biomedical & Health Sciences ($p = 0.00$) and Social Sciences researchers ($p = 0.02$). This corresponded to the finding that Life & Earth Sciences researchers saved the articles in the most cases before tweeting them.

After tweeting, researchers in different disciplines had mixed patterns in terms of skimming. Specifically, Mathematics & Computer Science researchers tended to skim the article after tweeting in more cases compared to researchers in Biomedical & Health Sciences ($p = 0.01$), Social Sciences ($p = 0.01$), Physical Sciences & Engineering ($p = 0.04$), and Humanities ($p = 0.01$). In addition, this was more of the case for Life & Earth Sciences than Biomedical & Health Sciences ($p = 0.00$) and Social Sciences ($p = 0.01$).

5.4.2 Scholarly Acts and Retweeting

Similar to Table 5.26 and Table 5.27, the following two tables present the number of survey respondents who would: 1) skim the article to gain a very basic idea of it; 2) read the

article in depth (examining at least some sections/figures/tables in the article very carefully); 3) look at online discussions of the article; 4) search for information about the author(s) of the article; 5) save the article to their computer or reference manager tools; 6) organize the article (such as renaming the article file or categorizing it into a folder); and 7) cite the article (in their working research papers or teaching materials) before and after retweeting a scholarly article.

Table 5.34 Acts Before Retweeting a Scholarly Article

	In all cases	In most of the cases	In half of the cases	In rare cases	Never
Skim article	324	438	285	165	21
Read article in depth	35	196	388	551	63
Look at online discussions of article	21	124	293	525	270
Search for information about authors of article	20	85	239	634	255
Save article	32	132	315	524	230
Organize article	23	85	218	484	423
Cite article	4	24	178	714	313

Table 5.35 presents the number of respondents who conducted these seven acts after retweeting a scholarly article.

Table 5.35 Acts After Retweeting a Scholarly Article

	In all cases	In most of the cases	In half of the cases	In rare cases	Never
Skim article	112	196	224	440	261
Read article in depth	24	142	352	560	155
Look at online discussions of article	18	105	228	584	298
Search for information about authors of article	6	61	198	676	292
Save article	37	94	261	564	277
Organize article	27	83	179	535	409
Cite article	9	34	236	763	191

5.4.2.1 Scholarly Acts and Retweeting by Age

Among researchers in different age groups, differences mainly existed in reading an article in depth before retweeting it and skimming it after retweeting it.

Before retweeting an article, researchers in relatively older age groups tended to read the article in more depth than relatively younger researchers. Specifically, researchers who were 50-59 years old tended to read the article in more depth in more cases compared to researchers who were 20-29 years old ($p = 0.01$), 30-39 years old ($p = 0.00$), and 40-49 years old ($p = 0.01$). Researchers who were 60-69 years old also read the article in more depth compared to researchers in the age group of not only 20-29 years old ($p = 0.00$), 30-39 years old ($p = 0.00$), and 40-49 years old ($p = 0.00$) but also 70 years or older ($p = 0.03$).

Table 5.36 Kruskal-Wallis Test Results of Acts Before and After Retweeting by Age

	Act	H	P
Before Retweeting	Skim article	4.28	0.51
	Read article in depth	24.01	0.00**
	Look at online discussions of article	1.70	0.89
	Search for information about authors of article	7.23	0.20
	Save article	6.36	0.27
	Organize article	9.00	0.11
	Cite article	10.68	0.06
After Retweeting	Skim article	21.73	0.00**
	Read article in depth	10.20	0.07
	Look at online discussions of article	3.84	0.57
	Search for information about authors of article	6.36	0.27
	Save article	7.17	0.221
	Organize article	10.38	0.07
	Cite article	6.34	0.27

On the contrary, researchers in relatively younger age groups tended to skim the article after retweeting it compared to relatively older researchers. Specifically, researchers who were

30-39 years old and 40-49 years old skimmed the articles in more cases compared to researchers who were 50-59 years old (p = 0.00, p = 0.01, respectively) and 60-69 years old (p = 0.00, p = 0.04, respectively).

5.4.2.2 Scholarly Acts and Retweeting by Gender

Differences were found between female and male researchers in skimming an article both before and after retweeting it. Specifically, female researchers skimmed the article in more cases compared to male researchers (p = 0.00) before retweeting it. However, male researchers skimmed the article in more cases after retweeting it (p = 0.03). This pattern of difference between skimming and retweeting was similar to the finding regarding skimming and tweeting described in Section 5.4.1.2.

In addition, female researchers tended to cite an article after retweeting it in more cases than male researchers (p = 0.03).

Table 5.37 Kruskal-Wallis Test Results of Acts Before and After Retweeting by Gender

	Act	H	P
Before Retweeting	Skim article	10.00	0.00**
	Read article in depth	1.50	0.22
	Look at online discussions of article	2.35	0.13
	Search for information about authors of article	0.66	0.42
	Save article	0.41	0.52
	Organize article	0.01	0.93
	Cite article	0.48	0.49
After Retweeting	Skim article	4.72	0.03**
	Read article in depth	0.26	0.61
	Look at online discussions of article	0.00	0.98
	Search for information about authors of article	0.01	0.93
	Save article	0.08	0.77
	Organize article	0.02	0.88
	Cite article	4.46	0.03**

5.4.2.3 Scholarly Acts and Retweeting by Continent

No statistical difference was found in these acts before and after retweeting among researchers from different continents.

Table 5.38 Kruskal-Wallis Test Results of Acts Before and After Retweeting by Continent

	Act	H	P
Before Retweeting	Skim article	0.73	0.98
	Read article in depth	5.04	0.41
	Look at online discussions of article	8.86	0.11
	Search for information about authors of article	7.79	0.17
	Save article	9.50	0.09
	Organize article	7.87	0.16
	Cite article	5.98	0.31
After Retweeting	Skim article	4.50	0.48
	Read article in depth	5.81	0.32
	Look at online discussions of article	3.31	0.65
	Search for information about authors of article	7.61	0.18
	Save article	9.86	0.08
	Organize article	10.47	0.06
	Cite article	7.42	0.19

5.4.2.4 Scholarly Acts and Retweeting by Education

Researchers with different educational backgrounds differed in the behavior of looking at the online discussions of articles both before and after retweeting the articles. In addition, differences were found in reading in depth before retweeting them, saving after retweeting them, and citing after retweeting them.

Similar to what was found in Section 5.4.1.4 about tweeting scholarly articles, researchers holding a doctoral degree tended to only occasionally read the online discussions about articles they retweeted. Specifically, they tended to read the online discussions of an article before retweeting it in fewer cases compared to researchers holding a master's degree ($p = 0.00$).

They also tended to read the online discussions of an article after retweeting it in fewer cases compared to researchers holding a professional degree ($p = 0.01$).

Before retweeting an article, researchers holding a doctoral degree tended to read the article in depth in fewer cases compared to researchers holding a professional degree ($p = 0.00$).

However, they saved the articles after retweeting them in more cases than researchers holding a master's degree ($p = 0.01$). In addition, they also cited the articles after retweeting them in more cases than researchers holding a professional degree ($p = 0.01$).

Table 5.39 Kruskal-Wallis Test Results of Acts Before and After Retweeting by Education

	Act	H	P
Before Retweeting	Skim article	4.15	0.25
	Read article in depth	13.51	0.00**
	Look at online discussions of article	15.19	0.00**
	Search for information about authors of article	6.73	0.08
	Save article	4.47	0.21
	Organize article	2.83	0.42
	Cite article	0.31	0.96
After Retweeting	Skim article	6.58	0.09
	Read article in depth	3.22	0.36
	Look at online discussions of article	10.82	0.01**
	Search for information about authors of article	2.80	0.42
	Save article	8.83	0.03**
	Organize article	5.55	0.14
	Cite article	8.68	0.03**

5.4.2.5 Scholarly Acts and Retweeting by Position

Both before and after retweeting an article, the researchers' acts differed in looking at the online discussions of the article, searching for information about the authors, and citing the article in working papers or teaching materials.

Specifically, statistical differences were found between lectures and tenured researchers in looking at the online discussions of articles. Before retweeting a scholarly article, lecturers

tended to look at the online discussions in more cases compared to tenured researchers ($p = 0.00$); they also did this in more cases than tenured researchers after retweeting the articles ($p = 0.04$). In addition, tenured researchers also read less online discussions of an article than early-career researchers ($p = 0.02$) after retweeting it, which was similar to the findings described in Section 5.4.1.5.

The patterns of searching for information about the authors of an article when retweeting was also found to be similar to what were described in Section 5.4.1.5 regarding the acts associated with tweeting. Early-career researchers searched for information about the authors before tweeting it more frequently compared to tenured researchers ($p = 0.01$) and other researchers ($p = 0.00$), including clinical researchers or physicians, government researchers, industry researchers, and non-profit or non-government organization researchers. Similarly, after retweeting, early-career researchers also searched about the authors in more cases compared to not only tenured researchers ($p = 0.00$) and other researchers ($p = 0.00$) but also lecturers ($p = 0.02$). In addition, pre-tenured tenure-track researchers tended to search for information about the authors after retweeting in more cases than other researchers ($p = 0.01$).

Citing an article in a working research paper or teaching materials before tweeting it was less the case for other researchers, compared to tenured researchers ($p = 0.00$), pre-tenure researchers ($p = 0.01$), lecturers ($p = 0.00$), as well as early-career researchers ($p = 0.03$). Meanwhile, other researchers also cited an article after retweeting it in less cases compared to tenured researchers ($p = 0.00$), pre-tenure researchers ($p = 0.00$), lecturers ($p = 0.00$), as well as early-career researchers ($p = 0.0$). This was also similar to the findings reported in Section 5.4.1.5 regarding the acts associated with tweeting.

Table 5.40 Kruskal-Wallis Test Results of Acts Before and After Retweeting by Position

	Act	H	P
Before Retweeting	Skim article	1.73	0.79
	Read article in depth	3.61	0.46
	Look at online discussions of article	9.71	0.05**
	Search for information about authors of article	9.62	0.05**
	Save article	6.19	0.19
	Organize article	4.46	0.35
	Cite article	18.57	0.00**
After Retweeting	Skim article	11.94	0.02**
	Read article in depth	23.53	0.00**
	Look at online discussions of article	10.00	0.04**
	Search for information about authors of article	16.43	0.00**
	Save article	19.68	0.00**
	Organize article	16.06	0.00**
	Cite article	22.15	0.00**

After retweeting a scholarly article, differences were found among researchers in different positions in skimming the article, reading it in depth, saving it, and organizing it.

Similar patterns of differences were found in the acts of skimming and reading in depth. Both tenured researchers and other researchers would skim an article after retweeting it in more cases compared to pre-tenure researchers ($p = 0.03$, $p = 0.02$, respectively) and early-career researchers ($p = 0.02$, $p = 0.01$, respectively). Similarly, when it comes to reading in depth, both tenured researchers and other researchers would read an article in depth after retweeting it compared to pre-tenure researchers ($p = 0.00$, $p = 0.00$, respectively) and early-career researchers ($p = 0.01$, $p = 0.00$, respectively).

Similar to the after-tweeting behaviors described in Section 5.4.1.5, saving an article after retweeting was less the case for other researchers compared to tenured researchers ($p = 0.04$), pre-tenure researchers ($p = 0.00$), lecturers ($p = 0.00$), and early-career researchers ($p = 0.00$). Also similar was that saving after retweeting also occurred less frequently in tenured researchers compared to pre-tenure researchers ($p = 0.02$) and early-career researchers ($p = 0.01$).

Similar to the pattern of organizing an article after tweeting it described in findings in Section 5.4.1.5, other researchers tended to do this in statistically less cases compared to tenured researchers ($p = 0.02$), pre-tenure researchers ($p = 0.00$), lecturers ($p = 0.03$), as well as early-career researchers ($p = 0.00$). In addition, it was also similar to after-tweeting that pre-tenure researchers organized the articles they retweeted in more cases than tenured researchers ($p = 0.04$).

5.4.2.6 Scholarly Acts and Retweeting by Discipline

According to the Kruskal-Wallis test results, before retweeting an article, researchers in different disciplines differed in their acts of skimming the article, reading it in depth, and searching for information about the authors.

Both Biomedical & Health Sciences and Humanities researchers would skim an article in more cases compared to Mathematics & Computer Science ($p = 0.05$, $p = 0.03$, respectively) and Social Sciences researchers ($p = 0.01$, $p = 0.05$, respectively) before retweeting it.

Similar to the findings that Biomedical & Health Sciences researchers tended to read an article in depth before tweeting it the most, they also tended to read an article in depth before retweeting it the most, followed by those in Social Sciences, Humanities, Physical Sciences & Engineering, and Life & Earth Science. On the contrary, researchers in Mathematics & Computer Science did this the least frequently – statistically less frequently than those in Biomedical & Health Sciences ($p = 0.01$), Social Sciences ($p = 0.05$), and Humanities ($p = 0.04$).

In terms of searching for information about the authors of an article before retweeting the article, it was less of the case for Biomedical & Health Sciences researchers compared to researchers in Social Sciences ($p = 0.00$) and Humanities ($p = 0.01$). This was also similar to what was reported in the acts associated with tweeting in Section 5.4.1.6.

Table 5.41 Kruskal-Wallis Test Results of Acts Before and After Retweeting by Position

	Act	H	P
Before Retweeting	Skim article	11.42	0.04**
	Read article in depth	16.24	0.01**
	Look at online discussions of article	6.50	0.26
	Search for information about authors of article	14.29	0.01**
	Save article	4.76	0.45
	Organize article	11.98	0.04**
	Cite article	15.02	0.01**
After Retweeting	Skim article	8.45	0.13
	Read article in depth	4.07	0.54
	Look at online discussions of article	11.29	0.05**
	Search for information about authors of article	5.66	0.34
	Save article	17.26	0.00**
	Organize article	13.96	0.02**
	Cite article	11.42	0.04**

After retweeting an article, researchers in different disciplines differed in their acts of looking at the online discussions of the article and saving the article.

Similar to the findings related to tweeting in Section 5.4.1.6 was that after retweeting, in more cases would Biomedical & Health Sciences researchers look at the online discussions of the articles compared to Social Sciences researchers ($p = 0.02$) and Life & Earth Sciences researchers ($p = 0.01$). In terms of saving an article after retweeting it, a similar pattern was also found in Section 5.4.1.6. It was more of the case for Life & Earth Sciences researchers to save an article after retweeting it compared to Biomedical & Health Sciences ($p = 0.00$) and Social Sciences researchers ($p = 0.00$).

For researchers in different disciplines, differences were found in organizing and citing the article both before and after retweeting an article.

Similar to saving after retweeting, organizing an article after retweeting it was more of the case of Life & Earth Sciences researchers compared to those in Biomedical & Health

Sciences (p = 0.00), Social Sciences researchers (p = 0.00), and Mathematics & Computer Science (p = 0.01). However, organizing an article before retweeting it displayed a different pattern. Mathematics & Computer Science researchers tended to organize the articles before retweeting it in less cases compared to researchers in all the other disciplines (Biomedical & Health Sciences, p = 0.00; Social Sciences, p = 0.00; Life & Earth Sciences, p = 0.00; Physical Sciences & Engineering, p = 0.01; Humanities, p = 0.01).

Meanwhile, Mathematics & Computer Science researchers would also cite an article in working papers or teaching materials before retweeting it in fewer cases compared to researchers in the other disciplines (Biomedical & Health Sciences, p = 0.00; Social Sciences, p = 0.00; Life & Earth Sciences, p = 0.01; Physical Sciences & Engineering, p = 0.02; Humanities, p = 0.01). In addition, Social Sciences researchers would cite the articles before retweeting them more often than Life & Earth Sciences researchers (p = 0.03). Lastly, Biomedical & Health Sciences researchers would cite the articles after retweeting them in fewer cases compared to Social Sciences (p = 0.01) and Life & Earth Sciences researchers (p = 0.01).

