Examining Peer-to-Peer and Patient-Provider Interactions on a Social Media Community Facilitating Ask the Doctor Services

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Abstract

Ask the Doctor (AtD) services provide patients the opportunity to seek medical advice using online platforms. While these services represent a new mode of healthcare delivery, study of these online health communities and how they are used is limited. In particular, it is unknown if these platforms replicate existing barriers and biases in traditional healthcare delivery across demographic groups. We present an analysis of AskDocs, a subreddit that functions as a public AtD platform on social media. We examine the demographics of users, the health topics discussed, if biases present in offline healthcare settings exist on this platform, and how empathy is expressed in interactions between users and physicians. Our findings suggest a number of implications to enhance and support peer-to-peer and patient-provider interactions on online platforms.

Introduction

People increasingly turn to online sources for health information and advice (Antheunis, Tates, and Nieboer 2013a; Amante et al. 2015)) and there is strong demand for online communication with physicians (NIH National Cancer Institute 2014). One modality to communicate with physicians online is Ask the Doctor (AtD) services. AtD services allow people to connect and obtain information and advice from physicians without a previously established relationship. For example, Fenda, a commercial Chinese Q&A platform, allows patients to ask a question and receive a one-minute voicemail response from a physician (Ma et al. 2018).

As online health care grows understanding how these services differ from traditional physician-patient interactions will be critical to ensuring high quality care. Reddit provides an avenue for studying this new healthcare modality. Established in July 2013 the subreddit r/AskDocs facilitates AtD services through an online community where people can access information from moderator-verified physicians for *"...personal health questions (*www.reddit.com/r/AskDocs).*"* Although r/AskDocs cannot provide all the benefits of a traditional setting (e.g., medical testing) or commercial AtD infrastructure (e.g., selecting a physician to re-

spond) provide, it has the advantages of being free, convenient with 24-7 access, and provides pseudo-anonymity, all within an existing popular social media interface. The public format enables study of the emerging AtD landscape.

Health disparities are a particularly interesting aspect that may differ between traditional and AtD healthcare delivery. Racial, ethnic, and gender minorities – regardless of their insurance status, income, age, and severity of conditions – often have less access to health care than their counterparts. Even with access, minorities frequently receive lower quality care with worse health outcomes than their counterparts for similar health issues. Despite substantial efforts to close this gap (e.g., insurance reforms and promoting greater workforce diversity) barriers and bias persist and contribute to a gap of unmet healthcare needs (Hardeman, Medina, and Kozhimannil 2016).

This paper examines how the public and physicians are leveraging publicly available social media for AtD services, and if biases present in traditional healthcare settings transcend mediums into this online community. Our analysis considers four research questions.

RQ1: What are the self-reported demographics (gender/sex and race/ethnicity) of posters on r/AskDocs? We automatically extract self-reported gender/sex and race/ethnicity from posts.

RQ2: What health topics do posters commonly ask about on r/AskDocs and how does this vary across demographics? We conduct a topic model analysis and examine how topics vary across demographics using odds ratios.

RQ3: Does receipt of a response in general or by a physician vary across demographics? We examine the association between demographics and the probability of receiving at least one response (in general and by a physician) using logistic regression.

RQ4: Does the empathy of response(s) by a peer or a physician vary across demographics or health topics? We examine variation in empathetic responses among the posters' demographics and health topics using language style matching (LSM).

We contextualize our findings using previous works on online AtD services, bias and barriers in traditional health care settings, and peer-to-peer and patient-provider interac-

tions in the health information exchange. We discuss implications to facilitate these organic interactions on a publicly available social media setting.

Ethics and Privacy. Our research was exempted from an ethics review by the University of California San Diego Human Research Protections Program and Johns Hopkins University Institutional Review Board. However, given the sensitivity of the topics discussed and vulnerable groups participating in r/AskDocs, we adhere to suggested data protections (Benton, Coppersmith, and Dredze 2017) including modifying quotes to avoid reverse identification (Ayers et al. 2018).

Related Work

Barriers and Biases in Traditional Health Care

Affordability About half of Reddit users live in the United States (US) (Alexa 2019). The US is the only high-income country without a publicly financed universal health system (Squires and Anderson 2015), and one-third of people (43% of low-income families) reported costs impeded access to health care (Osborn et al. 2016). Moreover, one-third of the 23 million uninsured US adults report forgoing necessary medical care in the past year because of costs (Hero et al. 2016).

Convenience and Accessibility Many US adults are unable to procure timely medical appointments (Liaw et al. 2019; Uscher-Pines and Mehrotra 2014), waiting an average of 24 days to see a physician (Team 2017). Travel and schedule availability create additional barriers with the time burden for racial/ethnic minorities averaging 25% longer (Ray et al. 2015).

Stigma Internalized or experienced stigma can hinder people from seeking health care assistance (Link 1987; Eisenberg et al. 2009; Scambler and Hopkins 1986; Hausmann et al. 2011). In lieu of face-to-face health care, people often turn to the internet to look for health information when they perceive stigmatization (Zhang 2014).

