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BRIEF COMMUNICATION

"A Light Switch in the #Brain": Optogenetics on Social Media

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Abstract Neuroscience communication is increasingly taking place on multidirectional social media platforms, creating new opportunities but also calling for critical ethical considerations. Twitter, one of the most popular social media applications in the world, is a leading platform for the dissemination of all information types, including emerging areas of neuroscience such as optogenetics, a technique aimed at the control of specific neurons. Since its discovery in 2005, optogenetics has been featured in the public eye and discussed extensively on social media, but little is known about how this new technique is portrayed and who the users participating in the conversation are. To address this gap, we conducted content analysis of a sample of 1000 tweets mentioning "optogenetics" over a one-year period between 2014 and 2015. We found that academic researchers are the largest group contributing to the conversation, that the tweets often contain links to third-party websites from news organizations and peer-reviewed journals, and that common thematic motifs include the applications of optogenetics specifically for the control of brain activity and the treatment of disease. We also found that the majority of the tweets are neutral in their tone regarding optogenetics. As Twitter serves as a current and dynamic forum for exchange about advances in neuroscience, the conversation about optogenetics on this engaging platform can inform socially-responsive knowledge dissemination efforts in this area.

Keywords Optogenetics · Social media · Internet · Neuroscience communication

Introduction

Neuroscience communication is at a turning point, with social media acting as a new channel to disseminate and share information about developments in brain research [1, 2]. In the digital era, interactive platforms play a large role in shaping public perceptions of scientific and healthcare discoveries by allowing interactions between users and the wealth of information available online [3], and providing new avenues for the public to partake in important discussions about advancements in research [2].

One such example of a social media platform is Twitter, one of the most popular social media sites in the world with 310 million active monthly users [4]. Twitter allows users to read and create "tweets" with a maximum of 140 characters, which can be "retweeted" by other users, allowing for the rapid propagation of information. As a wealth of information dissemination and communication is occurring on this platform, Twitter has been utilized as a tool to study opinions of its users in a variety of contexts, such as new

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biotechnologies [2], natural disasters [5], politics [6], and epidemics [7]. Other studies have investigated how Twitter is used to facilitate dialogic communication between different stakeholders [8]. Increasingly, scholars are examining the specific content of communicated messages, and these studies provide not only rich information about users' perspectives on the issues at hand, but also insight into the nature of human communication in an online era [9]. Traditional models in public relations and communications can also be applied to examine the direction, purpose and nature of the communication that takes place on Twitter, for example through Grunig and Hunt's four models: press agentry, public information, two-way asymmetry, and two-way summetry [10–12].

Despite the utility of social media to share information, this technology is not without risks in the context of neuroscience communication. Users participating in online discussions vary in their level of expertise, which may compromise the quality of information being shared [1]. Social media content may include inaccurate portrayals of the applications of new biotechnologies and thus may cause users to have unrealistic expectations of the impact of these scientific discoveries [13]. This presents salient ethical issues in the case of discoveries with potential therapeutic benefits since it may result in false hopes for patients and families affected by the illness which the discovery is touted to treat [1].

One emerging area in neuroscience research which has been featured prominently in online discussions is optogenetics, a technique that is receiving much acclaim for its potential to revolutionize the study of the brain [14]. Optogenetics involves the addition of an opsin gene into specific neurons, allowing for these neurons to be activated or inhibited by light in vivo at a much more precise level than was possible before [15]. This discovery has created many opportunities for studying specific neural circuits, and may shed light on the causal mechanisms of various disorders [16]. Translational applications are also on the horizon, as optogenetics is currently being studied as potential treatment for a wide variety of conditions such as epilepsy and addiction [17, 18].

Following the first demonstration of this technique in 2005 [14], optogenetics became increasingly present in the scientific literature [15]. In recent years, optogenetics has been featured frequently in mainstream media publications, and, like other biotechnologies, continues to garner increasing attention from the general public [19]. Active discussion among the public about developments in neuroscience can be greatly impactful in shaping public policy in a way best suited to benefit society at large [20]. However, as optogenetics is concerned with the intricate control of neuronal firing, and this essentially comprises our personality, experiences, and behaviour, it is imperative that the translation of optogenetic advances from the lab to the layperson is conscientious and precise as to avoid any misunderstandings regarding the capabilities and power of this technique [21]. Already, optogenetics is being discussed in the media in the context of "mind control" and sparking dialogue about autonomy [22].

