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In this study, we investigate the extent of polarisation among theist versus atheist groups on Arab Twitter and their networks. We find four main self-identified groups of Arab users that can be distinguished by different attitudes to religion. In addition to Atheists and Theists, there are Rationalists, who promote rational thinking regardless of religious affiliation, and Tanweeri, who promote religious reforms. Through a keyword search of Twitter account handles and biographies, we identified 2,673 active, public Twitter accounts that clearly state whether they are Atheists, Theists, Tanweeri or Rationalists and analysed the interactions among themselves and the accounts that are followed, retweeted, or mentioned the most in their networks. Depending on the network analysed, we found between four and seven sub-communities that highlight the rich socio-cultural context in which discussions of religion, non-religion, and religious reform unfold. While there was clear online polarisation between atheists and theists, Rationalist and Tanweeri accounts are spread among the two polarised sides, acting as natural bridges. We also found a clear separation between Arab atheists who engage with Arab accounts promoting atheism and those who primarily engage with Western accounts promoting atheism. We discuss implications for the study of religious debate and religious polarisation on social media.

CCS Concepts: • **Social and professional topics** → **Religious orientation**; *Cultural characteristics*; • **Human-centered computing** → **Social networks**; **Social media**; **Social network analysis**.

Additional Key Words and Phrases: datasets, Social media, Network analysis, Polarisation, Religion, Islam, Atheism, Arabs

1 INTRODUCTION

Arabs actively discuss religious beliefs and political views over social networks [3, 6, 52, 53]. In the last decade, Arabs have become increasingly polarised along a spectrum ranging from actively promoting non-belief (atheism) to actively promoting religious beliefs that are considered extreme or fundamentalist in the Arab world [6, 39]. It is not clear what leads to the rise of active atheists in Arab social media. Some researchers have suggested that this polarisation might be due to the spread of social media and the crises that followed the failed Arab spring [39, 53], which may encourage atheists to speak out more.

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While there is a substantial body of work on political polarisation in the online Arab world [18, 52], relatively little is known about the ways in which religious polarisation manifests itself in networks of social media users.

In this study, we aim to empirically investigate the social dynamics in online Arab communities that adhere to various levels of religiosity and non-religiosity. While there is obviously a political dimension to these religious issues as well, we believe that it is useful and necessary to clearly focus on religious views in order to reveal the rich tapestry of online Arab belief and non-belief. We use Twitter, because there is a rich literature on the expression of religious and political views on this platform, especially in the Arab world [3, 6, 8, 52].

Our main research goal is to establish whether there is polarisation between Arab Twitter users on different ends of the religiosity spectrum, and to characterise the extent of this polarisation. Specifically, we investigate three main research questions:

RQ1 What are the relevant communities of Twitter users, and where do they fall on the spectrum of religiosity?
RQ2 Do these communities form echo chambers or they have bridges between them?
RQ3 What is the nature of the networks that each of these religion-related communities interact with?

To the best of our knowledge, this is the first study that investigates religious polarisation between theists and atheists on Arab Twitter, without limiting itself to a particular region or country, and without a focus on hate speech or particular sub-communities. We perform a comprehensive search of Twitter biographies to identify Arab Twitter users who actively talk about matters of belief and non-belief and use network analysis to show how these users engage with each other and with the communities around them. While most previous work on polarisation focused on analysing the retweet network among users, in our study, we investigate three types of networks for our studied communities: follow network (the accounts they follow), retweet network (the accounts they retweet), and mention network (the accounts they reply and mention in their tweets). This network analysis adds an important sociocultural dimension to the analysis. It situates those accounts in the wider context of Arab and Western social media, and allows us to surface relevant political discussions that go beyond advocating for religious fundamentalism.

As our starting point, we distinguish four categories of users, based on their self-identification in their Twitter biography. Three of those categories are derived from a previous study [6], while the fourth emerged from the analysis of Twitter biographies.

Atheists: This category includes users who clearly show that they do not practice any specific religion. This group also includes those who used to adhere to an organised religion, such as ex-Muslims and ex-Christians, and who do not self-identify as having changed religious affiliation.

Theists: This category includes users who clearly state that they belong to an organised religion, and promote that religion. Unlike Tanweeri, they are not reformist.

Tanweeris: This category, introduced in [6], includes the accounts that described themselves by using the Arabic term tanweeri (تنويري). Tanweeri might adhere to an organised religion, but demand or support reforms or changes.

Rationalists: This category consists of theist and atheist users who clearly label themselves as Rationalists (عقلانيون) in their Twitter biography. They emphasise rational and logical discussion of diverging points of view.