Biases in Healthcare Delivery Patients with similar conditions, but differing social categorizations, often experience differences in the health care that they receive (Gengler and Jarrell 2015; Bailey et al. 2017; Homan 2019). For example, women and racial minorities receive less pain relief (Pryma 2017; Meghani, Byun, and Gallagher 2012) and Hispanics and blacks are less likely to receive the most effective forms of pain relief (Meghani, Byun, and Gallagher 2012). Gender minorities often have higher healthcare needs, but disproportionately receive less care (Reisner et al. 2016; Winter et al. 2016; James et al. 2016) and experience bias and microaggressions while receiving care (Marcelin et al. 2019), some being refused care entirely (James et al. 2016; White Hughto et al. 2016).

Online Ask The Doctor Services

All of these reasons – financial barriers, convenience, and dissatisfying interactions with medical care – are reasons people seek information on AtD services (Umefjord, Petersson, and Hamberg 2003). In response, many commercial and non-commercial platforms have emerged (Vinker et al. 2007; Björk et al. 2017a; Klinar et al. 2011; Deldar, Marouzi, and Assadi 2011a). For example, CrowdMed, a US-based commercial platform, allows users to present their medical case for a fee and professional case solvers make diagnoses, and Infomedica's AtD, a Sweden-based non-commercial platform, allows users to ask physicians questions (Meyer, Longhurst, and Singh 2016; Umefjord, Petersson, and Hamberg 2003). However, non-commercial platforms often are short-lived because they are under-staffed, lack funding, and lack scalability (Ma et al. 2018). We examine how patients and providers leverage free social media to create an online AtD community.

Empathy in Offline and Online Health Settings

Empathy – the ability to perceive and understand another person's feelings – is a crucial human interaction directly linked to health outcomes (Miller and Wallis 2011). Higher ratings of perceived empathy from a physician are associated with increased trust in the medical establishment and compliance with preventative care (Hojat et al. 2010). Moreover, even online empathy is associated with a greater sense of a virtual community and supportive communities are associated with positive health outcomes (Welbourne, Blanchard, and Boughton 2009).

Empathy often expresses itself with non-verbal cues (e.g., synchrony in voice tones or body language), but online interactions restrict the cues to language (Pfeil and Zaphiris 2007). Previous work on online empathy evaluated perceptions using surveys (Nambisan 2011) or with qualitative discourse analysis (Pfeil and Zaphiris 2007). Linguistic cues can be a simple restatement of content (indicated by nouns and verbs) or a more complex reflection of style (as indicated by pronouns and articles) (Ireland and Pennebaker 2010; Lord et al. 2015). Ireland and Pennebaker (2010) developed a method for measuring linguistic conversation synchrony (using function words) in offline settings (hereafter referred to as LSM), which was validated with measures of perceived empathy in an offline patient-medical provider setting (Lord et al. 2015). A variation of their LSM measurement has been applied in an online setting to verify linguistic accommodation on Twitter (Danescu-Niculescu-Mizil, Gamon, and Dumais 2011). Ours is the first study to examine cues of perceived empathy in an AtD service using LSM as a proxy.

Data

Reddit is a social media site with 330 million monthly users, primarily from the US (Alexa 2019). Individual communities (subreddits) host discussions about specific subjects. r/AskDocs is a large online health community with more than 185k subscribers (January 2020). The community allows users to submit questions about personal medical conditions which are answered by physicians that are verified by community moderators and indicated by user-level tags, or "flair," displayed next to username (e.g., dermatologist, physician, surgeon). Posters are required to provide as much

Total Unique Users	166,846
Total Posts	190,974
Total Unique Posters	131,020
Total Comments	694,533
Total Unique Commenters	106,306
Mean ± Std Dev Comments Per Post	1.28 ± 1.50
Median Comments Per Post	1.0
Total Comments by Physicians	83,180
Total Unique Physician Commenters	356

Table 1: Descriptive statistics about r/AskDocs.

detail as possible, including their demographics. Subreddit participants comment on the poster's inquiry (hereinafter referred to as commenters).

We collected all r/AskDocs posts, comments, and associated metadata (e.g., usernames, timestamps) from its inception in July 2013 through December 2018 from pushshift.io archives. Our final dataset (Table 1) contained 190,974 posts from 131,020 posters with 694,533 comments from 106,306 commenters. Physicians authored 12% of all comments. The number of posts has increased over time, while the percentage of posts that supply demographics and receive a comment in general or specifically from a physician has remained relatively stable. The average time to first response decreased substantially from 2013 to 2014 and has since stabilized at a median of 63 minutes. At least one new physician has joined and commented on r/AskDocs each month since 2014 with an average of 5 (SD = 3) new physicians commenting each month.

Methods

RQ1: Self-Reported Demographics in Posts

Our first research question quantifies the self-reported demographics of posters to contextualize the users of this online community. While r/AskDocs asks posters to provide demographics, including sex and race, they do not require a specific format. A 21 year-old Hispanic female may describe herself as "*21 year old Latina female*" or "*Age: 21 Sex: Female Race: Hispanic.*" Rather than adhering to pre-defined racial categories (e.g., defined by the US Census Bureau), we conformed to how posters described themselves. For example, although Hispanic is an ethnicity, posters commonly used it as a race. Additionally, some posters chose to provide their gender as opposed to binary sex. Similarly, we conformed to how posters described their gender. The final gender/sex categories were female, male, transgender, or unknown, and the final race/ethnicity categories were Asian, black, Hispanic, Indian, Middle Eastern, white, or unknown.