Despite the rising popularity of optogenetics in online discussions and its potential as both a research tool and therapy, little is known about the portrayal of optogenetics on social media platforms such as Twitter. This study attempts to explore the discourse surrounding optogenetics on Twitter by answering the following research question: What is thematic content of optogenetics-related tweets? Specifically, we aim to characterize: i) users participating in discussion; ii) the content of discussion; iii) the tone of the discussion.

Methods

Design

To establish the thematic content of tweets about optogenetics, a content analysis of posts on the social media platform Twitter was conducted following previously established methodology [7, 23, 24]. Data collection took place over a period of one year from February 2014 to January 2015.

Search Strategy

Using the Twitter application programming interface (API), we created an automated program in the C++ programming language to search for English-language tweets containing the word "optogenetic". All tweets, along with date, time and freely contributed user information were retrieved and collected into a database, and duplicate entries were removed. We limited the terms used in our search strategy to ensure we compiled a highly relevant and manageable sample of tweets. Therefore, our sample does not contain tweets that do not explicitly mention "optogenetics" by name either in the tweet text or in the link but still includes the majority

of tweets relevant to this discussion. The publicly available account information, such as location and occupation, of all unique users from the sample was also included for analysis (Table 1). No attempts were made to collect user information set as private and no Twitter users were contacted for this study. Similar to previous studies [2], we define unique tweets as tweets that were not exact duplicate "retweets" from other users. We applied content analysis to a random sample of 1000 unique tweets.

Development of Coding Scheme

We developed a coding scheme based on a pilot analysis of a sample of 10 % of the tweets. By combining a priori themes for the features of the tweets themselves and themes related specifically to optogenetics, we established several overarching categories for content analysis. The coding scheme was then refined by two researchers (JR, CL) through coding of an additional 10 % sample to produce the final version of the coding guide (Tables 2 and 3). The categories of the coding scheme for the tweets were: 1) basic information about links (e.g. country of origin); 2) content type of links (e.g. news article); 3) content type of tweet (e.g. study); 4) tone of tweet (e.g. positive, negative); 5) stakeholders mentioned in tweet (e.g. researcher); 6) application of optogenetics mentioned (e.g. control of behaviour); 7) mention of research; and 8) vocabulary used to describe optogenetics (e.g. "stimulate"). A coding scheme for the freely accessible user information was developed using the same iterative process and resulted in the following coded categories: 1) geographic information; 2) individuals and occupations (e.g. researcher); and 3) organizations and type (e.g. academic institution).

Using the final coding schemes, one researcher (CL) coded the entire sample, while a second coder (TF) then analyzed 20 % of the sample to establish intercoder agreement.

Results

Intercoder Agreement

Agreement between the two coders was calculated using Krippendorf's alpha, which ranges from 0 to 1 [25]. Initial agreement was 0.83 for tweet information and 0.93 for user information, indicating good to excellent agreement between coders. All disagreements were resolved through discussion and complete consensus was achieved.

Sample

A total of N = 10,458 tweets about optogenetics were collected from February 20th, 2014 to January 23rd, 2015. Unique tweets constituted 31 % (n = 3284) of the initial sample and were contributed by a total of N = 2043 unique users. The entire sample of users was analyzed, while a random sample of 1000 tweets was selected for further analysis.

Users

A total of 1372 users from the entire sample of tweets (67 %) provided their geographic location in their publicly available Twitter profile. Of those users, the largest proportion was from the United States (57 %), while 13 % of users were from the United Kingdom, and 5 % from Canada.

In addition to geographic information, a majority (83 %) of account descriptions contained details about the user (Fig. 1a; see Table 1 for examples). Over half (58 %) of accounts were identified as belonging to an individual. The most frequent occupations of individuals in our sample were academic researchers (48 %), of which 23 % were neuroscientists specifically. Occupations in the area of science communication, such as editor of an academic journal, were described in 7 % of individual accounts. Other occupations outside of scientific research included physicians (5 %) and psychologists (1 %).