5.4.3 Relationship between the Scholarly Acts

5.4.3.1 Correlations between the Scholarly Acts

Table 5.42 is a correlation matrix presenting the Spearman Correlation Coefficients between the acts before and after tweeting. The 14 columns and 14 rows indicate the acts described in the previous sections. Specifically, B1 – B7 indicate seven acts that happened Before tweeting, including 1) skim the article to gain a very basic idea of it; 2) read the article in depth (examining at least some sections/figures/tables in the article very carefully); 3) look at online discussions of the article; 4) search for information about the author(s) of the article; 5) save the article to their computer or reference manager tools; 6) organize the article (such as

renaming the article file or categorizing it into a folder); and 7) cite the article (in their working research papers or teaching materials) before tweeting a scholarly article. For the convenience of reading, these seven acts are abbreviated as SKIM, READ, DISC, AUTH, SAVE, ORG, and CITE, respectively. Similarly, A1 – A7 indicate these seven acts After tweeting. The different shades of blue indicate different levels of correlations (see in Table 4.1 for the rule of thumb adopted in this study in interpreting the size of a correlation). Cells that were not filled with any blue color indicate non-statistically significant relationships ($p \geqslant 0.05$).

Table 5.42 Correlation Matrix of Scholarly Acts Before and After Tweeting

	B1 SKIM	B2 READ	B3 DISC	B4 AUTH	B5 SAVE	B6 ORG	B7 CITE	A1 SKIM	A2 READ	A3 DISC	A4 AUTH	A5 SAVE	A6 ORG	A7 CITE
B1 SKIM	1.00	0.05	0.07	-0.01	0.05	0.04	-0.01	0.11	0.08	0.01	0.01	0.05	0.05	0.03
B2 READ		1.00	0.04	0.06	0.14	0.10	0.05	-0.08	0.09	0.06	0.05	0.06	0.04	0.05
B3 DISC			1.00	0.30	-0.01	0.02	0.09	0.06	0.10	0.50	0.23	0.09	0.09	0.04
B4 AUTH				1.00	0.16	0.13	0.16	0.12	0.13	0.24	0.42	0.15	0.14	0.14
B5 SAVE					1.00	0.42	0.24	0.02	0.03	0.05	0.12	0.24	0.20	0.18
B6 ORG						1.00	0.31	0.04	0.03	0.05	0.16	0.16	0.46	0.19
B7 CITE							1.00	0.08	0.07	0.07	0.12	0.12	0.15	0.27
A1 SKIM								1.00	0.36	0.15	0.30	0.38	0.31	0.17
A2 READ									1.00	0.22	0.33	0.38	0.31	0.25
A3 DISC										1.00	0.39	0.22	0.18	0.14
A4 AUTH											1.00	0.41	0.37	0.30
A5 SAVE												1.00	0.64	0.38
A6 ORG													1.00	0.38
A7 CITE														1.00

As shown in Table 5.42, some scholarly acts associated with the article being tweeted were correlated. A moderate positive correlation was found between reading the discussions online relevant to a scholarly article before and after tweeting it. In other words, a researcher who tended to look at the online discussions of an article before tweeting was also likely to do this after tweeting it. In addition, a moderate positive correlation between saving and organizing article after tweeting indicated that a researcher who tended to save an article after tweeting it also tended to organize it.

In addition, low positive correlations were found between eighteen pairs of acts. Among these pairs, two were between the same acts before and after tweeting. Specifically, searching for information about the authors of an article before and after tweeting were correlated; organizing an article before and after tweeting were correlated.

The other low positive correlations were between acts either before tweeting or after tweeting. Before tweeting, there were low positive correlations between looking at online discussions of an article and searching for information about the authors of the article, between saving an article and organizing it, as well as between organizing an article and citing it. After tweeting, searching for information about the authors was low correlated with skimming, reading in depth, and looking at online discussions of it. Similarly, both saving and organizing an article were correlated with skimming, reading in depth, and looking at online discussions of it. Lastly, citing an article after tweeting was low correlated with searching for information about the authors, saving it, and organizing it.

Similar to Table 5.42, Table 5.43 is a correlation matrix presenting the Spearman Correlation Coefficients between the acts before and after retweeting. The different shades of blue indicate different levels of correlations (see in Table 4.1 for the rule of thumb adopted in

this study in interpreting the size of a correlation). Cells that were not filled with any blue color indicate non-statistically significant relationships ($p \geqslant 0.05$).

Table 5.43 Correlation Matrix of Scholarly Acts Before and After Retweeting

	B1 SKIM	B2 READ	B3 DISC	B4 AUTH	B5 SAVE	B6 ORG	B7 CITE	A1 SKIM	A2 READ	A3 DISC	A4 AUTH	A5 SAVE	A6 ORG	A7 CITE
B1 SKIM	1.00	0.13	0.07	0.10	0.06	0.07	0.06	0.14	0.07	0.03	0.08	0.03	0.03	0.03
B2 READ		1.00	0.17	0.26	0.23	0.20	0.18	-0.06	0.20	0.12	0.12	0.06	0.08	0.14
B3 DISC			1.00	0.43	0.15	0.14	0.18	0.07	0.12	0.62	0.32	0.09	0.10	0.09
B4 AUTH				1.00	0.31	0.26	0.31	0.09	0.17	0.36	0.53	0.21	0.22	0.24
B5 SAVE					1.00	0.62	0.49	0.09	0.19	0.16	0.23	0.43	0.36	0.34
B6 ORG						1.00	0.49	0.09	0.14	0.16	0.24	0.34	0.61	0.32
B7 CITE							1.00	0.07	0.06	0.17	0.20	0.27	0.31	0.41
A1 SKIM								1.00	0.47	0.25	0.36	0.40	0.31	0.25
A2 READ									1.00	0.33	0.47	0.47	0.37	0.39
A3 DISC										1.00	0.54	0.23	0.23	0.23
A4 AUTH											1.00	0.49	0.44	0.41
A5 SAVE												1.00	0.71	0.56
A6 ORG													1.00	0.52
A7 CITE														1.00

A high positive correlation was found between saving and organizing an article after retweeting it. In other words, a researcher who tended to save an article after retweeting it also tended to organize it. This is similar to what was observed in the acts associated with tweeting an article.

Moderate positive correlations were found between five pairs of acts. Looking at the online discussions of an article before retweeting was found to be moderately correlated with doing it after tweeting. Meanwhile, before retweeting, saving an article was correlated with organizing it. In addition, after retweeting an article, moderate correlations existed between reading the online discussions and searching for information about the authors, between saving the article and citing it, as well as between organizing the article and citing it.

Low positive correlations were found between 30 pairs of acts. These included between four pairs of acts before and after retweeting, specifically, between searching for information about the authors, saving, organizing, and citing the articles. These acts were observed to have a low correlation coefficient in the acts associated with tweeting in the analyses above.

Before retweeting an article, searching for information about the authors had low correlations with looking at online discussions and saving it. Searching for information about the authors, saving it, and organizing it were low correlated with citing it.

After retweeting an article, reading it had a low correlation with looking at online discussions about it. Searching for information about the authors was low correlated with skimming it and reading it in depth. In addition, saving an article had low correlations with skimming it, reading it in depth, and searching for information about the authors. Similar low correlations were found between organizing an article and these three acts. Last but not least, citing an article after retweeting was low correlated with reading it in depth, searching for information about the authors, saving it, as well as organizing it.

In addition to the descriptions above, there were also several low positive correlation coefficients indicating the correlations between different acts prior to and after retweeting. For instance, searching for author information before retweeting was correlated with looking at

online discussions not only before but also after retweeting; meanwhile, looking at online discussions of an article before retweeting was correlated with searching for information about the authors not only before but also after retweeting. A similar pattern was found among saving, organizing, and citing. These results might indicate that before or after retweeting, some acts of these researchers did not differ significantly. This led to the following analyses comparing the scholarly acts before and after both tweeting and retweeting.

5.4.3.2 Differences Between the Scholarly Acts Before and After Sharing

Wilcoxon Signed-rank tests were conducted to perform paired comparisons between the acts before and after tweeting. The results showed statistically significant differences in whether the acts occurred before or after tweeting. Specifically, looking at the online discussions of an article and citing an article occurred statistically more often after tweeting than prior to tweeting. Other acts, however, including skimming the article, reading it in depth, searching for information about the authors, saving it, and organizing it, occurred more often before tweeting than after tweeting.

Table 5.44 Wilcoxon Signed-rank Test Result (Before vs. After Tweeting)

Act	p	Before vs. after tweeting
Skim article	0.00**	In more cases before tweeting
Read article in depth	0.00**	In more cases before tweeting
Look at online discussions of article	0.00**	In more cases after tweeting
Search for information about authors of article	0.00**	In more cases before tweeting
Save article	0.00**	In more cases before tweeting
Organize article	0.00**	In more cases before tweeting
Cite article	0.00**	In more cases after tweeting

In order to better visualize how these acts fit into the researchers' workflow, Figure 5.24 was created to depict the order of the acts. For the convenience of reading, these seven acts are

abbreviated as SKIM, READ, DISC, AUTH, SAVE, ORG, and CITE, respectively. The bright boxes contain the acts that occurred more frequently comparing the before and after. In other words, the acts that are grayed out by a darker background on either the "before" or the "after" side when statistically significant differences were found indicating that they did not occur as frequently as the acts on the opposite side. Specifically, looking at the online discussions of an article and citing an article occurred statistically more frequently after tweeting it compared to before.

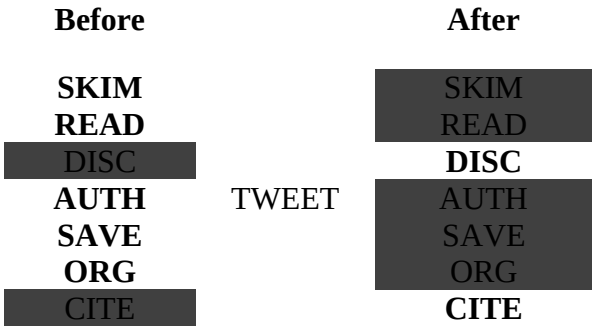

Figure 5.24 Differences Between the Scholarly Acts Before and After Tweeting

Table 5.45 compares the occurrences of these acts before and after retweeting. Significant differences were found in six out of seven pairs of acts. No statistically significant difference was found between organizing an article before and after retweeting.

Citing an article occurred more often after retweeting it compared to prior to retweeting it. On the contrary, skimming it, reading it in depth, searching for information about the authors, and saving it occurred more often before retweeting than after retweeting.

Table 5.45 Wilcoxon Signed-rank Test Result (Before vs. After Retweeting)

Act	p	Before vs. after retweeting
Skim article	0.00**	In more cases before retweeting
Read article in depth	0.00**	In more cases before retweeting
Look at online discussions of article	0.00**	In more cases before retweeting
Search for information about authors of article	0.00**	In more cases before retweeting
Save article	0.00**	In more cases before retweeting
Organize article	0.62	-
Cite article	0.00**	In more cases after retweeting

Different from what was found in the paired comparisons of acts associated with tweeting, researchers tended to look at the online discussions of an article before retweeting it instead of after, which resonated with the rationales reported in Section 5.3.3.2.

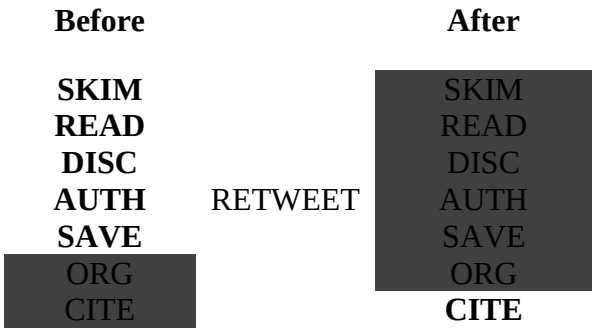

Figure 5.25 Differences Between the Scholarly Acts Before and After Retweeting

5.4.3.3 Differences Between the Scholarly Acts in Tweeting and Retweeting

To test if there existed differences between the scholarly acts associated with the behavior of tweeting and retweeting, Wilcoxon Signed-rank tests were performed. Statistically significant results were found between tweeting and retweeting in all these seven acts.

Table 5.46 Wilcoxon Signed-rank Test Result (Before Tweeting vs. Retweeting)

Act	p	Before tweeting vs. retweeting
Skim article	0.00**	In more cases before tweeting
Read article in depth	0.00**	In more cases before tweeting
Look at online discussions of article	0.00**	In more cases before retweeting
Search for information about authors of article	0.00**	In more cases before tweeting
Save article	0.00**	In more cases before tweeting
Organize article	0.00**	In more cases before tweeting
Cite article	0.00**	In more cases before tweeting

Before tweeting and retweeting a scholarly article, the survey respondents tended to skim the article, read the article in depth, search for information about the authors of an article, save the article, organize the article in more cases before tweeting compared to before retweeting. However, these researchers tended to be more likely to look at the online discussions of the article before retweeting compared to before tweeting. These results are visualized in Figure 5.26 below.

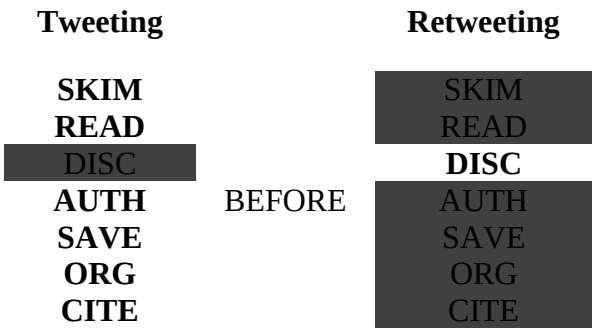

Figure 5.26 Differences Between the Scholarly Acts Before Tweeting and Retweeting

Comparing the acts after tweeting and retweeting an article, there was no statistically significant difference in terms of skimming the article. However, all the other six acts, including reading the article in depth, looking at the online discussions, searching for information about the

authors, saving it, organizing it, and citing it, would occur more frequently after tweeting than after retweeting.

The results were similar to the findings regarding the acts before tweeting and retweeting, despite that looking at the online discussions of articles occurred more frequently after retweeting compared to after tweeting.

Table 5.47 Wilcoxon Signed-rank Test Result (After Tweeting vs. Retweeting)

Act	p	After tweeting vs. retweeting
Skim article	0.26	-
Read article in depth	0.00**	In more cases after tweeting
Look at online discussions of article	0.00**	In more cases after tweeting
Search for information about authors of article	0.00**	In more cases after tweeting
Save article	0.00**	In more cases after tweeting
Organize article	0.00**	In more cases after tweeting
Cite article	0.00**	In more cases after tweeting

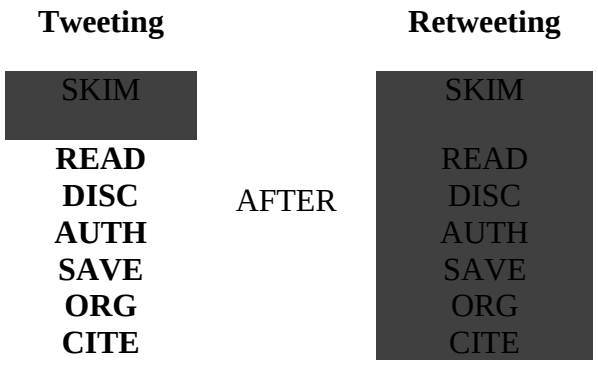

Figure 5.27 Differences Between the Scholarly Acts After Tweeting and Retweeting

5.4.4 Stories behind Tweeting, Retweeting, and Workflow of Researchers

For the ten specific instances of tweets and retweets identified for each of the interview participants, I asked them if they have conducted the seven acts as a prompt to further discuss

how the tweeting and retweeting fit into their research workflow. Although these results were based on self-report, with some researchers not being able to clearly remember what had happened, many other researchers were able to provide clear and rich information for a better understanding of this question. Therefore, in this section, I still present the analyses of this part of the interview, aiming to provide some additional context about the acts that occurred in the critical incidents. In total, 147 instances of tweets and 53 instances of retweets containing a scholarly article link were analyzed.