We developed regular expressions to extract a poster's binary sex (male/female) and race/ethnicity based on how posters self-described themselves using iterative samples of 100 random posts until no new descriptions of demographics appeared in the sample. If the regex identified a singular match for a demographic category, we labeled the post with the matching demographic. However, if we found multiple matches that differed within a demographic category, we labeled the post as unknown. Additionally, we negated common English patterns that are not references to race (e.g., Indian food). After applying the rules to extract binary sex,

we applied rules to extract posts that self-identified as transgender using patterns for trans, transgender, MtF (male to female), and FtM (female to male). If a transgender pattern matched, we overrode the binary sex label to assign the transgender label.

Performance of our rule-based approach for binary sex and race/ethnicity was measured based on a heldout sample of 100 random posts. A total of 50 posts that were labeled as transgender were reviewed for precision.

RQ2: Health Topics in Posts

Our second research question examines the content of posts using topics to contextualize the types of medical issues discussed in the community. We applied Latent Dirichlet Allocation (LDA) (Blei, Ng, and Jordan 2003), a probabilistic topic model that identifies major topics in a text corpus by inferring topic distributions for each post and a word distribution for each topic; topics are defined as distributions over words. LDA has been previously employed to identify themes in health-related social media (Paul and Dredze 2014; Wang et al. 2014; De Choudhury and De 2014; Resnik et al. 2015; Surian et al. 2016; Park and Conway 2017; Record et al. 2018).

Text was pre-processed to lower case, remove punctuation, remove stop words, and replace numbers with 'num_token.' We used the LDA implementation in MALLET (McCallum 2002) via the Gensim package (Řehůřek and Sojka 2010). Each post was assigned the highest probability topic (Chen and Dredze 2018). Two authors collaboratively labeled the topics by qualitatively reviewing the top 10 words associated with the topic and five randomly selected posts associated with the topic. The authors' backgrounds are in digital health; author one has a background in online health information seeking and computational social science and author two has a background in public health. We repeated this process for models with varying numbers of topics (50, 75, 100), and selected the model with 100 topics as it had the highest quality topics based on human judgement.

We compared differences in topic prevalence across demographics (e.g. what do females versus males talk about) by calculating the odds of each topic in the demographic of interest to the reference group (i.e. the majority group).

RQ3: Receipt of Response

Our third research question measures the association between self-reported demographics and the receipt of a response either in general or by a physician. We used multivariable logistic regression to assess the relationship between the explanatory variables of gender/sex and race/ethnicity in the post and the probability of (1) receiving any response and (2) receiving a response from a physician. While holding the other explanatory variables at their means, we estimated the probability of receiving a response (any response or a response from a physician) for each variable and corresponding 95% confidence intervals (CIs) by using 1000 simulations from the multivariable normal distribution with the mean equal to the maximum likelihood point estimate and the variance equal to the coefficient covariance matrix (King, Tomz, and Wittenberg 2000).

Category	Examples
Personal pronouns	*I, his, their*
Impersonal pronouns	*it, that, anything*
Articles	*a, an, the*
Conjunctions	*and, but, because*
Prepositions	*in, under, about*
Auxiliary verbs	*shall, be, was*
High-frequency adverbs	*very, rather, just*
Negations	*no, not, never*
Quantifiers	*much, few, lots*

Table 2: Functional word categories for LSM as defined by LIWC 2015 (Pennebaker et al. 2015)
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	n	%		n	%
Race/Ethnicity			**Gender/Sex**		
Asian	4,611	2.4	Female	39,318	20.6
Black	3,084	1.6	Male	82,126	43.0
Hispanic	1,593	0.8	Transgender	319	0.2
Indian	786	0.4	Unknown	69,211	36.2
Middle Eastern	231	0.1			
Multiracial	1,040	0.6			
White	48,354	25.3			
Unknown	131,275	68.8			

Table 3: Self-reported demographics as extracted from posts. n = number, % = percentage of total posts.

RQ4: Empathy of Response

Our fourth research question measured the empathy of responses by physicians and non-physicians. Adapting the procedure in Ireland and Pennebaker (2010), we measured the LSM of each conversation (i.e., the post and associated response(s)) as a proxy for empathy. We included all posts with at least one response that was not the original poster (follow-up comments from original posters were excluded). First, we used Linguistic Inquiry and Word Count software (Pennebaker et al. 2015) to calculate the percentage of the total words that fall into nine function-word categories (see Table 2 for categories). Second, separate LSM scores were calculated for each of the function-word categories using Equation 1, where aux_p is the percentage of auxiliary verbs used in the post and aux_r is the percentage of auxiliary verbs used in the response.

$$LSM_{aux} = 1 - [(|aux_p - aux_r|)/(aux_p + aux_r + 0.0001)]$$
(1)

Third, a composite LSM score for each post-response pair was calculated using the mean of the nine function category-level LSM scores. Finally, if there were multiple responses, we calculated a single conversational LSM score for each post as the mean of the composite LSM scores. To calculate the conversational LSM for peer-to-peer interactions, we only included responses from non-physicians. To calculate the conversational LSM for patient-provider interactions, we only included responses from physicians. Confidence intervals were calculated from bootstrapped samples.

Results

RQ1: Self-Reported Demographics in Posts

Performance of Demographic Identification We correctly identified 100% of the self-reported gender/sex and 99% of the race/ethnicity of the posts in the heldout sample. Sixty-six of the posts contained a gender/sex and 34 posts did not. Thirty-two of the posts contained a race/ethnicity and 67 did not. The one mislabeled post was a false negative; the poster mentioned their race, but our regex matched several other keywords so race/ethnicity was incorrectly marked as unknown. Of the 50 randomly selected posts labeled as transgender, two were incorrectly labeled. These results exhibit a high confidence in our inferred demographic labels.