A quarter of accounts were identified as representing an organization (Fig. 1b). The most frequent types of organizations in the sample were news groups (20 %) and medical and technology companies (15 %). Organizations in the "Science Organization or Society" category (e.g., Brain & Behaviour Research Foundation), which were defined as groups that promote increased awareness and research in their field of study, accounted for 9 % of accounts. "Research Organizations," indicated by an explicit statement that they conduct research, such as the Allen Institute, constituted another 9 % of accounts. "Social media feeds" are curated, either manually or by a bot, Twitter feeds that solely tweets links to academic papers about a certain topic and comprised a further 9 % of the sample. Six percent of the accounts were coded as "Advocacy Groups", which advocate for

Table 1 User information codebook

Question	Category	Code	Definition	Example	%
Did the user provide personal information on their profile?	User (general)	No useful info	User's profile does not contain any relevant information	Radical honesty & clear teachings resonate most deeply with me. here	12
Does the user still exist?	User (general)	Doesn't exist	User no longer exists	N/A	5
Where is the user from?	User (general)	Country	Indicates the user's country of residence	USA	67
Does the user represent an individual or an organization?	Individual user	Individual	Indicates that account represents an individual	I'm Henry. I do science. Probably sunburnt and drunk.	58
Who is tweeting about optogenetics?	Individual user	Not disclosed	User did not disclose any information regarding their occupation	I've put more thought into what Hogwarts house I'm in than any other decision in my life.	20
Who is tweeting about optogenetics?	Individual user	Undetermined researcher (neuro-science)	Based solely on the information proided on their Twitter profile, it is not clear what level of neuroscience researcher the individual is	Phish stuff. Freelance Neuroscientist. Trying to take the hypotenuse through life.	14
Who is tweeting about optogenetics?	Individual user	Undetermined researcher (general)	Based solely on the information proided on their Twitter profile, it is not clear what level of researcher the individual is in a discipline other than neuroscience	Metabolism researcher, husband, father, golfer and cheeseburger aficionado	11
Who is tweeting about optogenetics?	Individual user	Science communicator	Individual works primarily as a science communicator	Science writer and author of The Brain Supremacy, fascinated by brains in their contexts, from new tech to social neuroscience, neuroethics to neurochemistry.	7
Who is tweeting about optogenetics?	Individual user	Faculty researcher (general)	Individual holds a faculty position at a university in a discipline other than neuroscience	PhD in Molecular Biology Professor of Biology and Geology	7
Who is tweeting about optogenetics?	Individual user	Trainee researcher (general)	Individual is a grad student or post-doc conducting research in a discipline other than neuroscience	Postdoc at CRM, Edinburgh. Working on RNA biology. Worked on genome annotation and evolution.	6
Who is tweeting about optogenetics?	Individual user	General business professional	Individual is a business professional in an area unrelated to science	Entrepreneur dedicated to finding more positive and efficient solutions for every day things. With genuine love of life, I aim to uplift all in what I do.	6
Who is tweeting about optogenetics?	Individual user	Trainee researcher (neuroscience)	Individual is a grad student or post-doc conducting research in neuroscience	Graduate student in Molecular Neuroscience, University of British Columbia. Studying synaptic connections and dendritic growth to understand learning/behavior.	6
Who is tweeting about optogenetics?	Individual user	Physician	Individual is a physician in any discipline	Neurologist at Children's Memorial Health Institute. Interested in mechanisms of neurodegeneration and epileptogenesis.	5
What are these users interested in?	Individual user	Interests: neuroscience	Individual implies an interest in neuroscience in their profile	Artificial Intelligence, Poetry, Neuroscience, Prose, Illustration, Programming, Health, Creativity, Natural Language Processing, Machine Learning, Smart Music	29
What are these users interested in?	Individual user	Interests: tech	Individual implies a general interest in new technology in their profile	All things technology. All comments and thoughts are my own.	20
Does the user represent an individual or an organization?	Organization user	Organization	Indicates that account represents an organization	Official Twitter account of the Defense Adanced Research Projects Agency. Shares and retweets do not imply endorsement.	25
What organizations are tweeting about optogenetics?	Organization user	News-based	Organization is a print or internet-based news corporation	Science news covering top stories of the day in health, enironment, animals, technology and space. Part of @Purch	20
What organizations are tweeting about optogenetics?	Organization user	Med/tech companies	Organization is a company that specializes in medical or tech products	Supplier of high quality precision optical & scientific components around the globe.	15
What organizations are tweeting about optogenetics?	Organization user	Research organizations	Organization is a research institution within a university	The Kali Institute for Neuroscience at Yale. Neuroscientists working to advance our understanding of the human brain.	9
What organizations are tweeting about optogenetics?	Organization user	Science society	Organization is a society of scientists dedicated to advocating for advancements in their field	Official account for American Epilepsy Society. We support research and education for professionals committed to a world without epilepsy. RTs not endorsements.	9
What organizations are tweeting about optogenetics?	Organization user	Academic institution	Organization is an university	For more than 250 years, Columbia has been a leader in higher education in the nation and around the world.	8
What organizations are tweeting about optogenetics?	Organization user	Journal/publisher	Organization is a journal or publishing company	Nature Methods is a monthly scientific research journal dedicated to publishing high impact methods and tools for laboratory researchers in the life sciences.	7
What organizations are tweeting about optogenetics?	Organization user	Advocacy	Organization primarily advocates for a certain cause	Fighting Blindness is an Irish patient-led medical research charity. Our vision is to CURE blindness, SUPPORT people living with sight loss & EMPOWER patients.	6