As been discussed at the beginning of Section 5.3.3, the exact prevalence of codes and categories was not reported in this section due to the qualitative nature of this part of the study. The sample of researchers interviewed was not necessarily representative of all researchers who used Twitter. In addition, the sample of tweets and retweets used in the Critical Incident interviewing were not necessarily representative of all of their tweets. As a result, this study used consistent conventions of "a few" (0-4; 0-20%), "some" (5-9; 25%-45%), "many"(10-14; 50%-70%), "almost all" (15-19; 75%-95%), and "all" (20; 100%) in reporting the results, as was suggested in previous research (Braun & Clark, 2006; Chen, 2018).

Similar to what was found in Section 5.3.3.1, the primary resources of articles researchers tweeted were from "table of content" subscriptions of journals in emails, conference settings, colleague recommendations, and literature search of articles.

More specifically, a few different scenarios were associated with searching for literature before tweeting an article. Many researchers (P1, P3, P4, P9, P17, P12, P13, P18, P19, and P20) tweeted articles they came across in a conference setting. In some cases, they tried to search for a relevant article, mostly on pre-print platforms such as bioRxiv and Arxiv, during the presentation session. In a few cases, they tried to tweet a reference included in the presentation slides while

they were listening to the presentation. In a few cases, they tried to search for the relevant article and tweeted it after the conference.

Some researchers decided to tweet an article while they were searching for literature for their research or teaching. For instance,

> P13: "I was really excited to find this article because it was a really good fit for a course that I was prepping. And I guess I was just so motivated that I ended up hopping up on Twitter to say 'Oh, this is great!'".

A few cases were due to serendipitous encounters in their non-working time. For instance, P1 once watched a TED talk video introducing a research project, and then managed to find the link to the original article to read in more depth.

In the case of retweeting, many cases occurred when the researchers were browsing Twitter as a routine or taking a break from work. A few also mentioned retweeting from Twitter alerts. A few researchers mentioned using hashtags to find tweets to retweet during academic conferences. Also discovered about retweeting was that researchers in this sample in many cases were not aware if they were following the accounts who posted the original tweet. Among these cases, in many cases, they would retweet articles that were previously retweeted by accounts they were following.

Many researchers read at least some parts of the articles they tweeted. Some only skimmed the articles. In some cases, researchers only skimmed the articles but listened to the conference presentations relevant to the articles. Only a few researchers reported saving the articles to their computers. Fewer researchers reported organizing the articles. A few researchers reported printing the articles out to read and saving them in their stack of readings.

Some researchers reported cases where they looked at the online discussions of the articles that they tweeted or retweeted. For instance, P9 retweeted a researchers' comments about a research article revealing the prevalence of pulmonary embolism among patients hospitalized for syncope and pointed out the danger of ignoring the design and population of this study. By looking at the online discussions, she also found a report written by Medscape, a website referencing medical journal articles to provide access to medical information for clinicians, to ask them fix the title and content of their report. Later, Medscape changed their report according to her feedback.

> P9: "If you look at the article, it completely did not apply in the United States' patients. It was published in [a prestigious journal in the medical field] and made this big splash across in the lay media. I was super concerned that it would change doctors' practices and change what patients expected. It might ultimately make care very dangerous because most people are not trained to appraise research."

However, in only a few cases, researchers searched for information about the authors of the articles. In many cases, it seemed they were quite aware of the authors.

Some other acts were identified in addition to the seven acts investigated in this study. In some cases, researchers emailed the articles to their colleagues and friends. One participant (P8) mentioned using WhatsApp to send an article to several colleagues. Another participant (P12) mentioned sharing a news article relevant to an article he tweeted to family members because the article was behind the paywall.

In some cases, researchers recommended the articles to their students they mentored. There were a few cases in both tweeting and retweeting, where they recommended the article to a specific student of theirs. There were two cases where they discussed the articles in lab

meetings. P7 assigned one article that she retweeted to one student of hers to present and lead discussions in their weekly lab meeting. P10 recommended one article to his colleagues in one of his lab meetings. One researcher (P14) made one article that he tweeted a must-read for all incoming students to his lab.

In a few cases, the researchers had further discussions of the paper with either the authors of the paper or colleagues sharing similar research interests. For instance, P1 mentioned going to the conference session of the author an article she retweeted to talk with her. One article P9 tweeted led to further conversations with the author both by email and by phone calls. P13 talked about an article with a researcher she met when she was invited to give a talk at another university. P14 was able to invite the author of an article she tweeted to give a talk in her department.

In a few cases, although the articles the participants tweeted were not cited in a working research paper or teaching material, they were reported to been further used. For instance, P9 wrote a summary and reflection about one paper in her "reading notes" that she openly shared on Twitter through Google Docs. P14 had a further discussion with a very well-established researcher in his field about the method discussed in one paper he tweeted and published a commentary article regarding this method. P11 cited two articles in her presentations introducing her work at a non-profit research institute. P16 tweeted one article of a researcher, but read the whole body of this author's research. P15 tweeted a book review. After she read the book review, she also read the book.

Some researchers had a relatively clearer pattern of how tweeting and retweeting fit into their workflow, while some others did not have a clear pattern. For instance, the majority of the incidents from P19 were from conferences, workshops, or tutorial-type of conference lectures.

He also commented that it was a common practice in his field of quantum information and that other researchers in his field would also do a lot of conference live-tweeting. The majority of P6's tweets were due to his broad research interests or personal interests in social issues. Most of his tweeting or retweeting was not part of his research workflow.

5.5 Motivation behind Tweeting and Retweeting

In the interviews, I tried to explore the researchers' motivations behind tweeting and retweeting. In total, 200 instances of tweets and retweets were used to facilitate my interview with the participants and to help them better recall the context of their tweeting and retweeting acts. These included 147 tweets and 53 retweets, each containing a link to a scholarly article.

As been discussed at the beginning of Section 5.3.3 and Section 5.4.4, the exact prevalence of codes and categories was not reported in this section due to the qualitative nature of this part of the study. Instead, this study used consistent conventions of "a few" (0-4; 0-20%), "some" (5-9; 25%-45%), "many"(10-14; 50%-70%), "almost all" (15-19; 75%-95%), and "all" (20; 100%) in reporting the results, as was suggested in previous research (Braun & Clark, 2006; Chen, 2018).

This study resulted in the construction of seven categories of codes representing the motivations researchers had when they were tweeting and retweeting scholarly articles. The coding scheme is attached in Appendix VI. In presenting the results, I further grouped the seven categories into four larger categories: Building social relationships, communications, acknowledgment, and saving for later reference.

5.5.1 Building Social Relationships

This section discusses two categories of motivations that are related to building social relationships on Twitter: networking, and promoting. Many researchers interviewed mentioned

building a professional network on Twitter by tweeting, retweeting, replying, and liking scholarly articles. In this process, researchers discussed not only conforming to the professional image or identity that they were trying to build on Twitter but also maintaining their presence in other researchers' networks. To achieve this, they not only proactively shared research from their Twitter accounts but also interacted with the articles posted by other researchers by retweeting, replying to, and liking others' tweets. These two categories, networking and promoting, were in some cases interrelated with each other.

5.5.1.1 Networking

Maintaining a professional network on Twitter was important for many researchers interviewed. P13, a sociologist, described her Twitter network as: "Well, they are not my friends, but my people -- my sociology people." Also, as commented by P5,

> P5: "To me, the point of Twitter is not so much sharing the science as it is building the community and making the relationships with the other researches. By tweeting out papers I'm trying to add a service to my fellow researchers to help them find papers they might have not noticed before, or they might be interested in."

When networking with other researchers or organizations, two different scenarios were identified. In some cases, researchers used a scholarly article to initiate or respond to a conversation with a person or an organization that they already had a connection with, which was coded as "maintaining an existing relationship." In other cases, they tried to use an article to initiate or respond to a conversation with a person or an organization that they did not have a connection with, which was coded as "building a new relationship."

Both early-career researchers and relatively more established researchers would network with others on Twitter. Half of the incidents of P1, an early-career researcher, were solely to

build or maintain a professional relationship with others. Meanwhile, P16, an Emeritus Professor who was still actively doing research, also tweeted others' works to network with them. In one of the critical incidents, P15 tweeted three articles published by the same researcher that he had met in a previous conference, at which both of them were invited to give a talk. Prior to meeting this researcher at the conference, he happened to have criticized one of this researcher's works in his blog article before. He then met this researcher at the conference and got to learn more about his research. After he returned home, he further read all the publications of this researcher and found that he liked the other researcher's work. He then decided to tweet to this researcher to tell him that he liked his works.

Researchers also networked with organizations. For instance, P14 tried to network with the partner art institute of her department by tweeting a relevant article to their Twitter account. She commented that it was because that art institute had been providing lecturers and internship opportunities to their department, and that it was important to maintain a good relationship with them. Another example was an incident of P10's. In one of his tweets, he mentioned the Twitter account of a regional site of a national research program supporting ecological discoveries. This research program had been funded by the National Science Foundation since 1980. Currently, it has 28 sites across the U.S. The article P10 tweeted utilized data collected at this regional research site.

The academic conference was a common occasion where researchers networked with each other. Twitter was used to complement and extend the face-to-face networking. For instance, P10 tweeted two articles in the conference settings for the purpose of maintaining existing relationships with the authors. In one tweet of his, he reached out to a potential

collaborator by tweeting her conference presentation and was able to build a collaborative relationship with the author later on.

5.5.1.2 Promoting

Four sub-categories of promoting related motivations were found in the analysis: self-promotion, promoting a colleague, promoting a journal, and promoting an institute.

There was a full spectrum of promotion, from the more altruistic end of promotion, to the middle area of simultaneously acknowledging the work and intending to amplify the online visibility of the researchers or organizations, to the other end, which was promotion solely due to institutional reasons.

On the more altruistic end of the spectrum, there were cases where researchers promoted scholarly articles because they had a high opinion about the research and would like to let more people know about the research. For instance, P2 shared an article of a student working in the same lab (but not under his advisory) that he had been aware of since the initial phase of the work and considered it very important. P9 shared an article of an author that she knew and commented on the work as "great and clinically important." In another incident, one researcher (P20) specifically mentioned promoting researchers in her subfield, which was a relatively small subfield in her field. She believed that promoting the researcher and the researchers' work was beneficial for the promotion of her field. In these cases, a strong sense of "acknowledgment" co-existed with the purpose of "promoting."

In the middle area, some participants said that they would share the works of their students, former students, colleagues, "friendly colleagues," or "friends" because they believed that they were doing good work. These participants believed sharing these researchers' work on Twitter would help enhance the visibility or potential impact of these researchers. Among these

cases, P5 promoted the works of his colleagues working in the same area as him in two cases. P7 promoted the works of her former students in two cases. P12 promoted the work of a former student's wife's. P17 commented on one of her promotional tweets and said that she wanted to promote a researcher who was at a similar career stage as her (early-career). In addition, P7 specifically commented that in one case, she intended to promote a female researcher to increase the impact of women in science. P14 also commented that in one case, she intended to promote a female researcher who was from the same country.

Some participants pointed out that promoting was a reciprocal activity on Twitter. For instance, one of the retweets of P15 was for the purpose of "returning a favor" to someone who had promoted her work before. She said,

> P15: "In a way, my activity sharing the work of others is also about promoting and strengthening my own research networks, and building capital within the scholarly and research-aligned professional worlds. So, there is self-interest and self-promotion involved in promoting the work of others. Sharing the work of a scholar in a public way online can be a useful way to begin to build a scholarly connection that may be valuable later on - i.e., on a grant application, sharing conference calls for papers, etc."

Towards the other end of the spectrum, there were a few cases where researchers reported promoting a researcher, a journal, or an organization more because of "institutional reasons" (P5). P9, for instance, was asked to share an article from a journal that she was serving as the "social media editor". In this case, although the initial purpose was to promote the article and journal, she said her opinion on the article was "neutral to negative." She shared her comments on the article together with the article link when she was tweeting it.

Researchers tried to promote their own works as well. Some researchers shared links to their own works when the works were newly published. Sometimes, for instance, P5 promoted an article that had cited his own work, which involved both promoting the authors of this article but also self-promotion.

5.5.2 Communications

Almost all participants in the interview used Twitter for communicative purposes. Tweeting and retweeting scholarly articles online, they hoped to shape the discussion around the topics in which their research community would be interested. For instance, P14 described using Twitter as having a "scholarly companionship," "just like there is another researcher in this room that you can talk to."

Three categories of codes were formed in the analysis: disseminating, commenting, and communicating with intended users, which will be described in detail in the three subsections below.

5.5.2.1 Disseminating

For the purpose of disseminating scholarly articles on Twitter, seven sub-categories were developed. The first three sub-categories were concerned with the potential contribution of the research, which involved disseminating scholarly articles in terms of the relevance of the research topic, research method, and implementation aspects. There were also cases in which researchers were trying to disseminate articles in terms of their relevance to research practices of researchers instead of the research per se. Additionally, researchers also disseminated articles out of their personal interests in science or social issues in general. In addition, researchers tried to share articles relevant to a conference presentation, including the preprints or references cited in the presentations, to the audience who were not at the conference. Last but not least, researchers

also deliberately tried to disseminate research findings to the general public instead of to the research community.

Almost all researchers interviewed used Twitter to disseminate relevant articles in terms of the research topic. When they talked about relevance, in many cases, they tried to distinguish relevance of the articles to themselves from to their research community; sometimes they tried to distinguish between communities of researchers in their subdisciplines and in the broader disciplines. In some cases, they also mentioned past relevance, current relevance, and potential relevance of the topics. For instance,

> P6: "Not all research that I share are directly relevant to my own research, but I still wanted to share them. You know, you don't have the chance to meet these many people in your real life, but on Twitter, you can be heard by many people. I value the exchange of ideas among different disciplines. I have a very broad spectrum of research interests, and I believe, as a social sciences researcher, you should not drop your previous research interests because they will be useful in the long term. The topics that I'm not publishing about now, it doesn't mean I won't publish about them in the future."
>
> P10: "I also post when I see something that is really interesting to me and to the people that I interact with on Twitter, but in a journal that is not something that they would generally see. So there are journals that researchers would always read in my discipline and my subdiscipline. I will tweet an article if it is not from these most reputable journals so people in my community can still see them. By doing this, I can bring new discourse into my discipline."

Some researchers shared articles because the technique, tool, or research method in general used was relevant. P5 shared a research tool that he was not familiar with and tried to see

if he could get feedback on the tool from researchers who were more familiar with it. P8 shared a new technology in the health-related area with the potential to be popularized for everyone to use on mobile phones. P11, a beamline specialist, shared two articles that used beamline in their research. P17 shared a research article which she considered could be used as a "guideline-type of article" if any other researchers would like to use the same method in their research.

Some researchers shared articles because the application of research findings was relevant to researchers and practitioners in their fields. For instance, P4 shared three articles that might inform the work of athletic trainers and dieticians related to injury, nutrition, and related medical conditions in athletes' physical and sports activities. P9 shared an article to inform other physicians about the use of a particular type of CT device.

In some cases, researchers shared articles because they were relevant to the research practices of researchers. Specifically, they shared articles relevant to several topics: research data management, research data sharing, writing habits, writing research proposals, open access, reproducibility, research data privacy, as well as communicating science with the public.

Overall, a strong theme that emerged was building and maintaining a professional image online. Most of the researchers I interviewed tried to tweet and retweet content that was "on-brand" (P13), in other words, content that was on topic with a certain focus related to their research topic, methods, and application aspects of their research.