Demographics of Posters Table 3 presents self-reported demographics in the posts. Although 63.8% of posts provide a gender/sex, 67.5% of posts do not provide a race/ethnicity. Of the posts that included self-reported gender/sex, 67.5% were authored by individuals identifying as male, 32.3% as female, and 0.3% as transgender. Of the posts that included self-reported race/ethnicity, 81% were authored by individuals identifying as white, 7.7% as Asian, 5.2% as black, 2.7% as Hispanic, 1.7% as multiracial, 1.3% as Indian, and 0.4% as Middle Eastern.

RQ2: Health Topics of Posts

Figure 1 visualizes the topics with manually assigned labels. The 100 topics collapsed into 75 because of duplicate topic labels. Table 4 presents the odd ratios for the prevalence of topics from demographics of interest (minority users of r/AskDocs) compared to reference groups (majority users of r/AskDocs: whites and males).

The ten most frequent medical topics included dermatology, reproductive health, diagnostic testing, dental and oral care, issues related to lower extremities, colds/sinus infections/allergies, fractures/sprains, cardiology, issues related to upper extremities, and nutrition. We briefly describe some of the topics and share example posts to highlight the diversity of questions in this online community.

The most common topic requested crowd-diagnosis (Nobles et al. 2019) of a dermatological issue. These posts were often accompanied by a photo to aid diagnosis. For example, one post requested a second opinion from r/AskDocs about a cluster of painful bumps that had been previously diagnosed as a bacterial infection and was prescribed a topical antibiotic. An alarmed physician indicated that the poster had been misdiagnosed, diagnosed the poster with shingles (a viral, herpetic infection), and provided instructions for care. The poster followed up that they sought a second opinion in person and it was indeed shingles.

As suggested by previous research (Umefjord, Petersson, and Hamberg 2003; Nobles et al. 2018), posters may prefer the pseudo-anonymity of the platform to discuss and request information about stigmatized health issues, such as sexually transmitted infections. For example,

> I was treated for chlamydia with antibiotics several months ago. I started to feel similar symptoms a week ago. Is it possible for it to come back?

Similarly, people posted about subjects that are often considered taboo or volatile in mainstream culture. Posts on substance use discussed dangers of long-term alcohol consumption, the potential relationship between dys-
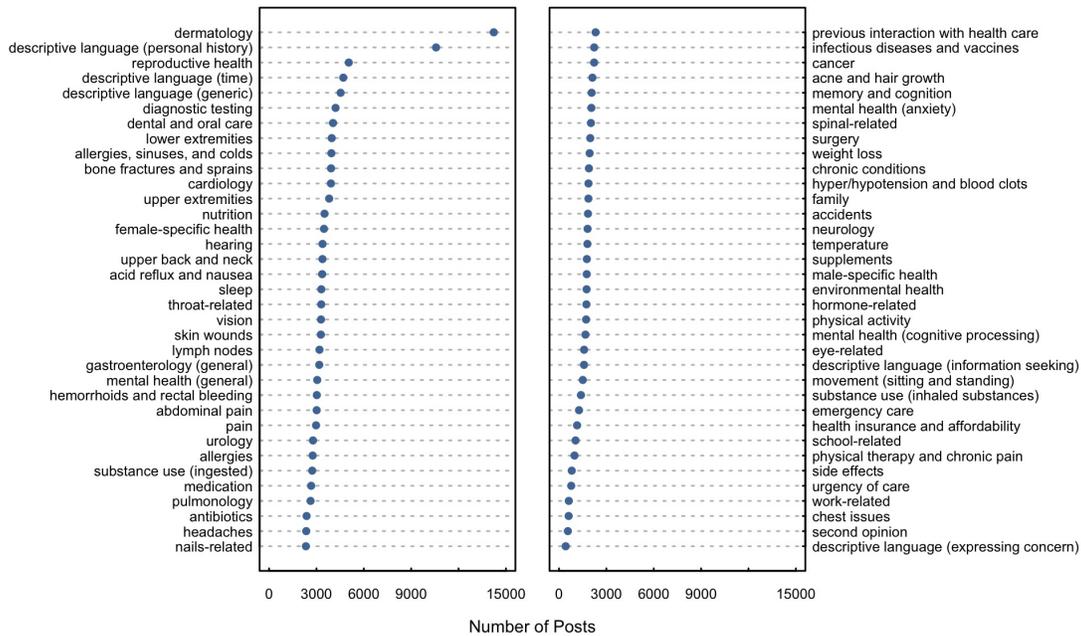
Figure 1: Dot plot of the topics present in the posts. The dot indicates the number of posts that were assigned the topic.

pnea (shortness of breath) and marijuana usage, risks of 3,4-methylenedioxy-methamphetamine (MDMA) for people who have a history of epilepsy, and the symptoms of lung cancer for a long-term smoker. For example,

I have a history of epilepsy, but stopped having seizures a few years ago. I want to take MDMA for the first time. Is there a serious health risk for seizures with molly?

I'm desperate to sleep so I've been taking benzos I got from a friend to help. I'm having trouble weening myself off the benzos without symptoms. I'm afraid to tell the doc for fear of being labeled a drug addict. Could this be withdrawal?