Table 2 Link content codebook

Question	Category	Code	Definition	Example	%
What country are the links from?	Link information	Link country	Indicates the country of origin of the website the links directs to, as determined by information hosted on the site	Canada	84
What is the content of the link?	Link content type	News	Link directs to any news report	http://www.bbc.com/news/health-28836134	32
What is the content of the link?	Link content type	Science news	Link directs to a news report related to science	http://www.mcgill.ca/channels/news/timing-everything-scientists-control-rapid-re-wiring-brain-circuits-using-patterned-visual-stimulati-236849	29
What is the content of the link?	Link content type	Journal	Link directs to the website of an academic journal	http://www.nature.com/news/flashes-of-light-show-how-memories-are-made-1.15330?WT.mc_id=TWT_NatureNews	15
What is the content of the link?	Link content type	Scientific summary	Link directs to an article that does not discuss the most recent news, but rather provide historical summary of the scientific topic	http://www.technologyreview.com/featuredstory/528226/neurosciences-new-toolbox/	7
What is the content of the link?	Link content type	Video	Link directs to a video	https://www.youtube.com/watch?v=Nb07TLkJ3Ww&feature=youtu.be	5
What is the content of the link?	Link content type	Broken/irrelevant	Link is broken or the content of the page it directs to is no longer related to optogenetics	N/A	5

increased support for their specific cause and included organizations such as Addictions.com,

Links

A majority of tweets (80 %) in the sample contained a link to a third party website, with most of these websites based in the United States (60 %). Thirty-two percent of the links directed to a news article, and of these, 87 % of the articles were classified as science news (Table 2). Fifteen percent of tweets contained links that directed to websites of peer-reviewed journals and 7 % of links directed to scientific summaries.

Tweets

The content type of the tweet was determined based on the text of the tweet in conjunction with any associated links. The most prominent content types were: assertions (35 %), news reports (34 %), and results of research studies (13 %; Table 3). The following is an example of an assertion: "*#Optogenetics, controlling the brain with light, is getting a lot of buzz at #SfN14.*" News reports of study findings included tweets such as: "*UK researchers read and write #brain activity with light [LINK] #neuroscience #optogenetics #imaging.*" Tweets about research studies often contained a link to a peer-reviewed publication and the title of the publication as part of the text: "*Optogenetic Stimulation of Adrenergic C1 Neurons Causes Sleep State Dependent Cardiorespiratory Stimulation [LINK].*"

The prevailing tone of the tweets about optogenetics was neutral (88 %). Tweets that were not neutral in tone tended to be polarized. An example of a tweet with a positive tone (11 %): "*Optogenetics is hugely invigorating, a testament to human ingenuity, and the value of fundamental research. [LINK] #neuro.*"

Negatively-valenced tweets (1 %) included those such as, "*Scary weapons in 10-20 yrs: smart explosive rounds, cheap Genspace, Energy Weapons, AI kill decision, Microrobots, battlesuits, optogenetics.*"

We further coded each tweet for applications of optogenetics, and found that nearly half of the sample of tweets mentioned optogenetics in the context of medical research (48 %). However, only 20 % of those tweets disclosed that the research was conducted on an animal model. The tweets that mentioned a disease or condition were primarily concerned with pain (15 %), epilepsy (13 %), addiction (11 %), Parkinson's disease