In many cases, disseminating was the main purpose; however, in some cases, other purposes co-existed. For instance, P3 shared a scholarly article because of its topical relevance. At the same time, he also expressed his position in a controversy related to that topic. P9 tried to correct how the lay media interpreted a research article that might potentially change the practice of physicians and the expectations of patients in one medical setting, which she considered "very

dangerous" if the implication of the research was misinterpreted. P10 called attention to a classic paper introducing the history of the research method that he commonly used in his research. At the same time, he also acknowledged this work and recommended it to researchers who were also using this technique in their research. P13 shared a scholarly article relevant to both her teaching and research. P20 shared an article that had been recommended by a colleague via email on Twitter to a broader community. At the same time, she was also trying to acknowledge the recommendation by her colleague.

In addition to the motivations mentioned above, researchers also shared research for fun, for personal relevance, and out of personal intellectual interest. For instance, P11 shared a research article investigating the composition of lunar materials and commented that this article was fun. She also added the hashtag of #MakingScienceFunAgain when sharing this article. P15, a researcher in computational chemistry, shared research related to neutrinos in the area of Physics. P6 shared an article relevant to the reforms of the healthcare system in his country.

Similar to what has been described in Section 5.3.3.1, in academic conferences, researchers shared articles relevant to the conference presentations to inform those who did not attend the presentations. These included preprints of the research and the references mentioned in the presentations. As described in Section 5.5.1.1, this motivation also co-existed with the purpose of networking in some cases. Besides networking with the presenters or authors of the presentations, researchers sometimes also intended to disseminate information about conference presentations with other conference attendees who would potentially user Twitter (usually, hashtags) to browse information about presentations. The conferences in the critical incidents were found to encompass a wider range of conferences, including research-oriented conferences, practitioner-oriented conferences, discussion-oriented workshops, and tutorial-like lectures.

Last but not least, disseminating research findings to the public was also a major motivation of researchers in this sample. They believed that it was the responsibility of researchers to communicate scientific work for the benefit of society. This was mentioned by many researchers in the interviews. Particularly, all participants in Biomedical & Health Sciences emphasized their responsibility to communicate science, particularly health sciences, to the general public. In addition, participants in the areas of human-animal interaction (P16), parenting and education (P13), nutrition and exercises (P4) also highlighted their role as a researcher in the scholarly communication on Twitter. For instance,

> P9: "I believe that researchers, especially researchers who get public funding, for instance, NIH money, basically taxpayers funded their research. They have the obligation to disseminate their findings to the public. Sometimes I would peer pressure people to get on to social media to share their research."
>
> P8: "I was mainly tweeting in English to be able to reach a wider audience. But I'm a little conflicted because I also wanted to communicate with the public in my country. I think in a lot of cases, I was failing that."
>
> P13: "As a researcher, I wanted to make sure that I tweet things that are interesting and have scientific value. I wanted to be reliable and trustworthy. So I'm pretty conservative about what I put there, with the research and what I know as factual. I'm not going to say something that I couldn't defend."

Cases were found in a few researchers' tweets inviting the public to read the articles they shared. Some of them used hashtags like #OpenAccess or #FreeAccess. Sometimes they specifically point to the "plain English summary" (e.g., P16) inside the scholarly article. In some cases, they additionally shared a relevant lay media article for the public to read. P15, who

worked in the intersection of Computer Science and Chemistry, had been writing a science blog for over ten years. He had also been going to primary schools and middle schools to give lecturers to engage young students in science. Using Twitter to communicate science was a part but not all of his endeavors in communicating science with the public.

5.5.2.2 Commenting

Four different motivations related to commenting were developed in the coding process, including expressing opinions on related issues, calling attention to a misconception, relating to one's own work, and guarding science.

Many researchers commented on the scholarly articles they shared to express their opinions on an existing controversy, problem, or issue related to research. As was noted by P11,

> P11: "Well, I feel like, if we aren't saying it out loud, people might get the idea that everything in science is just, fine. Like, dissent within science is the only way that science is ever going to be what we wanted it to be. I think it is our job as a scientist to make sure that we are not complacent with the current state of science, and I don't want anyone to think that I love science as it is. It is flawed. I like what science could be."

P3 shared an article to support the consistent use of taxonomy in his field. P10 shared a long-existing debate in his field. Although the debate was still ongoing and would probably not result in a consensus, he would like to express his opinion and let people know about this debate. P15 commented on the use of terminology in his field and called for caution in using this term. P16 pointed out the importance of understanding the limitations of using statistical methods for a better interpretation of research findings. P13 corrected a typo in the first sentence of a scholarly publication by one of her colleagues and mentioned the publisher in her tweet. P16 retweeted to support a colleague's argument about an existing problem in their field. P17 retweeted a pre-

print article, which was criticizing another recent pre-print article. Although the authors of both of these pre-prints were "established and well-known" authors in her field, she commented that she wanted to support the second author. However, at the same time, she also thought that it probably be better if the authors of the second article could have communicated with those of the first article privately before openly publishing a piece to criticize them. She commented, "The first article, it was not a misconduct. They just didn't do it right."

Sometimes researchers commented on existing controversies, problems, or issues not related to their research per se. Instead, they were controversies, problems, or issues in science in general. For instance, three incidents of P11's were regarding the pervasive overworking of scientists, scientists being underpaid, and difficulties for women in science on the job market, respectively. P14 raised awareness of diversity by criticizing a current anthology in which women poets were underrepresented (not represented). P15, a male scientist, also advocated for women in science in his discipline. P17 expressed her hope for a more open data sharing environment, noting that the type of research data used in the article she shared could not be available for other researchers. P19 called for better conduct in research related to data privacy. P15 also tried to raise awareness about the difficulties for researchers in non-English-speaking countries to write and publish in English.

There were different opinions regarding how freely the researchers felt they could express their opinions. On the one hand, for instance, P16 believed that: "This is what Twitter is for. I can express my opinions. Take it or leave it." On the other hand, researchers were relatively more careful about what they said. Like what P7 noted: "Just like when you are on a public bus, you should be aware that what you say is public on Twitter." P13's analogy of using Twitter as a researcher was "I'm on my soapbox."

Correcting misconceptions was one of the major motivations of researchers when sharing scholarly articles on Twitter. The misconceptions that had been called attention to by this sample of researchers expanded many areas of research. These included existing misleading theories, misinterpretations about research findings, misunderstandings about certain phenomena, and common practices that were not grounded in science. For instance, P9, a practicing emergency physician, would skim 25-40 articles every week in fields that were related to her practice. When she was tweeting, she often chose an article that was "either controversial, or affirms or refutes to my biases, or, sometimes an article that I think is going to get a lot of attention from lay press but is actually trash." Some other researchers also had a similar motivation and sense of responsibility. For instance,

> P9: "I post a lot of articles that are good and people should read, or alternatively, are very bad, and people should be careful of."
>
> P13: "What I try to do is try to quote the article. You know, I don't want to say, well, 'I feel this…'. I'm still trying to keep it within the bounds of the research, but I'm deliberately selecting something that I think is consistent with the body of research that I know to be true."
>
> P16: "I'm very concerned that in my field there is a lot of misleading information online. In my case, for instance, the misinformation produced by the pet product industry. What they do is sometimes they will find studies and they will use them to push the idea that having pets is good for people… Like, if you have a dog or a cat you're going to be healthier or happier or stuff like that. I don't think that the data is so strong on that. So what I usually do is I will tweet studies that will conflict these media reports that pets are good for people. I'm not anti-pets, I'm just pro-science."

In many cases, researchers were trying to relate scholarly articles to their own research. They tried to infuse a discussion with the message or framework from their research lenses. Some were also promoting their research at the same time.

Lastly, there were a few cases in which researchers were trying to support science from anti-science incidents or viewpoints, coded as "guarding science" in this study. For instance, P7 was trying to call attention to an incident where a researcher in her country was attacked by the government because of this researcher's work on oil sands development in a lake ecosystem. She shared the research findings of that researcher on Twitter. P11 tried to recommend research on vaccination to his audience to support science on the Inauguration day of the new president of a country. P6 and P11 also tried to share research on climate change to support science.

5.5.2.3 Communicating with Intended Users

Although Twitter is an open platform, sometimes researchers used Twitter to talk with intended users instead of the entire body of their audience. This included colleagues, advisors, students, past and current collaborators, researchers sharing similar research interests, as well as practitioners and industry friends. They were relatively smaller networks inside the entire network on Twitter. P2 expressed how he valued this type of discussion:

> P2: "I don't want to create a bubble. I don't want to be isolated. If I don't agree with something, I want to share with people and to discuss with people. I think Twitter can be a place for me to engage with the ideas and communicate with my research network."

Specifically, three sub-categories of motivations were developed based on the Twitter interactions in this sample, including initiating a discussion, participating in a discussion, and recommending an article to specific users.

In some cases discussed in the interview, researchers tried to express their opinions or ask questions about articles by mentioning specific users. For instance, P8 provided constructive feedback about a pre-print article on Twitter by mentioning one of the authors of that article. After seeing that the author did not see this tweet on Twitter, he further emailed him to talk about this. P8 commented, "I felt comfortable tweeting to him publicly because we already know each other very well. I think it is healthy to provide feedback to researchers that I know, especially for pre-prints. This is what pre-prints are for." Another example was that P16 tried to tweet to a colleague about a study that did not replicate this colleague's research.

Researchers also participated in existing online discussions. Among these cases, there were cases when they were mentioned by people who wanted them to answer questions or provide insights; there were also cases when they proactively participated in others' discussions. An example of the former case was one of the incidents of P13's, when she responded to a journalist's tweet asking for recommendations about research articles on a specific topic in parenting. Meanwhile, P2 tried to participate in a discussion initiated by his former advisor about a relevant research question.

Recommending research articles to specific users was also common. Some participants, e.g., P6 and P19, had multiple cases of recommending research to other users. They shared research with their colleagues or students as "FYI" ("For Your Information") with no intention to initiate a discussion and no expectation of seeing their responses. A few researchers commented mentioning on Twitter was less intrusive compared to directly emailing the people. For instance, P6 would tweet relevant articles to an important policymaker in the department of health in his country, who was also his acquaintance, because he did not want to intrude.

5.5.3 Acknowledgement

Acknowledgment was developed as a separate category of motivation in the analysis. However, it is a category that co-existed the most with the other categories. Almost all researchers in this sample had incidents of acknowledging the scholarly article they tweeted or retweeted, in diverse ways.

There were multiple cases where researchers highly recommended the works they shared both in their tweet text and in the interview. They used phrases including “high-quality” (e.g., P1, P5, P12), “classic paper”(e.g., P8, P10), “great review article”(e.g., P10, P13, P18), “a guideline-type article” (e.g., P19), “must-read” (e.g., P8), “fascinating research” (e.g., P13), and so on to appraise these articles.

In addition to these cases, researchers also acknowledged the articles they shared for other specific reasons. For instance, P1 recommended an article of a researcher because the researcher was her “hero” as an academic role model. P7 recommended an article because it had a nice graph so that people could read the main findings of the article easily. She also shared the figure in her tweet in addition to the link to the article. P9 acknowledged an article because of the clinical importance of the research findings. P10 recommended an article as it provided better understanding of a technique from a historical point of view. P13 recommended an article that can be used as a good example in teaching the relevant subject. P19 appraised an article which was using the same technique that she had used to analyze a more complex dataset. During a time period of two years and a half, P20 tried to use the hashtag of #paperoftheweek to constantly recommend articles for her audience to read.

A few participants mentioned that acknowledging other's work was also relevant to maintaining a positive and professional presence online. For instance,

P5: “I increasingly feel, actually a little irritated or downbeat, because people increasingly, it seems on Twitter, tweet negative things – you know, problems in the world. I really don’t like it when people are being super negative. It is not helpful, and uncollegial. Acknowledging others' work is very important in science.”

5.5.4 Saving for Later Reference

Saving articles for later reference by tweeting and retweeting them was used less frequently than using the “liking” functionality on Twitter to do this (see Section 5.3.3.4). However, it was mentioned by some researchers in our sample. For instance, P10 shared a technical report about a technique, intending to save it for later reference when they needed to use that technique. P19 tweeted an article from a conference to remind himself to read later as time was limited during the conference. P20 also tweeted an article to remind herself to print it out and read later on her “reading day.”

In one of the critical incidents of P3’s, he included a link of an article with no additional context in the tweet. He explained that he did that when he was on the bus to work and found the article was behind the paywall. To be able to remember to read the article, he saved the article in the tweet and later opened the link on his laptop on campus.

5.6 Impact of Tweeted and Retweeted Scholarly Articles

In the interview, I also tried to explore the impact of the shared articles on the researchers who were sharing them. In total, 200 instances of tweets and retweets (147 tweets and 53 retweets) were used to facilitate my interview with the participants and to help them better recall the context of their tweeting and retweeting acts.

As been discussed at the beginning of Section 5.3.3 and Section 5.4.4, the exact prevalence of codes and categories was not reported in this section due to the qualitative nature

of this part of the study. Instead, this study used consistent conventions of "a few" (0-4; 0-20%), "some" (5-9; 25%-45%), "many"(10-14; 50%-70%), "almost all" (15-19; 75%-95%), and "all" (20; 100%) in reporting the results, as was suggested in previous research (Braun & Clark, 2006; Chen, 2018).

Although this part of the exploration was qualitative in nature, it should be noted that in 113 cases out of these 200 cases, researchers reported that the articles they shared on Twitter had no impact on their own works. Therefore, the following analysis was based on 87 Critical Incidents of theirs.

This study resulted in the construction of five categories of codes representing the impact of the shared articles to the researchers who shared them on Twitter. They are: informing, connecting, practice-changing, beyond research, and potential impact. The coding scheme is attached in Appendix VII.

5.6.1 Informing

Five sub-categories of impact were developed for the category of informing: contributed to the cumulative knowledge base, supported the interpretation of findings, inspired further ideas, confirmed ideas, and learned/improved research methods.

5.6.1.1 Built Knowledge Base

Researchers reported that the articles they shared had provided help in their understanding of a topic, problem, or issue in areas relevant to their research. P1 discussed how an article helped her better understand the application of her previous research. P8 said that an article he shared helped him better understand a long-existing debate in his field. P10 was trying to understand the history behind a model that he was using in his research. This model did not originate from his discipline but was nowadays widely applied in the research in his field.

Although that article was not directly related to the use of this model, he commented that it was helpful for him conducting this "deep background research."

> P10: "I think that papers, especially old papers from not in your discipline, don't get read enough… I was really fascinated with paper like this. Tracing the idea that we hold near and dear in science, and like going backward in time and seeing how it's formed, what criticisms of it are, things like that… It gave me an understanding why it was used and what people thought of it. If I got critiques of it in the peer review process, like if somebody said oh you cannot use this model because x, y, and z, I'll just go back and say, well, it has been critiqued on this standpoint and this standpoint, and this was what people said. It was me doing the research to make sure that I understood the problem well enough that I can defend and argument I was making."

5.6.1.2 Learned/Improved Research Methods

Some articles that researchers shared provided help in their learning or improvement of a technique, tool, or research method in general in their research. For instance, P3 reported that the method in a paper that he shared on Twitter largely informed the method that he was using in a current research project. P8 discussed how the technique he learned from an article helped with his research design in one of his recent research projects. P10 had been thinking about using a technique in his research but did not have enough time to explore the feasibility. An article he shared managed to do that. He commented, "It didn't get me thinking about using this technique, but it was good to learn that this can be done." P11 learned about a better technique that she could reapply to her doctoral research and commented that she had been using this technique until today. P18 was having difficulties using a tool in his research. His colleagues recommended

a paper for him as a tutorial for the method. He found it much easier learning from this article and shared this article on Twitter for others who might find it helpful.

5.6.1.3 Supported the Interpretation of Findings

A few researchers reported articles they shared helped support the interpretation of findings in their research. One of them was the example mentioned earlier by P8. He provided constructive feedback for a relevant pre-print article by mentioning the author on Twitter; they had further discussions about it via email. The author later improved this article according to his feedback. Meanwhile, this same article resulted in a better understanding of the research findings in P8's research. Another example was discussed by P20, which she reported to have cited in "two to three papers."