Another example are posts inquiring about the efficacy and potential complications of vaccinations. For example,

I had a severe reaction to the first pertussis vaccine as a child and did not receive the rest of the series. Now with the anti-vaccination movement, I'm worried about my risk of whooping cough. Has the vaccine changed in the last two decades?

Posts focused on health issues, such as dental/oral care and mental health that are often compartmentalized and perceived as less essential (Petersen et al. 2005). For example,

I have small red painful bumps around my teeth. It could be from a new toothpaste. Should I see a doctor?

Posts about mental health focused not only on mental health disorders (e.g., anxiety, depression, schizophrenia), but also on cognition and memory. For example,

I'm in my mid-50s and noticed that I can't remember what happened in the past few weeks. I'm really scared because I'm the only provider in my house. Could this be from depression or stress? Should I go to the emergency department?

Finally, posts also sought information about how to provide care while waiting on an appointment with a physician or the necessity of medical care. For example,

I broke my front tooth while I was eating [link to image]. It doesn't hurt. I'm going to see the dentist, but meanwhile is it safe to drink and eat? Should I brush the tooth?

An urgent care center told me that I may have angiodema [rapid swelling that can be due to an allergic reaction]. I'm hesitant to go to the emergency department because of cost. Should I wait it out?

Differences in Topics Among Gender/Sex. The odds of inquiring about female-specific health issues were 110 times higher among posts authored by females than males. Female-specific health issues exhibited concerns about birth control efficacy, painful menstruation, hormones, miscarriages, physical signs of pregnancy, and bleeding during pregnancy. For example, one poster inquired about the best method to manage their recent pregnancy loss - whether to miscarry naturally or to have a dilation and curettage procedure.

The odds of inquiring about female-specific health issues and hormonal issues were 44 and 18 times higher, respectively, among posts authored by transgender people than males. For example, one poster, assigned female at birth, expressed that they had severe gender dysphoria and because of the discomfort could not bear to receive gynecological care. The poster inquired about cervical cancer and the ability for a viable pregnancy if they neglected gynecological care. One poster, assigned male at birth and transitioning to female, inquired if hormone replacement therapy would

Category	Five Largest Odds Ratios
Gender/Sex	
Female	female-specific health (110.75), chronic conditions (3.12), antibiotics (2.02), emergency care (1.92), urgency of care (1.92)
Transgender	female-specific health (43.95), hormone-related (17.28), side effects (5.19), medication (4.22), previous interaction with health care (3.87)
Race/Ethnicity	
Asian	acne and hair growth (1.76), allergies (1.60), school-related (1.57), nutrition (1.47), previous interaction with health care (1.42)
Black	environmental health (5.27), nails-related (5.02), accidents (3.20), hemorrhoids and rectal bleeding (3.15), vision (2.88)
Hispanic	descriptive language (expressing concern) (1.93), school-related (1.92), urgency of care (1.64), family (1.47), health insurance and affordability (1.47)
Indian	second opinion (2.64), acne and hair growth (2.15), side effects (2.00), supplements (1.97), diagnostic testing (1.79)
Middle Eastern	family (5.40), chest (3.83), health insurance and affordability (3.78), school-related (2.84), supplements (2.58)
Multiracial	substance use (ingested) (5.26), side effects (4.55), environmental health (4.50), hemorrhoids and rectal bleeding (3.85), substance use (inhaled) (3.12)

Table 4: The five largest odds ratios for the prevalence of topics from minority users of r/AskDocs compared to reference groups (white and male). Odds ratios greater than 1 indicate that the topic is more likely to occur in the posts of minority users.

achieve desired facial attributes. Another poster, assigned female at birth and transitioning to male, had elevated lab results indicative of a blood cancer and inquired about the safety of starting testosterone. A physician responded that despite the blood work, the symptoms seemed indicative of a more benign condition.

Differences in Topics Among Race/Ethnicity There were fewer differences in race/ethnicity compared to differences by gender/sex. While a few high odds ratios stand out, we caution in interpretation because the number of posts grouped by racial/ethnic category and topic is substantially smaller than the number of posts grouped by gender/sex category and topic. The odds of inquiring about environmental health were five times higher among posts authored by people identifying as black than white. Posts mentioning a family-related issue were five times more likely by people identifying as Middle Eastern than white. Substance use posts were five times more likely by people identifying as multiracial than white.

RQ3: Receipt of Response

Table 5 shows the probability of receiving a response associated with each demographic and 95% confidence intervals. In the logistic regression models estimating the association between demographics and receiving a response, there was no evidence that self-reported gender/sex or race/ethnicity were associated with a practically significant difference in the probability of receiving any response or receiving a response from a physician.

Receipt of Any Response Across the entire sample, the probability of receiving a response was 71.6%. Males had a slightly lower probability of receiving a response than females and posts where gender/sex were unknown. Posts authored by transgender people had a similar probability of receiving a response as females, males, and unknown gender/sex. Posts authored by people identifying as white had a slightly lower probability of receiving a response than posts authored by people who identified black, multiracial, or posts where race/ethnicity were unknown. Overall, we found that poster demographics had little to no effect in receiving a response.