Table 3 Tweet content codebook

Question	Category	Code	Definition	Example	%
What are people saying about optogenetics?	Tweet content type	News report	Text of tweet is a statement about optogenetics with a corresponding link to a news report	Manipulating memory with light: Scientists erase specific memories in mice #optogenetics #memory #memories #UCDavis [LINK]	35
What are people saying about optogenetics?	Tweet content type	Assertion	Tweet is a statement about optogenetics and not a study or news report	Optogenetics. Implant neurons with light-sensitive proteins called opsins, can stimulate or silence them with a simple optic fibre.	34
What are people saying about optogenetics?	Tweet content type	Study	Text of tweet corresponds to link to a published study	Optogenetics Reveal Delayed Afferent Synaptogenesis on Grafted hiPSC-Derived Neural Progenitors [LINK]	13
What are people saying about optogenetics?	Tweet content type	Personal	Tweet is not of a professional capacity	'Tis only a matter of time before I implant cognitive performance enhancing optogenetic tech in my skull just u wait	8
What diseases are people discussing optogenetics in the context of?	Diseases mentioned	Disease	Indicates diseases mentioned in the context of optogenetics	Optogenetics: Identifying New Targets for Epilepsy Intervention [LINK] #science [LINK]	15
What do people think about optogenetics?	Tone	Neutral	Tone of the tweet is neutral regarding the application of optogenetics	Emerging science of Optogenetics. [LINK]	88
What do people think about optogenetics?	Tone	Positive	Tone of the tweet is positive regarding the application of optogenetics	This is amazing! Mind-controlled transgene expression by a wireless-powered optogenetic designer cell implant [LINK]	11
What do people think about optogenetics?	Tone	Negative	Tone of the tweet is negative regarding the application of optogenetics	Optogenetics (switching on neurons with a laser) sounds like some pretty scary sci-fi stuff to me - [LINK]	1
What key stakeholders are people mentioning?	Stakeholder mentioned	Academic institution	Tweet mentions an university	Using light to control the activity of the brain now used @ Stanford to understand brain's wiring & unravel behavior:[LINK]	8
What key stakeholders are people mentioning?	Stakeholder mentioned	General researcher	Tweet mentions a researcher	Researchers shine light on how stress circuits learn [LINK] #Optogenetics #Stress	7
What applications of optogenetics are people discussing?	Applications of optogenetics	Control of brain/ neurons/ genes	Tweet states optogenetics can be used to control genes, neurons, or the brain	Controlling the brain with light [LINK]	17
What applications of optogenetics are people discussing?	Applications of optogenetics	Treatment/cure of disease	Tweet states optogenetics can be used as a treatment or cure for disease	Researchers use optogenetics to obliterate fearful memories in mice. May help w/ treating PTSD & anxietydisorders [LINK]	10
What applications of optogenetics are people discussing?	Applications of optogenetics	Control of memories	Tweet states optogenetics can be used to control memories	Optogenetics: New Technology to Manipulate Memories [LINK]	7
What applications of optogenetics are people discussing?	Applications of optogenetics	Understanding brain	Tweet states optogenetics can be used to study the brain	Optogenetics sheds causal light upon workings of brain [LINK]	7
What aspects of research on optogenetics are people discussing?	Research	Research	Tweet makes any mention of research	Optogenetics research is transferring synthetic photoreceptor molecules to the neural layer in the eye - early success	48
What aspects of research on optogenetics are people discussing?	Research	Mouse model	Tweet discusses research carried out on a mouse model	Virally mediated optogenetic excitation and inhibition of pain in freely moving nontransgenic mice [LINK]	5
What words are people using to discuss optogenetics?	Vocabulary used	Control	Tweet mentions the word "control" or any forms of the word in the context of optogenetics	Optogenetics and mind control– on the borders of the plausible? [LINK] #Science	14