5.6.1.4 Confirmed Ideas

A few articles were reported to confirm the ongoing ideas or doubts of researchers. For instance, one of the articles that P11 shared confirmed the preliminary findings of her doctoral research when she in her doctoral program. This article strengthened her determination to continue with her research, although one of her committee members was against her idea at that moment. She commented that she tweeted this article because this article was "close to the bottom of her heart." Another example was what was described in Section 5.6.1.2 in P10's case. P10 confirmed his idea of using a technique in his research from one of the articles he shared. Later, he was able to replicate the technique in his own research.

5.6.1.5 Inspired Further Ideas

Researchers reported cases where the articles they shared provided inspirations for them to think critically or creatively about a topic, problem, or issue in areas relevant to their research. For instance, P8 shared an ongoing debate in his field about if fish could feel pain or not.

According to him, this was not only a technical question but also a philosophical problem. Although his own research found that fish could feel pain, he shared an article arguing that fish cannot feel pain. After continuous pondering on this topic, he published a commentary article in a journal elaborating more on this topic. P10 discussed an article he shared that was published by one of the earliest researchers in his field. This article inspired him to think more critically about his current research. P2 also discussed an example where he used "generative" to describe the inspirations the article had on his research later on.

5.6.2 Connecting

In the interview, researchers reported nine cases where sharing the articles helped them connect with a collaborator or strengthened their relationship with a collaborator. In this category of "connecting," the articles that researchers shared were relevant to their research. More importantly, the act of sharing the articles on Twitter helped connect with their collaborators.

5.6.2.1 Developed Collaborative Relationships

Some researchers described cases where tweeting or retweeting an article provided help in connecting them with a collaborator. For instance, P2 reported getting to know and collaborate with a researcher by participating in an online discussion initiated by his former advisor. They published an article together later on. P3 shared an article using a "cool" technique that could be applied to his research. After some preliminary discussions on Twitter, he and his students reached out to the author of that paper via E-mail and invited him to participate in their research. So far, that researcher had contributed to two of P3's research projects. In addition, P18 reported a case where tweeting a researcher's work at a conference helped him build a connection with that researcher. Even after that researcher moved to another country later, they had been keeping a collaborative relationship with each other.

5.6.2.2 Maintained Collaborative Relationships

A few researchers discussed cases where sharing articles facilitated continuous collaborations with existing collaborators, particularly collaborators that they were not able to interact with very frequently. Specifically, they mentioned researchers, practitioners, and industry partners as collaborators. For instance, P3 shared an article authored by a researcher that he had worked with before. The article he shared was also relevant to his research. They continued to collaborate with each other later on. In the case discussed in Section 5.5.1.1, P14 shared an article with an art institute that had been providing lecturers and internship opportunities to her department. She shared this article with them because it was relevant to a part of their strategic development. The art institute's account replied to her tweet thanking her for sharing this article with them.

5.6.3 Practice-Changing

Researchers described cases where the shared articles provided inspirations, guidelines, or support to change their research practices.

P7 shared an article on open access and had one of her students lead the discussion in the weekly lab meeting to talk more about open access in research. Being an ecologist, she continued to work with her university library on topics related to open access and institutional repositories.

P1 talked about attending a conference presentation, where she learned more about better practices in research data management and sharing. P8 shared a story behind an article on data transparency that he shared on Twitter. In P8's research, he conducted experiments with zebrafish, during which he gradually felt the need and potential benefit of having a large database integrating zebrafish related research data in a wide range of research projects. After he read this article on data transparency, he tried to work with one of his colleagues to build a

nation-wide consortium based on which an open database of zebrafish related data could be shared. Although the consortium did not work out by the time of the interview, he still thought it would be beneficial to zebrafish related research in his country to have such a database. P10 also discussed how he was trying to see how he could follow the practice guidelines recommended by one of the articles he shared for better research reproducibility and data reusability in this research. P11 discussed how an article about research data management inspired her to start working on improving the automation of storing and managing the research data in her work.

5.6.4 Beyond Research

Beyond research, researchers talked about using the articles they shared on Twitter in their teaching, mentoring, and other activities.

5.6.4.1 Used in Teaching

Researchers used articles they shared on Twitter in their teaching as reading materials or examples. A few researchers reported that one of the articles they shared was what they used in their teaching "all the time." P10 shared an article based on which his former lab mate developed an important lesson plan for middle school students. One of the articles P16 shared was on the rubber tail illusion phenomenon in mice. He had demonstrated this experiment multiple times in his class. Two researchers commented that they should and would incorporate one of the articles mentioned in this interview in their current teaching.

5.6.4.2 Used in Mentoring

Researchers also used articles they shared on Twitter in their mentoring work. They reported recommending the articles to their students to read and discuss. This included not only articles relevant to their students' research content but also in research practices. For instance, P7 commented, "I am also modeling how to do research for my students."

5.6.4.3 Used in Practices

Researchers described cases where the shared articles were used in their practical activities. Particularly, in many cases of P4 and P9's, they used the articles to provide data-driven or evidence-driven recommendations for practitioners and practicing physicians. In their cases, all of the articles were in medical and health-related domains.

P7 remembered mentioning one of the articles she tweeted in a committee meeting in a human-wildlife conflict conference. The findings of that article provided some evidence on a better understanding of this subject matter.

Researchers also reported using the articles to engage more attention in their research fields. For instance, two articles shared by P11 she frequently used when introducing the importance of her research to lay audiences or researchers in other fields. P15 developed a blog post based on one of the articles he shared to promote computational approaches in the field of chemistry. P16 introduced the findings of one of the articles he shared on Twitter in his popular science book.

5.6.5 Potential Impact

In addition to the various types of impact discussed in the previous sections, there were also cases where researchers commented that the articles they shared would potentially impact their research activities. For instance, P2 shared an article introducing a tool that he wanted to learn and use in his research. He commented, "I didn't specifically have the expertise in this area, but I could see this tool could be very helpful for my research further down the line."

Some other researchers indicated that some articles they shared would potentially impact their research, but they "did not have time for it yet" or "did not go that direction" (e.g., P2, P5, P3, P9, P10, P12, P14, P17, P18). In these cases, these articles were generally related to their

research areas but not directly related to their research projects. For instance, P5 mentioned that he should revisit one of the articles he shared because it became very relevant to his current research. In some cases, researchers were not able to use the articles in their research because of other uncontrollable reasons. For instance, P17 commented that if she were able to have access to the data used in one of the articles she shared, she could be able to apply her analytic approach in that data, which might lead to new findings.

There were a few cases where researchers reported that the articles they shared on Twitter might lead to potential collaborations in the future, depending on the focus of their future research agendas (e.g., P14, P20).

CHAPTER 6: DISCUSSION

6.1 Summary of Findings

This dissertation study explored researchers' activities around scholarly articles on Twitter. Using a mixed-methods design, this study analyzed data collected from a large-scale survey and twenty semi-structured interviews. The Critical Incident Technique was used as part of the interview study to learn about the full stories behind researchers' sharing of scholarly articles on Twitter. Through the lens of the exploratory framework of Digital Trace of Scholarly Acts (DTSA), this study contributed to a better understanding of the digital traces left by researchers on Twitter by providing richer descriptions and narratives of their activities.

The following four sections briefly summarize and discuss the results for each of the four research questions.

6.1.1 What opinions do researchers have on the scholarly articles they interact with on Twitter? (RQ1)

There were variations in the researcher's sentiment of opinions on articles they tweeted, retweeted, replied, and liked, based on their demographics.

Overall, younger researchers or researchers in relatively early-career stages seemed to have a neutral opinion on the articles more often than older ones. For instance, researchers in their 20s had a neutral opinion towards the articles they liked in more cases compared to those in other age groups. When retweeting an article, early-career researchers had a neutral opinion about it in more cases compared to researchers in other positions. This may be due to younger

researchers are more familiar with sharing through their more extensive social media use, and more prone to similarly sharing in scholarly situation even when neutral about the item shared.

Compared to male researchers, female researchers seemed to more frequently have a positive opinion when communicating scholarly articles on Twitter. Specifically, female researchers in more cases had a positive opinion on an article when they were tweeting, retweeting, replying to, and liking it compared to male researchers. On the contrary, male researchers in more cases had a negative opinion on an article they tweeted, retweeted, replied to, and liked. Male researchers also tended to have a neutral opinion in more cases when they were replying to an article. This may be relevant to the findings in some existing research that communication in women's relationships is more empathetic and nurturing than men (Sapadin, 1988; Cross & Madson, 1997). In the interviews, four female researchers mentioned they would like to maintain a positive image online, but only one male researcher mentioned this. On a conflict-aversion view, women may participate less in discussions that are potentially conflictual, while men may seek the opposite or be less affected by this dimension (Smith-Lovin & Brody, 1989; Mendelberg & Karpowitz, 2016). It was also possible for female researchers to do this to avoid online harassment and cyberbullying that occur more generally in social media (Megarry, 2014).

Researchers in North America and Oceania seemed to more frequently have a positive opinion when communicating scholarly articles on Twitter. More specifically, they felt positive about an article they tweeted and retweeted in more cases than those in South America and Europe. In terms of replying, Oceania researchers most frequently had a positive opinion on an article they replied to. Researchers in South America felt positive about an article they replied to in fewer cases compared with those in Africa, North America, and Oceania. Similarly,

researchers in South America also had a positive opinion on an article they liked in fewer cases compared with those in North America, Oceania, and Europe.

Researchers in Biomedical & Health Sciences and Social Sciences seemed to be the most critical when they were communicating scholarly articles on Twitter. When tweeting an article, researchers in these two areas tended to have a negative opinion on it in the most cases. Researchers in Physical Sciences & Engineering had a negative opinion on it in the least cases. Similarly, when retweeting, those in Biomedical & Health Sciences and Social Sciences also had a negative opinion on the article in more cases than researchers in Physical Sciences & Engineering and Life & Earth Sciences. The same pattern was found again in the case of replying to a tweet containing a scholarly article. This might be reflective of the outward-looking culture of applied social sciences when the critical and evaluative function is performed online in a larger community of discourse (Becher, 1987; Becher, 1994). In addition, the research findings in these two disciplines are more directly relevant to people's everyday lives compared to other disciplines because their relevance to health-related and social related issues. Thus, they are probably the most prone to generate potential negative impact on society in case of the dissemination of misconceptions or misinterpretations of the findings. In the interviews, researchers in these two disciplines expressed a strong feeling of concern and responsibility to correctly and clearly communicate issues and findings of which they were trained to have a better understanding with the lay audience.

Several clusters of researchers were detected in terms of tweeting, retweeting, replying, and liking, which indicated that researchers used Twitter very differently. In the interviews, it was also found that researchers' different perceptions about these acts resulted in their different patterns of acts. For instance, they had different opinions on whether these acts equaled to

endorsing. Many interviewees reported that if the people tweeting the academic articles were a trusted expert in their field, they would feel comfortable tweeting the article without reading it, or even without reading the abstract of it, which indicated the important role of academic capital in the scholarly communications on Twitter. In addition, most researchers felt comfortable liking tweets containing a scholarly article without reading the articles. Meanwhile, they had more diverging opinions about replying. Researchers also expressed different opinions about using Twitter for promoting purposes.

Despite the different patterns found among researchers, there was an overall positive tendency in researchers' sentiment of opinions on the articles. There were slight gradations of different sentiment among the clusters.

It is important to note the sometimes blurred boundary between the positive and neutral sentiment, particularly in social interaction related purposes, including promoting, encouraging, and generally connecting with others.

6.1.2 How does sharing (tweeting and retweeting) scholarly articles on Twitter fit into researchers' workflows? (RQ2)

There were variations in how sharing scholarly articles on Twitter fit into researchers' scholarly acts workflow, based on their demographics.

Overall, researchers in their 30s searched for information about the authors of the papers in more cases compared to relatively more established researchers. Comparisons based on positions also revealed similar findings. Specifically, early-career and pre-tenure researchers searched information about the authors in more cases compared to tenured researchers. This was found in both tweeting and retweeting. In addition, early-career researchers also looked at the online discussions about the articles in more cases than tenured researchers, which was also

found in both tweeting and retweeting. This might be due to their early career stage, during which the junior researchers are not as familiar with researchers and their research in their fields as the senior researchers.

Tenured researchers also tended to both save and organize the articles they shared in fewer cases compared to early-career and pre-tenure researchers. Maybe early career researchers are more focusing on building and organizing their personal library of relevant scholarly articles than senior researchers. For instance, as suggested by Gingras, Larivière, Macaluso, and Robitaille (2008), researchers tend to actively follow the literature and accumulate references until they are about 40; after that, they more likely reuse their accumulated sets of references in their research.

Additionally, researchers in their 30s cited the papers they shared in more cases compared to relatively more established researchers. This might be caused by the shift of roles of researchers in their career path. For instance, Gingras and colleagues (2008) investigated the effect of aging on Quebec university professors' publication patterns and found that older professors published fewer first-authored papers and moved closer to the end of the co-authors list. In this process, they might gradually take less role in writing and referencing scholarly articles, particularly in STEM disciplines.

Other differences were also found in the comparisons based on positions. One of the major findings was that researchers in other sectors (including "Clinical researcher or physician," "Government researcher," "Industry researcher," and "Non-profit or Non-government organization researcher") both saved and organized the articles they shared on Twitter in fewer cases. This was found in the cases of both tweeting and retweeting. Similarly, they also tended to cite the articles they tweeted and retweeted in fewer cases. This might be reflective of the

different focuses of their job responsibilities, which require less publishing of articles compared to that of most academic researchers.

Compared to female researchers, male researchers tended to skim the articles after sharing them; female researchers tended to skim or read the articles before sharing them. In the interview, one female researcher (P7) repeatedly emphasized the importance of being cautious with her acts on Twitter, particularly around scientific information in her field. She felt the obligation to read all articles before sharing, replying to, and even liking them. She also felt she was constantly modeling for her students in communicating science online. In addition, it seemed that female researchers tended to save articles after tweeting them in more cases; they also tended to cite them in more cases after retweeting them.

Researchers with different educational backgrounds also had different patterns. Overall, doctoral degree holders looked at the online discussions about the articles they shared in fewer cases compared to professional degree holders and master's degree holders. Maybe doctoral degree holders feel less compulsory to look for affirmation of their thoughts on the articles through the online discussions. Meanwhile, doctoral degree holders tended to both save the articles and cite them in more cases after sharing them. This is relevant to the expected role of most academic researchers, in that their research workflow more typically include saving and citing discovered articles in their research manuscripts and teaching materials.

There were also variations among researchers in different disciplines. Overall, it seemed that Biomedical & Health Sciences researchers read the articles they shared in depth the most. They also liked to look at the online discussions about the articles they shared the most compared to researchers in other disciplines. However, they searched for information about the authors of the articles they shared the least often. They also saved the articles the least often. These were

found in both tweeting and retweeting. This corresponds to the findings in the interview, where Biomedical & Health Sciences researchers discussed their awareness of the obligation to engage in online discussions of scientific articles. They believe their role is critical in the translation of biomedical research to physicians, medical practitioners, and the public, as has been discussed in Section 6.1.1.

In addition, Life & Earth Sciences researchers tended to save and organize the articles they shared in the most cases, which was also found in both tweeting and retweeting. Social Sciences researchers tended to save the articles they shared in relatively fewer cases. Researchers in Social Sciences and Mathematics & Computer Science tended to search for information about the authors of the papers before tweeting in more cases.

Comparisons based on the geospatial locations of the researchers showed that overall, researchers in South America seemed to look at the online discussions about the article they shared the most frequently.

Further analyses on the relationships between these acts showed that saving, organizing, and citing seemed to be more correlated with each other compared to other acts. For most people, saving and organizing is probably part of the same process, with the goal of capturing information for further reuse. In the interview, one participant (P10) was trying to recall if he saved the article mentioned in the tweet. He started searching in his local folders and found it in the designated folder, with the file name unchanged from his previous downloading. He commented that his goal of saving and organizing articles was to be able to find an article in a very short time just as the time he had when we were conducting the interview. The relatively high correlation between saving/organizing and citing might be suggestive of the usefulness of

reference managing tools, which connect the preservation of scholarly works and the creation of new scholarship.