Receipt of Response from a Physician Across the entire sample, the probability of receiving a response was 11.2%. A null association of self-reporting gender/sex and probability of receiving a response from a physician was observed for posts authored by females, males, transgender people, and unknown gender/sex. A null association of self-reporting race/ethnicity and probability of receiving a response from a physician was observed for posts authored by people who identify as Asian, black, Hispanic, Indian, Middle Eastern, multiracial, white, and unknown race/ethnicity.

RQ4: Empathy of Response(s)

Empathy across Demographics Table 5 presents the LSM and differences in LSM between physician and non-physician responses across demographics. Posts that self-identify as female are associated with slightly more empathetic responses than males. Posts that self-identify as Asian, black, Hispanic, Indian, or Middle Eastern are associated with slightly less empathetic responses than their white counterparts.

To better understand these computational differences in empathy, we qualitatively reviewed a random sample of 20 posts identifying as female and 20 posts identifying as male inquiring about dermatology (the most common topic in this community). The posts contained similar types of inquiries (e.g., questions about skin irritation, insect bites), had similar lengths (mean 161.9 ± 65.0 words for female-authored posts and mean 161.4 ± 157.6 words for male-authored posts), and received a similar number of comments (mean 1.7 ± 1.2 for female-authored posts and mean 1.1 ± 0.7 for male-authored posts). Despite similarities, the comments for male-authored posts often focused on brief diagnoses contrasted to comments to female-authored posts which often focused on providing contextual information, resources, and suggested treatments in addition to diagnosing. We share conversations below that exemplify this.

Post (male author): I've had a red rash on my face for several years (see image). The only med I take is [medication name] for a mood disorder. What could this be?

Comment 1: Eczema.

Comment 2: Rosacea.

	Any Response[a]		Physician Response[a]		Empathy of Response(s)[b]		Difference in Empathy[c]	
	P	95% CI	P	95% CI	Mean	95% CI	Mean	95% CI
Total Probability	71.6	–	11.2	–	–	–	–	–
Gender/Sex								
Female	72.9	72.5, 73.3	11.1	10.8, 11.5	58.6	58.4, 58.8	-2.2	-2.7, -1.6
Male	69.6	69.2, 69.9	10.8	10.6, 11.0	56.0	55.9, 56.2	-2.8	-3.2, -2.4
Transgender	69.7	64.8, 74.6	12.9	9.7, 17.4	58.1	55.5, 60.6	-4.5	-11.1, 1.6
Unknown	73.5	73.1, 73.8	11.5	11.3, 11.8	56.0	55.8, 56.1	-1.9	-2.3, -1.7
Race/Ethnicity								
Asian	68.0	66.7, 69.4	11.9	11.0, 12.9	54.8	54.1, 55.6	-4.6	-6.3, -2.9
Black	74.7	73.2, 76.2	12.4	11.3, 13.5	55.9	55.1, 56.7	-3.0	-4.9, -1.0
Hispanic	68.8	66.5, 70.9	12.3	10.8, 14.0	55.6	54.4, 56.7	-1.2	-4.0, 1.49
Indian	71.2	67.8, 74.1	13.2	11.0, 15.6	53.3	51.2, 54.8	-3.2	-7.1, 0.4
Middle Eastern	75.0	68.6, 80.1	11.4	7.9, 16.2	52.8	50.2, 55.4	-1.4	-8.3, 4.9
Multiracial	75.5	72.6, 77.9	10.2	8.6, 12.1	59.2	57.9, 60.1	-1.7	-5.1, 1.2
White	69.7	69.3, 70.2	10.9	10.6, 11.2	57.3	57.1, 57.5	-3.1	-3.6, -2.6
Unknown	72.4	72.2, 72.7	11.2	11.0, 11.4	56.4	56.2, 56.5	-2.0	-2.3, -1.7

Table 5: [a]Probability of receiving a response and 95% confidence intervals. P = probability, CI = confidence interval. The overlapping CIs indicate that the differences in response rates are not significant. [b]Empathy of response(s) measured by language style matching on [0,100] scale. [c]Difference between physician and non-physician responses. Positive values indicate physician responses are more empathetic; negative values that non-physician responses are more empathetic.

Post (female author): I have a painful rash on my back that feels like sunburn (see image). I take several medications for depression and anxiety including [medication name] and [medication name]. I also used to smoke. What is this?

Comment: That looks like seborrheic eczema. It's a very common condition, I even have it myself. I suggest trying an over-the-counter anti-fungal cream and hydrocortisone.

Physician responses were slightly less empathetic than responses by non-physicians for posts that self-identified their race/ethnicity as Asian, black, white or unknown, and their gender/sex as female, male, or unknown.

Empathy across Topics The LSM across topics varied more than across demographics ranging from 50.1% (dermatology) to 62.4% (emergency care). Topics with the most empathetic responses were emergencies (62.4, 95% CI [61.4, 63.4], general mental health (62.4, 95% CI [61.7, 63.0]), and discussions related to cognition (61.6, 95% CI [60.6, 62.5]). Topics with the least empathetic responses were dermatology (50.1, 95% CI [49.7, 50.6]), discussions with a lot of descriptive language about their history (52.1, 95% CI [51.6, 52.5]), and nails (53.1, 95% CI [51.2, 54.0]).