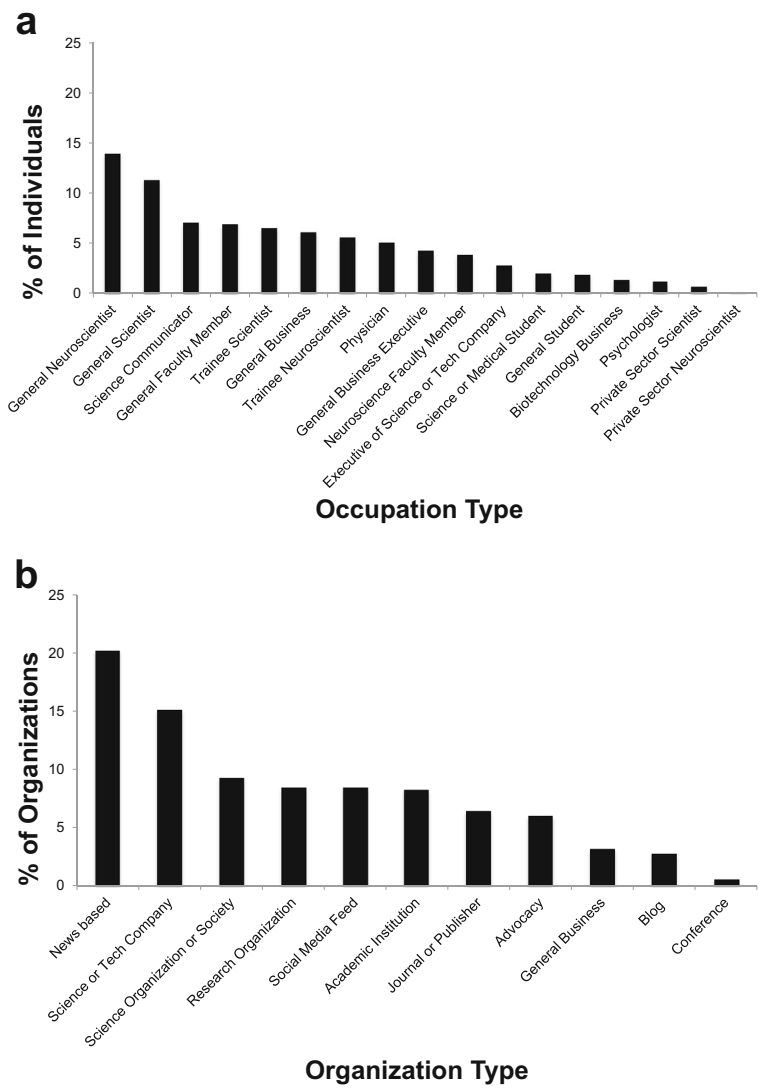

Fig. 1 Twitter user types contributing unique tweets about optogenetics **a** User-provided occupation for accounts belonging to individuals ($n = 754$) **b** User-provided organization type for accounts representing an organization ($n = 495$)

(10 %), and stroke (10 %). For example: "*#Optogenetics is a noninvasive technique of controlling #brain activity, a possible future therapy for #epilepsy. [LINK].*"

Additionally, tweets often cited the application of optogenetics for treatment of disease (10 %) but frequently gave little indication of the timeframes in which these treatments can be expected: "*Scientists @NYULMC use optogenetics to develop new treatments for psychiatric disorders [LINK].*"

The most prominent nonmedical application discussed was the ability to control brain activity (17 %; Fig. 2). However, claims about optogenetic control of the brain often gave little context of the extent of this control: "*Optogenetics: Controlling the brain with light [LINK].*"

A portion of tweets mentioned stakeholders, scientific researchers in particular (9 %), that are integral to the development of optogenetics research. Generally, these mentions were in the context of a new scientific discovery: "*Researchers erase memories in mice using optogenetics [LINK] #PSYC2385.*"

Discussion

Analysis of content about optogenetics on Twitter reveals that: 1) academic researchers and technology companies are the main contributors to the discussion; 2) research findings dominate the discussion through links to peer-reviewed articles; and 3) the tone of the discussion is