Looking at the online discussions about the articles was correlated with searching for author information relatively more strongly. Twitter is an open platform featured with crowdsourced information and democratized comments. Researchers participating in the online dissemination and discussion of scientific information on Twitter creates a unique environment coupled with but different from the more traditional scholarly communication environment through publications or conferences. This online environment is not limited to the sphere of Twitter but covers a broad range of online platforms, including researchers' university or personal websites. In the interviews, many participants mentioned trying to find the authors of articles they shared on Twitter or trying to find their university/personal websites to learn more about their works.

Which acts associated with an article tend to occur before researchers share them on Twitter? Which acts usually occur after they are shared on Twitter as opposed to before? Citing an article is the only act that occurred more often after sharing as opposed to before sharing, in the case of both tweeting and retweeting. Most of the other acts occurred more often before sharing. The only exception was looking at online discussions about the article, which occurred more often after tweeting but more often before retweeting, probably due to the convenience of looking at the online discussions when an article was already previously tweeted by others.

Last but not least, the occurrences of scholarly acts associated with tweeting and retweeting were significantly different. Looking at the online discussions of the article before sharing it occurred more in retweeting than tweeting, due to the easy availability of online discussions before retweeting. However, all the other acts occurred more frequently before

tweeting than retweeting. Similarly, after an article is shared on Twitter, all acts except for skimming occurred more after tweeting than after retweeting. This included reading in depth, looking at the online discussions, searching for information about the authors, saving, organizing, and citing the article. It seemed that researchers tended to be more engaged when tweeting a scholarly article compared to retweeting an article.

6.1.3 What are the motivations behind researchers' sharing of scholarly articles on Twitter? (RQ3)

Motivations behind "citing" others' works in the online sphere were different from those behind citing others' works in scholarly publishing. Behaviors were classified into seven categories during the analysis: networking, promoting, disseminating, commenting, communicating with intended users, acknowledgment, and saving for later reference.

Sharing scholarly articles to build social relationships was common among the researchers in this sample. Cases were reported about successfully building new relationships on Twitter and maintaining existing relationships. Different types of promotions, including self-promotion, promoting a colleague, promoting a journal, and promoting an institute were discussed. In promotion, there was a spectrum from the more altruistic promotion to promotion purely for institutional reasons. Some researchers believed that promoting other researchers on Twitter was a reciprocal process and was beneficial to building a professional network for themselves. Networking with other researchers and promoting other researchers tended to be interrelated with each other especially when the researchers were in a similar career stage.

Many researchers were willing to add to the crowd-sourced wisdom by disseminating scholarly articles on Twitter, sometimes with their comments. In the commenting category, the major motivations of commenting identified were expressing one's opinion on a related issue,

calling attention to a misconception, relating the research to one's own works, and guarding science. When sharing scholarly articles with comments, many researchers intended to share the information with not only their research community but also a broader audience. In some cases, the articles they shared were related to problems and issues in science which were relevant to the whole science community; they also shared problems and issues in the entire society which were relevant to everyone's daily life.

There were also cases where researchers were using Twitter to communicate scholarly articles with a certain user or a certain group of users, including initiating a discussion, participating in a discussion, and sharing an article to specific users with no intention or expectation to initiate a discussion.

Acknowledgment co-existed with many codes in the other categories. Almost all researchers in this sample had incidents of acknowledging the scholarly article they tweeted or retweeted, in diverse ways.

6.1.4 Do the scholarly articles shared by researchers on Twitter have an impact on their own work? (RQ4)

Based on the critical incidents, five categories of impact were formed in the analysis of the impact of the shared articles on the researchers who shared them. They included: informing, connecting, practice-changing, beyond research, and potential impact. In 113 cases out of these 200 cases, researchers reported that the articles they shared on Twitter had no impact on their own works. Therefore, the analysis was based on 87 Critical Incidents of theirs.

The categories of "informing," "practice-changing," and "beyond research," describes the impact of researchers' shared articles on their research, teaching, mentoring, and practices. However, it should be noted that the second category, "connecting," describes not only the

impact of the shared articles on the researchers' works but also the additional effect of the act of sharing the articles on Twitter. Specifically, researchers reported nine cases where sharing the articles helped them connect with a collaborator or strengthened their relationship with a collaborator. Although no other type of impact was found owning to the interactions on Twitter (e.g., receiving feedback, recommendation, or inspiration in others replies) in these two hundred Critical Incidents, interactions in other means including email, phone call, and in-person meetings were discussed by the participants. This pointed to the limited role of Twitter as a single band of communication in a larger scholarly communication landscape.

On Twitter, researchers shared scholarly articles that informed their own research by different means. Some articles contributed to their cumulative knowledge base by providing help in their understanding of a topic, problem, or issue in areas related to their research. Some articles helped them learn or improve a technique, tool, or research method in general. Some articles supported the interpretation of findings of their ongoing research by providing additional evidence related to their works. Some articles inspired them to think critically or creatively about a topic, problem, or issue in areas relevant to their research. Some articles confirmed their ideas or doubts in their research.

Another dimension of impact was that some articles changed researchers' research practices, including a wide range of aspects like research data management, data sharing practices, and open access publishing. In the long run, these changes would benefit not only their own research but also the entire scientific body. The impact of the articles on research practices also fostered the primary goal of science.

Researchers also talked about using the articles they shared on Twitter in their teaching, mentoring, and practices. Translating research to provide evidence-based recommendations in practice was particularly meaningful in health-related areas.

Sharing articles on Twitter also helped them with building or maintaining collaborative relationships in their research community. This confirmed with the findings in their motivations behind sharing articles on Twitter.

Investigating the impact of the articles for the researchers lead to a better understanding of what types of articles had a higher premium of sharing for researchers, and how different these articles were from the most highly tweeted articles, which were usually "trendy."

6.2 Reflections on the Methods

6.2.1 Using Self-report in the Survey

Due to the limited availability of publicly accessible digital traces in most online platforms, this study aimed to experiment with exploring a sample of scholars' scholarly acts across platforms based on their self-report. Specifically, this study targeted researchers who were Twitter users. There are several advantages of using self-report in surveys. First, it is an inexpensive and relatively more efficient way of obtaining data. With the aid of electronic survey tools like Qualtrics, this study was able to reach a wide variety of research subjects than could be reached by other methods. More importantly, the self-reports can be made in private and can be anonymized to protect sensitive information and perhaps promote truthful responses. If not relying on self-report, it would be difficult, if not impossible, to obtain the footprints of their other scholarly acts (e.g., reading, saving, citing) on a relatively large scale.

However, self-reports have drawbacks due to factors including respondents' misunderstanding of questions, degree of devotion to the survey, inability to recall past events

accurately, instability of opinions and attitudes, as well as the lack of truthfulness (Dixon, Singleton, & Straits, 2016). Because the survey in this study heavily relied on self-report from the respondents, which might cause biases, caution needed to be used in the analysis and interpretation of the data. Previous research has recommended using self-report in conjunction with other methods (Fan et al., 2006). So, in this study, a test-retest approach was employed to assess the reliability of operational definitions. Specifically, for the 20 interview participants, their responses in the survey were cross-compared to their responses in the interviews as a data triangulation approach.

There were two levels of comparisons. The first one was between two types of self-reports: answering an online survey on the laptop or cellphone and talking to an interviewer. In this comparison, no significant unreliability was found. When asked about the rationale behind their survey responses in the interviews, their answers were specific and grounded in their previous descriptions of relevant questions. The second level of comparison was between reporting general behaviors and discussing specific incidents. In this comparison, only one participant (P19) commented not remembering the stories in multiple cases. Except for P19, the other participants all told detailed stories behind their critical incidents. Their answers also corresponded to their "typical activities" of workflow answered in the survey. This multi-method approach provided a more global and therefore likely more accurate picture of the stories.

6.2.2 Reliability Checking in the Survey Data

In addition to the multi-method checks conducted in the previous section to examine the reliability of self-report, another approach of reliability checking was conducted on the survey data. Specifically, in the survey, the researchers were asked: "When you posted tweets regarding scholarly articles, how often did you have a positive/neutral/negative opinion of the articles?"

This same question was asked four times regarding the four acts of tweeting, retweeting, replying and liking. In the survey data cleaning process, the answers from the participants were checked to see if there were contradicting or incongruent patterns of answers based on logic. For instance, one cannot always have a positive opinion on the articles they tweeted while at the same time always having a neutral or negative opinion on the articles they tweeted. In total, seven types of responses were identified and further examined. The process of data cleaning is described in more detail in Appendix IV.

This further examination revealed some unreliable and therefore erroneous data, which were deleted from the analysis. Meanwhile, it also revealed some problems in respondents' interpretation of the survey questions. These might be due to the different introspective abilities of the participants, their degrees of devotion to the survey, or due to the wording and design of the survey.

Overall, two problems were found (and discussed in Appendix IV). First, in very few cases, participants might overuse "Always" and "Most of the time." Particularly, "always" should mean and did mean "in all cases" to the majority of the participants. However, it seemed that in some cases, participants might "always" have a positive opinion on the articles they tweeted but at the same time additionally "sometimes" had a neutral opinion on them. Secondly, in a few cases, participants tended to overuse "Rarely" or "Never" for the acts that did not conduct very frequently in general. In the design of the survey, the anchors here ("Always," "Most of the time," "Sometimes," "Rarely," "Never") should be in relevance to all cases within the four categories of acts. However, if an act was conducted very infrequently by a participant, it was possible they might answer "Never" or "Rarely" to all categories of "Positive," "Neutral," and "Negative."

An additional minor problem was found based on the responses regarding the act of liking: a small number of participants "sometimes" had a positive opinion on the articles they liked while "sometimes" had a negative opinion on the articles they "liked." While this might truly reflect their behavior, it is also possible that this was due to careless responses. Being the fourth question in a series of similar questions, there was a possibility that some participants provided this response due to the patterns of their answers in the previous three questions, which was similar to the straight-lining behavior when responding to surveys.

6.3 Other Limitations

There were various limitations of this study. First, there were several sources of bias in the sample. The selection of the target survey audience relied on the authorship of articles indexed in Web of Science. This approach might lead to the underrepresentation of certain disciplines. For instance, Mongeon and Paul-Hus (2016) find that biases of coverage existed in Web of Science that favor Natural Sciences and Engineering as well as the Biomedical field to Social Sciences and Arts and Humanities. However, Costas et al. (2017) discussed in their paper that in this sample of researchers on Twitter, a relatively strong presence of researchers in the Social Sciences and the Humanities was found compared to the coverage of Web of Science. Meanwhile, Natural Sciences researchers were underrepresented the most on Twitter. In another systematic identification of scholars on Twitter which did not rely on any bibliographic databased (Ke et al., 2017), it was found that social scientists were overrepresented on Twitter and that mathematicians were particularly underrepresented. This was similar to the composition of the survey sample in this study.

Second, the reliance on existing authorship may also to some extent overlook early-career researchers. Costas et al. (2017) discussed in their paper that the researchers identified to be

active on Twitter tended to be younger than those that were not on Twitter. Third, because English-language journals are overrepresented compared to other languages indexed by Web of Science (Van Leeuwen, Moed, Tijssen, Visser, & Van Raan, 2001; Archambault, Vignola-Gagné, Côté, Larivière, & Gingrasb, 2006; Mongeon & Paul-Hus, 2016), it was also possible that researchers in non-English speaking countries and countries with a relatively shorter history in academic publishing were underrepresented in this study. This, in particular, would lead to the underrepresentation of researchers in developing countries.

In the data collection process of the survey, there were both a potential coverage bias and a potential nonresponse bias. Coverage error was due to incomplete sampling frames due to the availability of data. For instance, there was the absence of a good frame for sampling Chinese researchers, as Twitter was not accessible in mainland China. A nonresponse bias might also exist for researchers with certain characteristics, for instance, researchers in non-English speaking countries probably feel less inclined to respond to an English survey in a recruitment email written by English. In some countries like China, there are alternative platforms that are similar to Twitter, for instance, Weibo.com, on which researchers mainly use Chinese in their online communication. Exploring how researchers use these platforms might be an important future direction to this research.

Another limitation of this study was that all the interviews were conducted on the phone. Qualitative research has a high requirement for the observational, interactive, and interpretive skills of the researcher (Dixon et al., 2016). It might be easier to establish rapport in a face-to-face interview, especially when we had ten critical incidents to go through, about each the same questions were asked repeatedly.

CHAPTER 7: CONCLUSION

7.1 Theoretical Implications

Current altmetric indicators have been somewhat "extrapolated" from citation-based approaches. However, the lack of understanding of the acts associated with these digital traces can cause problems in using altmetrics for impact assessment. Studies on these acts were needed to add to the understanding of these digital traces, just like how the in-depth investigations of citation motivations (see the Literature Review section) were needed in a better understanding of the meaning of citations and responsible uses of citation-based metrics.

In the construction and evaluation of citation theories, extensive empirical studies were conducted. This dissertation study attempted to take a preliminary step towards the theory development around traces created around scholarly articles on Twitter. Through the lens of the exploratory framework of Digital Trace of Scholarly Acts (DTSA), this study contributed to a better understanding of the digital traces left by researchers on Twitter by providing richer descriptions and narratives of their activities. The in-depth interviews provided a basis for theoretical inference on the motivations behind researchers' sharing of scholarly articles on Twitter. The better understanding of the motivations and the impact of the articles can also potentially enhance the confidence and interpretations of metrics based on the digital traces of these acts on Twitter.

In the context of citation-related research, the impact being investigated was normally the impact of the cited article on the citing articles and their authors' research. On Twitter, sharing articles publicly with the potential of receiving interactions and feedback timely entails more

sociological influences. Specifically, the impact of a scholarly article "cited" in a tweet is threefold: First, there is the impact of the article on the researchers who were tweeting or retweeting them. This article might influence various aspects of their research, teaching, and practices. Second, this article might have an impact on the audience of this tweet or retweet. Third, potentially, the follow-up interactions after the initial Twitter act might bring benefit to the researcher (for instance, a follow-up conversation that informs them, or a new connection in their research network). This type of impact is not easily seen through digital traces but can be discerned from interviews with researchers. Researchers who tweeted an article might have a better idea about what impact the article might have on their audience; this might be reflected in some dimensions of their motivations in deciding to tweet the article. Therefore, understanding their motivations was also helpful for a better understanding of the impact of the scholarly works on other audiences.

Based on the explorations of motivations and the impact of the shared articles on the researchers' own works, evidence was observed to support both the normative theory (Kaplan, 1965) and the social constructivist theories (Gilbert, 1977) in researchers' sharing of scholarly articles on Twitter. The role of the *actor* in the Twitter DTSA framework is of particular importance given its proximity to other users on Twitter. Compound sentiment might be found to be associated with a particular act because of the actor. For instance, a researcher liking a tweet containing a scholarly article might indicate their sentiment towards the article, and (or) their sentiment towards the sharing of the article by the actor.

Borgman and Furner (2002) discussed three levels of goals of inquiry into citation behavior. First, to "describe and classify" the behavior; second, to "explain" the behavior; third, to "evaluate or even prescribe" the behavior based on judgments as to its relative worth or utility

(Borgman & Furner, 2002, pp. 37). These three phases of understanding about the behavior and act apply in the study of other scholarly acts: first, description and classification; second, explanation; third, evaluation and even prescription. By interpreting the meaning that the participants assigned to their scholarly activities on Twitter and to the context in which the activities took place, this study was able to move the current understanding of Twitter acts and Twitter digital traces one step further into the explanation phase.

The solid theoretical and empirical foundations regarding the meaning of digital traces is equally essential in the broader field of social computing (Freelon, 2014; Freelon, 2018; boyd et al., 2010). The multiplicity of *actor* and *media* in the DTSA apply in other sociotechnical contexts to describe and understand other social phenomena. With the increasing availability of big data online, caution needs to be employed to evaluate the fitness of the data as a measurement of construct for any research purposes in any domain.