We qualitatively reviewed a random sample of 10 posts inquiring about dermatology (the topic with the least empathetic responses) and 10 posts inquiring about emergency care (the topic with the most empathetic responses) authored by white males (the most common demographic in this community). The posts inquiring about emergency care were longer (mean 501 ± 303 words compared to mean 178 ± 131 words for dermatology inquiries), received more comments (mean 2.3 ± 2 compared to mean 1.5 ± 1.0 for dermatology inquiries), and received longer comments (mean 97 ± 112 words compared to mean 42 ± 64 words for dermatology inquiries). Emergency care inquiries focused on the immediacy of receiving care for a number of issues including chest pain, infections, fevers, car accidents, falls, and complications with existing medical issues, whereas dermatology inquiries mostly focused on the issues previously described. In contrast to the dermatology inquiries, emergency care inquiries often received responses prompting the poster to supply additional contextual information and used hedges (e.g., "*sounds like*") to avoid bold statements (Recasens, Danescu-Niculescu-Mizil, and Jurafsky 2013). We share an emergency care conversation below that exemplifies this.

Post: I need urgent advice! I have heart palpitations that I thought were panic attacks. Yesterday I went to the ER, where they did several diagnostic tests. I was cleared. It's worse today. The nurse line tole me to seek care, but I don't have the money for another ER visit. Am I having a heart attack? Could it be something else?

Comment: I'm not a doc, but I have [medical condition]. It sounds like you may have a serious heart condition. Diagnostic tests that you mentioned can be normal even when there is a problem. I suggest you go to the ER for a wearable device that will track it for longer. Try not to worry. I manage my condition using [medication name]. Keep us updated!

Responses by physicians were either similar in empathy or less empathetic (e.g., the greatest difference were discussions related to nails (-7.6, 95% CI [-9.9, -8.3]), vision (-6.2, 95% CI [-8.3, -4.0]), and acne (-5.7, 95% CI [-7.8, -3.5]) than responses from non-physicians across topics.

We qualitatively reviewed a random sample of 20 posts inquiring about nail-related issues (the topic with the largest difference in empathy between physicians and non-physicians) that had comments from both a physician and non-physician. Inquiries about nails focused on injuries, discoloration, ingrown nails, and fungal infections. Not surprisingly, posts received more comments from non-physicians (mean 1.6 ± 0.6) than physicians (mean 1.2 ± 0.4). Comments from non-physicians were longer (mean 43 ± 41 words compared to mean 34 ± 34 words for physicians). Responses from non-physicians with higher scores of empathy tended to use more pronouns to empathize of share a personal experience (e.g., "*I understand how you feel*," "*I know someone who was diagnosed with that*"), whereas responses from physicians with lower scores of empathy tended to focus on supplying direct, factual information (e.g., "*Unless the nail is removed, it will stay like this*"). We share a con-

versation below that exemplifies this.

> **Post:** I injured my nail several years ago (see image). My primary care doctor said that it would grow back with time and it hasn't. Will it?
>
> **Physician Comment:** It won't grow back unless you have surgery to remove it, but sometimes the surgery makes it worse.
>
> **Non-Physician Comment:** I also injured my nail and I think it grew back immediately after the incident, but now I also have a a white spot underneath that nail.

Discussion

Using self-reported demographics and discovered health topics on a social media platform with AtD services, we identified that this online community was primarily male and white, users most commonly sought help for low acuity conditions like dermatology, and females and transgender people sought help on sensitive topics at a higher rate than their male counterparts. There were also small differences in how empathetic a response was across demographics, where females received more empathetic responses than males and racial/ethnic minorities received less empathetic responses than their white counterparts. In general, physicians responses were also less empathetic than non-physicians across demographics and topics.

Contextualizing the Findings

Online Ask the Doctor Services   To our knowledge, this is the first study examining how patients and providers have leveraged publicly available social media to establish an organic AtD service. Most AtD services are either facilitated by governmental health agencies (Deldar, Marouzi, and Assadi 2011b; Vinker et al. 2007) or for-profit companies (Ma et al. 2018). The barriers to participation (as either a poster, peer responder, or physician responder) in this community are low in comparison to other AtD services. For example, all posts and responses can be read without an account; accounts to participate are free; and physicians can verify their status by providing identification to the moderators. Since most information seeking is limited to passively viewing websites (Zhang 2014), the audience of this Reddit community is likely larger than the active users of the platform.

Known motivations for using commercial AtD platforms are supported by this community (Ma et al. 2018). For example, people seek information to weigh if they should receive clinical care, are preparing for a clinical visit, are looking for a second opinion, need help deciphering medical diagnostic results or instructions following a clinical visit, and need help navigating their health insurance or health care system.

Unlike commercial AtD platforms, criteria to verify the credentials of the participating physicians is less stringent and not continuously verified. As of January 2020, the subreddit accepts a "*medical ID, diploma, or other forms of verification*" as valid for verification. Additionally, physicians are allowed to self-describe their expertise for their flair therefore there is no consistency on how a physician describes themselves (e.g., a dermatologist may opt to identify as a physician or a dermatologist).

Bias & Barriers in Health Care   Users inquire about numerous health issues, including issues that are often compartmentalized and perceived as less vital when financially constrained (e.g., dental health, mental health) (Petersen et al. 2005), or stigmatized (e.g., mental health, substance use, reproductive health, sexual health). Previous research has shown that stigmatized issues can generate discomfort and lead to help-seeking outside of the traditional health care setting (Corrigan 2004; Magee et al. 2012; Mitchell et al. 2014; Flanders et al. 2017; Aicken et al. 2016). Conversing with peers and physicians in a pseudo-anonymous setting may help the poster better understand how seemingly compartmentalized issues contribute to a holistic impact on health as well as normalize stigmatized health issues (Nobles et al. 2019).