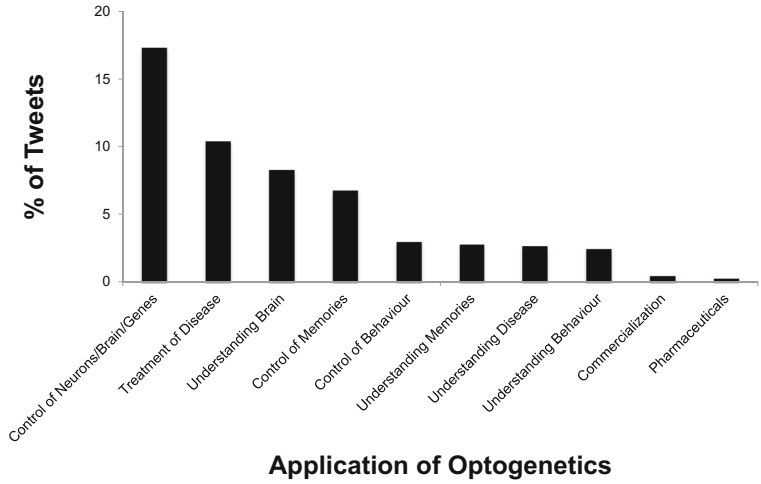

Fig. 2 Applications of optogenetics discussed in the tweets (n = 1000)

generally neutral. These findings contribute to the growing body of knowledge surrounding the discussion of novel biotechnologies on social media and to the understanding of perceptions of scientific discoveries as a whole.

In a departure from other work suggesting that researchers are apprehensive about social media platforms [26], academic researchers represented a large proportion of the sample of users in our study. Science communicators, such as editors of peer-reviewed journals or authors of popular science blogs, were also some of the most prominent occupations amongst users. We hypothesize that increased representation of science communicators on social media may lead to more responsible reporting of research discoveries, unlike what has been observed to date on the representation of other biotechnologies, such as stem cells, on Twitter [2, 27]. Among the organizations tweeting about optogenetics, news agencies represented the majority. Medical and technology companies were also involved in the conversation, despite optogenetics being very early in the translational pipeline.

The links associated with these tweets were generally from high-quality scientific news sources. The general trend seen in this study suggesting a relatively accurate portrayal of optogenetics-related discoveries may speak to the promise of social media as an appropriate tool for information dissemination when stakeholders involved in the process of the research participate in the conversation.

The content of tweets discussing novel biotechnologies are heavily influenced by real-world events and their subsequent representation in traditional media [2]. The potential applications of optogenetics for controlling the brain and treating disease were a strong focus. Though claims of these future applications were often made without discussion of their early stage in the translational timeline, the tone of the tweets generally remained neutral rather than overly optimistic. Furthermore, few of the tweets were highly polarized, in contrast with findings of other studies on Twitter on topics ranging from stem cells to political views [2, 6, 28]. This may be attributed to the higher proportion of researchers engaged in the discussion, as well as the greater prevalence of links to journal articles than found in other studies on Twitter using similar methods [2]. This highlights the importance of increased engagement between researchers and the general public to foster a better understanding of scientific findings [22]. However, as public attention surrounding optogenetics increases and more users begin to participate in the discussion, the quality of this information on Twitter may change; therefore it is imperative that researchers continue to participate in and contribute to the online discussion.

We appreciate the limitations of the present study. Other social media platforms such as Facebook that we did not study here also contribute to the discussion of optogenetic discoveries, and as tweets are limited to 140 characters, this may constrain the depth and detail of the discussion on Twitter. In terms of stakeholder engagement, previous studies have shown that organizations on Twitter still favor one-way communication rather than two-way symmetrical conversations [29]. As we did not analyze interactivity between accounts and tweets, we are not in measure to confirm these observations in our sample about optogenetics. Future work will examine the directionality of the discussions. A limitation intrinsic to research on Twitter data is that it is not possible to capture all the tweets that exist related to the topic of

interest in a sample using the API and there is no assurance of a representative sample [30]. Also related to sampling, there may also exist search terms analogous to "optogenetics" in lay language that may have yielded more tweets from users outside of the research field. Studies of content on social media are subject to selection bias, as greater proportions of users may be from younger and more racially diverse groups [30–32]; thus the opinions reflected here may not be representative of the general population; however, Smith and Brenner [33] indicate that Twitter users are well-distributed across gender, income and education levels. In addition, due to the anonymity of Twitter, it was not possible to verify the locations and occupations of each of the users who disclosed their personal information to ensure the information is accurate.

Despite these limitations, we show that the Twitter discussion about optogenetics is relatively conservative compared to discussion of other novel biotechnologies such as stem cells or gene therapy examined using similar methods [1, 2]. The data support the impetus for researchers to be active on social media to act as stewards of high quality neuroscience communication.

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Compliance with Ethical Standards

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