7.2 Practical Implications

The "altmetrics" data of scientific activities are now being provided in diverse scholarly communication platforms, aggregated data providers, as well as publishers and online repositories. Although the data are still far from being well understood, altmetrics in addition to standard metrics like citations are beginning to be known and tentatively used by individuals, publishers, departments, universities and research institutes in various ways, for instance, to determine the quality and popularity of research (Konkiel, 2013), to assess research impact in certain disciplines (Hammarfelt, 2014; Barnes, 2015), to support academic promotion and tenure evaluations (Cabrera, Roy, & Chisolm, 2018), and to inform funders about research impact (Dinsmore, Allen, & Dolby, 2014).

So is it a good idea to develop a Twitter metric completely based on researchers' sharing behaviors, given that it is possible to identify a large number of researchers on Twitter? In a positive sense, this would result in a more open, accountable, and outward-facing research system. However, many practical issues need to be taken into consideration, including not only technical but also ethical and privacy-related issues. Particularly, it should be noted that more than half of the shared articles examined in this study had no impact on the researchers' own work, indicating that Twitter metrics, even solely based on researchers' Twitter activities, should not be used as an evaluative metric of the articles shared. In many cases, researchers on Twitter share articles for their followers – which is essentially different from the scenario of citing in scholarly literature.

However, Twitter is important as a social network in community building and nurturing. Among the motivations identified, the findings particularly shed light on the role of Twitter in communicating research and network building. As an open platform featured with crowdsourced information and democratized comments, Twitter plays an irreplaceable role in connecting communities involving researchers. Similar to in the citation context, there is a spectrum of tweets from perfunctory tweets to reflective tweets. However, researchers participating in the online dissemination and discussion of scientific information on Twitter creates a unique environment coupled with but different from the more traditional scholarly communication environment through publications or conferences.

In the interpretation of the findings regarding how Twitter fits into researchers' workflow, it should be noted that in more than half of the Critical Incidents investigated in this study, the articles shared by researchers did not have direct impact on their own work. In a traditional view of research, this might mean that in many cases sharing articles on Twitter is not

a part of the researchers' work. However, maybe sharing research that is even just tangentially relevant to researchers' work to the research community and public should be a part of researcher's work to foster the primary goal of science.

In the interviews, Twitter was criticized from the researchers' perspectives for the purpose of scholarly communication. For instance, it was not convenient to bookmark articles to read later. Some researchers tried to use the liking or tweeting functionalities to bookmark content but turned out to be not successful. Some hoped to have a private list of bookmarks; some hoped to be able to better manage and organize the bookmarked content. Twitter launched the private "bookmark" functionality in 2018 but was not well adopted by researchers in this sample. Another area of criticism was around how Twitter made communications too simple for scholarly communications and discussions, which might easily generate polarization of opinions. Even after the word limit was canceled, Twitter seemed to continue to be used as a platform to primarily communicate brief ideas, which seemed to be not the best venue for scholarly communications. Using Twitter "thread" was a potential workaround, which was not widely adopted by researchers interviewed in this study. They would prefer to write blog posts or letters to editors to address relatively more complex issues.

Given that scholarly communication is a small part of Twitter activity, it is unlikely that Twitter can be motivated to change to fit the need of scholarly communication. In this study, Twitter was found to be utilized by researchers for their alternative purposes, which is similar to how users have repurposed other standard tools like email for many personal needs. Although in general, the design of a system determines the types of activities of its users it can support, it is critical to consider how the tools can be adapted for other purposes in the cautious interpretation of Twitter activities. For instance, the signal associated with the "like" function was reported to

have a diverse and evolving meaning. Activities from different devices might also indicate meanings. Researchers' adaptive behaviors remind us the danger of imputing social meaning to traces with no scrutinization. Particularly, with the availability and prevalence of Twitter bots, caution should be applied to avoid either intentional or unintentional gaming and distortion of metrics (Campbell, 1979; Karpf, 2012).

Appendix I: SURVEY CONTENT

Hello!

My name is Shenmeng Xu. I am a doctoral candidate in the School of Information and Library Science at the University of North Carolina at Chapel Hill. Thank you for your interest in participating in our research project investigating scholarly activities on Twitter. You were selected as a possible participant because you have tweeted scholarly articles on Twitter before. We would also like to invite you to an optional follow-up interview if you would like to have a further conversation about how you use Twitter and other scholarly tools (if any) to read, save, and share scholarly articles.

Please read this page and contact me with any questions that you may have BEFORE agreeing to take part in the research.

What is the purpose of this research? The purpose of this research is to gain a more in-depth understanding of scholars' activities communicating and reacting to scientific information on Twitter, as well as how these Twitter acts fit into the workflow pattern of other scholarly acts (such as reading, saving, sharing, citing, and so on.)

How long will this take? Your participation will take about 8-10 minutes.

Will I be compensated for participating? You will have the opportunity to receive a $100 Amazon gift card. We will be sending out three $100 Amazon gift cards in total. The drawing process will be random and will be completed after the data collection is completed. We aim to receive at least 200 complete responses. Participants who provide partial responses will not be part of the drawing.

Who will see my information? In research reports, there will be no information that will make it possible to identify you. Research records will be stored securely and only approved researchers will have access to the records.

Who do I contact with questions, concerns or complaints? If you have questions, concerns or complaints about the research, please feel free to contact the principal investigator, Shenmeng Xu (shenmeng@email.unc.edu). My academic advisor is Dr. Bradley M. Hemminger (bmh@ils.unc.edu). If you have questions or concerns about your rights as a research subject, you may

contact the UNC Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu.

Interested in the follow-up interview? We welcome you to participate in an in-depth interview. You will receive a $50 Amazon gift card after the interview. The interview will take place online (via Zoom) or on the phone. We estimate it will take 60 minutes of your time. We plan to have 20 participants in this follow-up interview. If you are willing to participate in the interview, please leave your email address at the end of the survey. We will be in touch soon with more details.

Who is sponsoring this study? This research is supported by a grant from the Ochiltree Foundation. This means that the funding is being used to pay stipends given to study participants. In addition, Dr. Hemminger's spouse has a board appointment with the Foundation. If you would like more information, please ask the researchers listed above.

If you would like, please print this consent document for your records. Thank you.

Section I: The aim of this sections is to collect descriptive background information regarding how you normally use Twitter.

1. How often do you use Twitter **professionally** (for the purposes relevant to research, teaching, or creative activities)?

- ○ Several times a day
- ○ About once a day
- ○ Several times a week
- ○ About once a week
- ○ Several times a month
- ○ About once a month
- ○ Fewer than once a month

2. Who do you **follow** on Twitter for **professional** uses? Please choose **ALL** that apply from the list below:

- ☐ Individual scholars
- ☐ Individual professionals (e.g., clinicians, doctors, practitioners)

- [ ] Individual scientific communicators/journalists
- [ ] Other individuals (the general public)
- [ ] Research institutions and universities
- [ ] Funding organizations
- [ ] Professional organizations and conferences
- [ ] Public authorities (e.g., legislative bodies, ministries)
- [ ] Civil society organizations (e.g., NGOs, consumer and patient organizations)
- [ ] Academic publishers
- [ ] News media
- [ ] Businesses
- [ ] Others, please indicate:

3. Who do you **interact with** the most on Twitter for **professional** uses? (By "interacting", you retweet, reply, or "like" their tweets.) Choose the (up to) **TOP FIVE** from the following options.

- [ ] Individual scholars
- [ ] Individual professionals (e.g., clinicians, doctors, practitioners)
- [ ] Individual scientific communicators/journalists
- [ ] Other individuals (the general public)
- [ ] Research institutions and universities
- [ ] Funding organizations
- [ ] Professional organizations and conferences
- [ ] Public authorities (e.g., legislative bodies, ministries)
- [ ] Civil society organizations (e.g., NGOs, consumer and patient organizations)
- [ ] Academic publishers
- [ ] News media
- [ ] Businesses
- [ ] Others, please indicate:

Section II: Now, please think about a **typical month** (e.g. May) that you were using Twitter:

1. In this typical month, how many times do you post, repost, reply to, and "like" a tweet regarding a scholarly article?

	Once a month or less	A couple times a month	Weekly	A couple times a week	Several times a week
Post a tweet regarding a scholarly article	○	○	○	○	○
Repost (Retweet) a tweet regarding a scholarly article	○	○	○	○	○
Reply to a tweet regarding a scholarly article	○	○	○	○	○
Like a tweet regarding a scholarly article	○	○	○	○	○

2. We would like you to think about how you felt about the scholarly articles contained in the tweets you wrote, retweeted, replied to, and "liked".
2.a When you **posted** tweets regarding scholarly articles, how often did you have a positive/neutral/negative opinion of the articles?

	Always	Most of the time	Sometimes	Rarely	Never
Positive	○	○	○	○	○
Neutral	○	○	○	○	○
Negative	○	○	○	○	○

2.b When you **retweeted** tweets regarding scholarly articles, how often did you have a positive/neutral/negative opinion of the articles?

	Always	Most of the time	Sometimes	Rarely	Never
Positive	○	○	○	○	○
Neutral	○	○	○	○	○
Negative	○	○	○	○	○

2.c When you **replied to** tweets regarding scholarly articles, how often did you have a positive/neutral/negative opinion of the articles?

	Always	Most of the time	Sometimes	Rarely	Never
Positive	○	○	○	○	○
Neutral	○	○	○	○	○
Negative	○	○	○	○	○

2.d When you **liked** tweets regarding scholarly articles, how often did you have a positive/neutral/negative opinion of the articles?

	Always	Most of the time	Sometimes	Rarely	Never
Positive	○	○	○	○	○
Neutral	○	○	○	○	○
Negative	○	○	○	○	○

Section III: We are interested in knowing about the effort and involvement you have BEFORE and AFTER tweeting and retweeting scholarly articles. Therefore, we would like you to think about how your tweeting and retweeting

behavior fit into your research process and estimate your effort in the following four questions.
Similarly, please think about a **typical month** (e.g., May) that you were using Twitter.
1. Which of these following actions do you typically do **BEFORE** you **tweet** a scholarly article?

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Skim the article to gain a very basic idea of it	○	○	○	○	○
Read the article in depth (examining at least some sections/figures/tables in the article very carefully)	○	○	○	○	○
Look at online discussions of the article	○	○	○	○	○
Search for information about the author(s) of the article	○	○	○	○	○
Save the article to your computer or reference manager tools	○	○	○	○	○
Organize the article (such as renaming the article file or categorizing it into a folder)	○	○	○	○	○

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Cite the article (in your working research paper or teaching materials)	○	○	○	○	○

2. Which of these following actions do you typically do **AFTER** you **tweet** a scholarly article?

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Skim the article to gain a very basic idea of it	○	○	○	○	○
Read the article in depth (examining at least some sections/figures/tables in the article very carefully)	○	○	○	○	○
Look at online discussions of the article	○	○	○	○	○
Search for information about the author(s) of the article	○	○	○	○	○
Save the article to your computer or reference manager tools	○	○	○	○	○

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Organize the article (such as renaming the article file or categorizing it into a folder)	○	○	○	○	○
Cite the article (in your working research paper or teaching materials)	○	○	○	○	○

3. Which of these following actions do you typically do **BEFORE** you **REtweet** a scholarly article?

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Skim the article to gain a very basic idea of it	○	○	○	○	○
Read the article in depth (examining at least some sections/figures/tables in the article very carefully)	○	○	○	○	○
Look at online discussions of the article	○	○	○	○	○
Search for information about the author(s) of the article	○	○	○	○	○

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Save the article to your computer or reference manager tools	○	○	○	○	○
Organize the article (such as renaming the article file or categorizing it into a folder)	○	○	○	○	○
Cite the article (in your working research paper or teaching materials)	○	○	○	○	○

4. Which of these following actions do you do typically do **AFTER** you **REtweet** a scholarly article?

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Skim the article to gain a very basic idea of it	○	○	○	○	○
Read the article in depth (examining at least some sections/figures/tables in the article very carefully)	○	○	○	○	○
Look at online discussions of the article	○	○	○	○	○

	In all cases	In most of the cases	In about half of the cases	In rare cases	Never
Search for information about the author(s) of the article	○	○	○	○	○
Save the article to your computer or reference manager toosls	○	○	○	○	○
Organize the article (such as renaming the article file or categorizing it into a folder)	○	○	○	○	○
Cite the article (in your working research paper or teaching materials)	○	○	○	○	○

Section IV: Thank you for reaching the end of our survey. Now, please tell us more about yourself.

1. Which is your primary discipline?

- ○ Social Sciences
- ○ Humanities
- ○ Biomedical & Health Sciences
- ○ Life & Earth Sciences
- ○ Physical Sciences & Engineering
- ○ Mathematics & Computer Science
- ○ Other, please specify: _____

2. What is the highest degree or level of school you have completed? If you are currently enrolled, please select the highest degree you have received.

- ○ Doctoral degree
- ○ Professional degree (MD, JD, etc.)
- ○ Master's degree
- ○ Bachelor's degree

3. What is your current primary role?

- ○ Professor
- ○ Associate Professor
- ○ Assistant Professor
- ○ Senior Lecturer
- ○ Lecturer
- ○ Post-Doctoral researcher
- ○ PhD student
- ○ Masters student
- ○ Librarian
- ○ Other, please indicate:

4. How many years have you been in the position?

- ○ 0-3 years
- ○ 4-6 years
- ○ 7-9 years
- ○ 10 years and above

5. What is your age?

- ○ 20-29 years old
- ○ 30-39 years old
- ○ 40-49 years old
- ○ 50-59 years old
- ○ 60-69 years old
- ○ 70 years or older

6. To which gender identify do you most identify?

- ○ Female
- ○ Male

- Transgender female
- Transgender male
- Gender variant/non-conforming
- Not listed:
- Prefer not to answer

7. In which country do you currently reside?

8. If you would like to enter the lottery pool of the three $100 Amazon gift cards, please leave your email address below. This email address will be used for no other purposes.

9. Are you willing to participate in our interview to have a further conversation about how you use Twitter and other scholarly tools (if any) to read, save, and share scholarly articles? A $50 Amazon gift card will be provided for your time and support.

- Yes. Please provide your email address: (This email address will be used for no other purposes.)
- No.

Appendix II: SEMI-STRUCTURAL INTERVIEW GUIDE

Hello! How are you? I hope you are having a good morning today.

Okay, let me introduce myself first. My name is Shenmeng Xu, and I'm a doctoral student in the School of Information and Library Science at the University of North Carolina at Chapel Hill. I use both quantitative and qualitative methods to study scholarly communication. I'm so glad to be able to talk with you. Thank you for being a part of this study.

Before we begin, let me tell you that this study is my dissertation research. The results will be used to better understand how researchers use Twitter to share scholarly information online, as well as further our understanding about what one tweet of a scholarly article can mean.

Thank you for signing the consent form. I've talked about this in the email, but again, let me assure you that all your answers will be kept completely confidential. No identifying information will be connected to you in any part of the dissertation manuscript. If you need to go at any point, we can finish the interview later to fit your schedule.

There are two sections in today's interview. The first section contains five big questions about how do you use Twitter in general, with some small follow-up or sub-questions. In the second section, we will talk about ten tweets of yours, and for each of them, I will ask you five small questions.
I will be in contact later after the interview with the Amazon gift card.

Before the interview starts, do you have any questions or concerns?

Is it okay if I start to record the audio now?

Section I:

First, thank you for completing the survey earlier. Before the first question, could you please confirm with me that you are a researcher actively doing research now? Which area do you work in?

Now, I will ask you some questions about how you generally use Twitter. These questions are also follow-up questions of the survey. Is that okay? There are five questions in total in this section.

1. When do you usually use Twitter? You said [ ] in the survey.

[Potential prompts]:

Do you have specific habit of using Twitter? In work? After work? Using Laptop? Or phone?