Consistent with the demographics of Reddit in general, most posters identify as male and white (Perrin and Anderson 2019). However, gender and racial/ethnic minorities participate in this community, albeit at lower rates than their majority counterparts. Some of the health issues that receive differential care in the offline setting are inquired about in this community at higher rates for females and transgender people than their male counterparts. We found that females and transgender people have higher odds of inquiring about sensitive or stigmatized topics than their male counterparts. For example, females and transgender people both discuss female-specific health concerns including pregnancy, pregnancy loss, and menstruation at higher rates. All of these are taboo topics in mainstream culture, and, most recently, there has been a push for technology that helps people connect over these topics (Andalibi and Forte 2018). Females also discuss chronic issues, such as fibromyalgia, at higher rates than males. In the offline setting, patient-provider conversations about chronic issues, including pain, are strained (Frantsve and Kerns 2007) and these conversations are more tense for females (Juni et al. 2010; Homan 2019). Transgender people have higher odds of inquiring about hormonal issues, side effects, medication, and health care interactions than males. Inquiries are often in the context of navigating a transition and, as previous research has shown, people often have difficulty obtaining care during this period (James et al. 2016).

Peer-to-Peer & Patient-Provider Interactions   While we did not find variance of response rates across demographics, we found that response empathy does vary across demographics and topics, which supports previous work that found differences in other online communities and information seeking contexts (Joiner et al. 2014; Wang and Jurgens 2018). We also found that responses from physicians are less empathetic than responses from non-physicians.

Empathetic communication, especially with medical professionals, is critical for coping with a health issue and obtaining a positive outcome (Ha and Longnecker 2010). Training for empathetic communication in face-to-face interactions has become standard in medical education (Shapiro, Morrison, and Boker 2004). As patient-provider communication shifts towards computer mediated interactions (Weiner 2012) there will be an increased focus on em-

pathetic linguistic cues (Pfeil and Zaphiris 2007).

Implications

Supporting Patient-Provider Interactions on Social Media This study has implications for enhancements that may facilitate and support interactions on AtD platforms, as well as other online health communities.

First, the number of physicians participating in this community is low in comparison to the number of posters. Physicians' use of online tools to communicate with patients is low, in part because physicians' experiences and attitudes towards information technology vary (Antoun 2015). Some do not believe their patients want or can communicate effectively online; others do not feel confident they can effectively use these platforms or perceive it as an additional burden (Antheunis, Tates, and Nieboer 2013b). However, as Thompson, Younes, and Miller (2012) noted, social media is the new vehicle for patient engagement in medicine - "our patients are doing it [using social media], so this is where we need to be." There are a number of ways that physician participation could be encouraged. For example, physicians must undertake continuing medical education (CME) and could receive CMEs by participating in online health communities. Similarly, medical trainees could use online communications as training for one-to-one communications with patients. Previous work found that physicians that participated in AtD services saw growth in their personal development, such as being better able to understand the patient's perspective, develop strategies to best answer patients' concerns, communicate empathetically, or explain medical terminology in lay terms (Björk et al. 2017b).

Second, beyond interpersonal interactions, information sharing and exchange that 'flows' is an important factor for a user to have a positive online experience (Nambisan 2011). Thoughtful tools, designed hand-in-hand with user experience experts, may improve our abilities to effectively search, locate, and extract information in online health communities. For example, auto-complete suggestions could be incorporated into the search function to allow people to use common terminology so their posts can be more easily located by peers/experts as well as allow them to better formulate their queries. By adding these types of features these communities may begin to serve as a knowledge repository and even allow public health experts to engage in resource sharing (Nambisan 2011).

Limitations and Future Work

Some limitations of this study suggest promising areas for future work. First, we did not distinguish between female-to-male or male-to-female transitions or examine the role of intersectionality. While certainly important (Kelly 2009), we could not make these assessments because of the small sample size once a post was grouped by race/ethnicity, gender/sex, and health topic. Second, we cannot infer physicians' or peers' motivations for volunteering to participate on the platform without complementary offline information. Related, we cannot assess the underlying motivations of posters who use the platform to seek health information

or provide (versus not provide) self-described demographics when doing so. Collectively, these limitations point to the utility of future participatory human-centered research strategies, such as interviews, that can elucidate the varying motivations of stakeholders using this platform (Baumer 2017; Chancellor, Baumer, and De Choudhury 2019). A better understanding of this could help design a better platform for health-based interactions. Fourth, we analyzed interactions using two measures: response rates and empathy. We sought to observe whether differential response rates were associated with demographics and found no practical differences. We did not consider other potential factors that may explain a differential response rate including the health topic, timing of the post (note that pushshift.io normalizes timestamps to UTC so this is not possible), or voting as a proxy for rendering of the display for posts (note that pushshift.io does not archive comments contextualized with the voting score at the time of the comment). Other measures could examine the quality of the response including computational approaches, such as linguistic approaches to examine potential biases of the language, and participatory approaches, such as whether a user perceives the responses as helpful or trustworthy. Finally, although we are encouraged that we do not immediately see very large biases in response rates or empathy across demographics, differences could exist in ways we were unable to detect. Future computational and qualitative discourse analyses could focus on examining if other linguistic cues may indicate if potential bias is present in the responses.

Acknowledgements

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