How often do you browse information vs posting and interacting with people on Twitter?

2. In the survey, I have asked you some questions regarding to the four types of activities: posting tweets, retweeting, replying to, and liking tweets linking to scholarly articles. Each of the following four questions is about one of these four activities.

2.1 Regarding the act of **posting** tweets about scholarly articles, can you help me better understand your thoughts in deciding to post a scholarly article?

[Potential prompts]:

Why frequent or infrequent? [ ]

Why positive, neutral, or negative opinions? [ ]

What are the common motivations?

2.2 Regarding the act of **retweeting** tweets about scholarly articles, can you help me better understand your thoughts in deciding to retweet a scholarly article?

[Potential prompts]:

Why frequent or infrequent? [ ]

Why positive, neutral, or negative opinions? [ ]

What are the common motivations?

2.3 Regarding the act of **replying** to tweets about scholarly articles, can you help me better understand your thoughts in deciding to reply to a scholarly article?

[Potential prompts]:

Why frequent or infrequent? [ ]

Why positive, neutral, or negative opinions? [ ]

What are the common motivations?

2.4 Regarding the act of **liking** tweets about scholarly articles, can you help us understand better your thoughts in choosing to post a scholarly article?

[Potential prompts]:

Why frequent or infrequent? [ ]

Why positive, neutral, or negative opinions? [ ]

What are the common motivations?

We have finished section one.

Now, we will finish the interview with some particular examples of your tweets. Specifically, each of them contains a link to a specific scholarly article. I will ask five question about each of them. I have selected ten tweets or retweets of yours.

Section II:

1. Why did you tweet/retweet this article?

[Potential prompts]:

How did you see this article?

Why did you feel that you want to tweet/retweet this article?

2. How important did you think this article was to you when you were tweeting/retweeting it?

[Potential prompts]:

How relevant is this article to your research interest?

How relevant is this article to your job?

How relevant is this article to your life?

3. Do you think tweeting/retweeting this article indicates your positive opinion towards this article? Why or why not?

4. How does tweeting/retweeting this article fit in your workflow? In other words, what scholarly actions have you engaged in before or after you tweeted the article?

[Potential prompts]:

For instance, have you paid particular attention to specific parts of the article? Have you looked at online discussions of the article? Have you got to know more or even contacted the authors? Have you saved this article to your computer or reference manager? Have you further organized this article (e.g., changing the name of the file, putting it into a specific folder, etc.)? Have you cited this article in your research works? Have you included this article in your teaching materials? Have you shared this article in other ways (including publicly, in a group, or individually)? Have you shared your opinion on this article to others (including publicly, in a group, or individually)?

5. It's been a while after you have tweeted the article. Now, can you talk about the impact of this article to you? For instance, so far, has this specific article in any way contributed to your research, teaching, and creative activities? If yes, how?

[Repeat the section above for each tweet.]

Okay, I'm done with my questions. Do you have any additional comments or thoughts?

Thank you for participating in this study!

Appendix III: PROCEDURES OF PILOT TESTINGS (SURVEY AND INTERVIEW)

Survey:

Four pilot studies were conducted on an iterative basis:

1. Concurrent pilot testing #1
2. Concurrent pilot testing #2
3. Retrospective pilot testing (desktop/laptop interface)
4. Retrospective pilot testing (phone interface)

Probes:

- Are the technical terms easy to understand? Is there need to give a further definition of the Twitter activities (tweet, retweet, reply, like, and follow)?
- Are the "positive", "neutral", "negative" question asked clearly? For instance, can you use your own word to describe being "neutral" about an article when tweeting it?
- Do you think it is difficult to keep in mind that this study only concerns "tweets regarding scholarly articles" but not just any tweet that you think is relevant to science or research?
- Do you think it is hard to answer the questions in Section II? How accurate do you think your answers were?
- Do you think it is hard to answer the questions in Section III? How accurate do you think your answers were?
- Which of the following three options can provide a better recall and higher accuracy of your answers to this question? Counts, percentages, or a Likert scale: "In all cases, In most cases, In about half of the cases, In rare cases, Never".
- If we were to use percentages, do you prefer to use the sliding bar to provide the answer or to type in the answer?

- Any other comments regarding the wording of questions, use of technical terms, as well as whether there are vague questions, biasing questions, and questions that are generally too lengthy to answer?
- Any comments regarding the survey interface design, flow of questions, or other usability issues?

Interview:

Three pilot studies were conducted on an iterative basis.

Probes:

- Did the interview questions make sense to you? Were they hard to answer?
- What do you feel about your recall of the example tweets and the articles in the tweets?
- How long before the interview should I send the file of tweets examples to you?
- What do you think about the number (ten) of example tweets (and articles)?

Appendix IV: SURVEY DATA CLEANING

To process and clean the survey data, first, the unfinished responses were deleted. Specifically, In the data exported from Qualtrics, rows with a value of 100% in the "Progress" column and the value of "TRUE" in the "Finished" column were removed.

The second step was to further examine incomplete responses. After identifying the incomplete responses, I examined 123 rows that missed responses to only one (89) or two (34) questions, and manually filled in the missing responses for 24 rows:

1. For those who only missed Q12_2 and Q12_3 and answered "Always" in Q12_1 ("When you liked tweets regarding scholarly articles, how often did you have a positive opinion on the articles?"), I filled in "Never" in Q12_2 (neutral opinion) and Q12_3 (negative opinion).
2. For those who only missed Q19 ("primary discipline"), I searched online to fill in their discipline information.
3. For those who only missed Q20 ("highest degree earned"), I searched online to fill in their degree information. Those cannot be filled were removed from the dataset.

After this step, there were 1248 complete responses.

To further understand the quality of the survey responses, responses to Question 2 (Q9_1 – Q12_3) in Section II were further investigated. The response anchors were: Always, Most of the time, Sometimes, Rarely, and Never. Contradicting or incongruent patterns of answers based on logics were examined in detail. For instance, one cannot always have a positive opinion on the articles they tweeted while at the same time always having a neutral or negative opinion on the articles they tweeted. In total, the following seven types of responses were identified and further examined:

- With two or three “always”
- With three “most of the time”
- With one or two “always” and one or two “most of the time”
- With three “rarely”
- With three “never”
- With one “rarely” and two “never”
- With one “never” and two “rarely”

The findings about these examinations are presented in Table A.1, and are discussed below.

On the one hand, some participants tended to overuse “Always” and “Most of the time” in Question 2 (Condition #1, #2, and #3 in Table A.1). One the other hand, some participants tended to overuse “Rarely” and “Never” (Condition #4, #5, #6, and #7 in Table A.1).

These two situations were slightly different from each other. Participants might overuse “Always” and “Most of the time” due to three potential reasons: First, they might have inconsistent conceptualization these two terms, particularly “Most of the time”, which can sometimes be conceptualized as “oftentimes” or “in many instances”. The second reason might be the difficulty to clearly separate “Positive” from “Neutral”. In the follow-up interview, this was explained by one interviewee who answered “Most of the time” in both of the “Positive” and “Neutral” questions. She commented that sometimes she believed she had a “positive to neutral” opinion on the articles she tweeted. A third potential reason might be the lack of care or honesty in taking the survey.

Table A.1 Survey Data Cleaning

Condition #	Condition	Posting (Q9_1-Q9_3)	Retweeting (Q10_1-Q10_3)	Replying (Q11_1-Q11_3)	Liking (Q12_1-Q12_3)
1	With two or three "always"	[455, 630]	[455, 537, 1203]	[181, 222, 537]	[185, 222, 809]
2	With one or two "always" and one or two "most of the time"	[198, 295, 463, 583, 831]	[123, 198, 208, 583]	[89, 123, 455, 583, 772]	[54, 79, 181, 198, 208, 392, 455, 522, 534, 583, 911, 982, 1203]
3	With three "most of the time"	[916]	[916]	[39, 531, 782, 916]	[39, 503, 916, 1164]
4	With one "never" and two "rarely"	[179, 948]	[179, 948, 968, 1194]	[235, 948, 1194]	[179, 271, 637, 948]
5	With one "rarely" and two "never"	[637, 995]	[637, 676, 855, 919]	[28, 431, 519, 719, 745]	[760]
6	With three "rarely"	[6, 89, 175, 1100, 1132]	[6, 89, 175, 503, 1037, 1100, 1107, 1132]	[158, 166, 175, 203, 371, 529, 581, 590, 650, 689, 712, 721, 768, 788, 797, 846, 852, 870, 957, 1012, 1071, 1084, 1132]	[175, 386, 590, 788, 797, 1084, 1132]
7	With three "never"	[7, 86, 431, 560, 594, 624, 940, 987, 1058, 1084]	[7, 86, 260, 431, 481, 560, 594, 624, 719, 739, 940, 987, 1058, 1084]	[7, 55, 74, 86, 106, 150, 246, 260, 322, 369, 386, 412, 430, 462, 466, 481, 560, 594, 624, 728, 739, 778, 794, 795, 823, 832, 838, 855, 904, 940, 942, 965, 987, 1058, 1096, 1100, 1129, 1152]	[1, 7, 26, 50, 57, 77, 86, 99, 197, 260, 349, 431, 466, 481, 560, 582, 594, 624, 648, 708, 739, 832, 895, 940, 970, 987, 1005, 1020, 1022, 1058, 1100]

For participants in Condition #4, #5, #6, and #7, there was an additional factor which would potentially affect their answers: the frequencies of their acts (posting, retweeting, replying, and liking tweets containing scholarly articles). The number of observations overusing "Never" and "Rarely" existed the most in the "replying" category, which was the least frequently conducted acts among the four acts. In the design of the survey, the anchors here ("Always", "Most of the time", "Sometimes", "Rarely", "Never") should be in relevance to all cases within the four categories of acts. However, if an act was conducted very infrequently by a participant, it was possible they might answer "Never" or "Rarely" to all categories of "Positive", "Neutral", and "Negative".

Taking the analyses above into consideration, I manually examined the 127 rows of data listed in Table A.1. In combination of the identification of straight-liner patterns, a listwise deletion was applied to 15 rows, including 7, 86, 260, 431, 481, 560, 594, 624, 940, 987, 1058, 1084, 1100, 222, and 91.

After this data cleaning process, at last, 1233 responses were used in the final analyses process.

Appendix V: CODING OF DISCIPLINES IN THE SURVEY

In the survey question asking the primary discipline of respondents, a text entry box was provided in case they did not have the most appropriate option to choose from. In the data analyses process, these text entries were categorized into the discipline categorizations adopted by this dissertation according to the following guidelines. In total, 73 responses were manually categorized and checked by a second coder.

1. The Research Areas (Categories / Classification) scheme of Web of Science (https://images.webofknowledge.com/images/help/WOS/hp_research_areas_easca.html) was taken as a reference in the categorization. For instance, “bioethics” was categorized into Biomedical and Health Sciences in this study “medical ethics” is categorized under the “Life Sciences and Biomedicine” category of Web of Science; “psychology” was categorized into Social Sciences because “psychology” is under the “Social Sciences” category of Web of Science.
2. This survey question asks the primary discipline of the respondents. Therefore, interdisciplinary studies are determined to have a primary discipline, although this is not perfect for some disciplines, for instance, cognitive psychology. In cases where it is hard to determine the primary discipline, the primary discipline was categorized according to the weight and order of disciplines filled out by the respondents. For instance, “Intersection Psychology/Medicine/Biology /Anthropology” was categorized into Biomedical and Health Science instead of Social Sciences or Humanities because of the emphasis on Medicine and Biology; “both social sciences and humanities” was categorized into Social Sciences because social sciences was mentioned ahead of humanities.

Table A.2 Coding of Disciplines

Fields	Narrow Fields
Biomedical and Health Sciences	Veterinary Medicine; Public Health; Bioethics; Intersection Psychology/Medicine/Biology /Anthropology; Neuroscience; Nutrition;
Life and Earth Sciences	Environmental Sciences; Renewable Energy; Life Sciences; Ecology/Evolution; Conservation; Agriculture; Marine sciences; Aquatic ecology and fisheries; Animal behavior and welfare science;
Mathematics and Computer Science	Computational Cognitive Science; Natural Language Processing; Data science and complex systems;
Physical Sciences and Engineering	Analytical Chemistry; Planetary sciences;
Social Sciences	Psychology; Library Science; Law; Cognitive Psychology (both social sciences and biomedical/health sciences); Social entrepreneurship; Library and Information Science; both social sciences and humanities; Information Science; Cognitive science and design; Journalism; Education; Business; Management; Linguistics; Communication; Archaeology;
Humanities	Arts and Design; Humanities and social sciences; Architecture; Theology

Appendix VI: CODING SCHEME OF MOTIVATIONS

Table A.3 Coding Scheme of Motivations

Category	Code	Definition of Code
networking	maintaining an existing relationship	To use an article to initiate or respond to a conversation with a person or an organization who one already had a connection with
	building a new relationship	To use an article to initiate or respond to a conversation with a person or an organization who one did not have a connection with
promoting	self-promotion	To share one's own work
	promoting a colleague	To share a colleague's work in order to increase the visibility of their works
	promoting a journal	To share a journal's publication in order to increase the visibility of the journal
	promoting an institute	To share a publication by researcher(s) from a university, research institute, department, or lab, to increase the visibility of these organizations
disseminating	disseminating a relevant article in terms of research topic	To share an article because of the topical relevance
	disseminating a relevant article in terms of research method	To share an article because the technique, tool, or research method in general used is relevant
	disseminating a relevant article in terms of implementation	To share an article because the application of research findings is relevant
	disseminating a relevant article in terms of research practice	To share an article because of the relevance to the research practices of researchers
	disseminating a relevant article out of personal interest	To share an article out of personal interest in science or social issues in general
	disseminating a relevant article to a conference presentation	To share an article relevant to a conference presentation (including the preprint or a reference cited in the presentation)
	disseminating research findings to the public	To share an article that is relevant and of value to the daily life of the broader audience on Twitter
commenting	expressing opinion on a related issue	To express one's opinion on an existing controversy, problem, or issue related to research or science in general

	relating to my work	To relate the topic, methods, or findings of an article to one's own research, teaching, practices, or services
	calling attention to a misconception	To call attention to and correct a common misconception
	guarding science	To support science against anti-science incidents or viewpoints
communicating with intended users	initiating a discussion	To express one's opinion or ask a question about an article by mentioning specific users
	participating in a discussion	To respond to the existing discussion about an article by mentioning/replying to specific users
	recommending an article (to a specific user)	To share an article's link with specific users without an intention to initiate a discussion
Acknowledgement	Acknowledgement	To acknowledge the merit of an article
Saving for later reference	Saving for later reference	To save an article for use or potential use in the future

Appendix VII: CODING SCHEME OF IMPACT

Table A.4 Coding Scheme of Impact

Category	Code	Definition of Code
Informing	Contributed to the cumulative knowledge base	Provided help in one's understanding about a topic, problem, or issue in areas relevant to one's research
	Learned/Improved research methods (technique(s) or tool(s))	Provided help in the learning or improvement of a technique, tool, or research method in general in one's research
	Supported the interpretation of findings	Provided additional evidence to support one's understanding of their own research findings
	Confirmed ideas	Provided evidence for one's ongoing ideas or doubts
	Inspired further ideas	Provided inspirations for someone to think critically or creatively about a topic, problem, or issue in areas relevant to one's research
Connecting	Developed a collaborative relationship	Provided help in connecting with a collaborator (researcher, practitioner, or industry partner)
	Maintained a collaborative relationship	Facilitated continuous collaborations with an existing collaborator (researcher, practitioner, or industry partner)
Practice Changing	Changed research practices	Provided inspirations, guidelines, or support to change research practices in one's daily work
Beyond Research	Used in practice	Used in practical activities
	Used in teaching	Used as teaching materials
	Used in mentoring	Used for mentoring purposes
Potential Impact	Another direction of research/teaching	Might be useful in research projects in the future
	A potential collaborative relationship	Might be able to collaborate with a potential researcher, practitioner, or industry partner

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