Our analysis of the networks of 2,673 users and the accounts they follow, mention and retweet, shows that there are 4–7 more or less clearly delineated sub-communities of users, depending on

the type of interaction that is used to build the networks. All analyses show that while largely theist and largely atheist communities are indeed polarised echo chambers. Across networks, we also find that the Arab atheist community on Twitter are not one coherent body. A portion of this community is connected more to the western world and has most of their interactions to non-Arab users, creating a clear echo-chamber that is isolated from all the Arab communities online, including other Arab atheists.

Our findings also indicate that while polarisation based on religion does exist on Twitter, there are natural bridges between the two opposite echo chambers, which allows for fruitful interactions and clear discussions on certain topics when it comes to religion. Tanweeri and Rationalists act as bridges between those communities, stoking the debates and facilitating interaction between diverging points of view. Thus, in order to understand the complex online dynamics of religious discussion on Arab Twitter, it is important to acknowledge the role of the comparatively small Tanweeri and Rationalist communities who reflect the rich diversity of thought in the Arab world in general and Islam in particular.

2 BACKGROUND AND RELATED WORK

2.1 Religiosity and Non-Religiosity

For the purpose of this paper, we define religion as a "complex cultural and social framework" [36][p. 126] that is built around spiritual experiences. This definition highlights religions as social organisations, and allows us to draw parallels with other forms of online polarisation by organisation, such as political polarisation. Partially following Buie [29], we see spirituality as a person's relationship with the transcendent, that which is larger than oneself, with basic values that give life meaning. The transcendent does not have to be linked to a deity; it is perfectly possible to be spiritual, but not religious, and without belief in any divine beings.

People's attitudes to religion vary depending on their own spirituality, their experiences of living within a religion, and their views of people who follow other religions or accept different doctrines. Intolerance of different religions or variations in doctrine is a major source of armed conflict. For an overview of the major sects and divisions in Islam, see [46]. Like Judaism and Christianity, Islam is a monotheist religion that postulates a single, supernatural deity, with the power to intervene in the human realm. Traditionally, those who are not religious have been classified according to their views about the existence of such a deity.

Atheists deny the existence of God, gods, or other spiritual beings [10], while agnostics claim that one cannot be certain whether such entities or beings exist [10, 37, 38]. Finally, deists believe that there is God who created the universe, but that this creator does not influence its course or directly interferes in human affairs. This also means that the Creator cannot contact humans or reveal holy doctrine [48]. Deists may be part of a religion that worships the Creator.

However, non-belief in a deity is only one way to characterise the varieties of non-religious experience [14, 42]. In 1874, Charles Bradlaugh [19] argued that atheism is "no mere disbelief"; instead, it is "a hearty, fruitful affirmation of all truth, and involves the positive assertion of action of highest humanity". Bradlaugh posits that atheists cannot reject God's existence, because to them, the concept of a God is not meaningful.

The non-religious share common ground with the religious in movements such as secularism, which emphasises the separation of religion and state and humanism, which emphasises human rights and asserts the value of all human beings. Other non-religious groups consider organised religion to be actively harmful, and take a strong anti-religious stance.

For the purpose of this paper, *atheist users* are those who describe themselves in their account biography as as agnostics, atheists, non-believers, or Deist. Although it is more complicated to

consider all of these as one group from anthropological and social prospects, we consider them as one group as they all share the same idea of doubting or rejecting religions that posit that there is a Creator who can connect with humans.

Previous work in HCI and CSCW on technology, religion, and spirituality has focused on three main aspects, leveraging technology for worship and adherence to religious practices [5, 27, 54, 56, 57], using technology to mediate transcendent experiences [29], and supporting social action that is linked to religion [43]. This study provides important background for the first aspect, technology for supporting religious practices.

2.2 Influential Users Among Twitter

The importance of influential users in the social media context are understood to be from their roles to generate and diffuse ideas, to promote knowledge, and to attract attention and interactions of users from different backgrounds to engage in discussions [1, 2, 12, 17, 44]. Hence, identifying the influencers and understanding their influence on others helps to understand the online behaviours of individuals and communities, and how information spreads within these communities.

For example, the work by Abidin and Ots [2] analyse social media influencers who joined campaigns aiming to discredit telecommunications providers in Singapore. They see how influencers can lead to trends that might be unethical or deceiving. They highlight that influencers and their followers are sensitive to what they experience as deceptive and unethical behaviours that put normative pressures onto the influencers to conform to certain ethical standards. This even extends to affect the brand clients they talk about.

In our study, we study the accounts that are followed, mentioned and retweeted the most by different religious group. We notice that some of these accounts are influencers in different areas, such as politics or culture.

2.3 Religious Discussions On Twitter

Similar to other technologies, web 2.0 and social media networks are widely used by people to broadcast their messages, communicate with their followers and to update the public with their projects, events and publications [20, 22, 24].

Previous work has examined kind of content religious versus non-religious people post on Twitter, and what sentiments they express[23, 45]. Using linguistic analysis tools, Ritter et al. [45] showed that Christians on Twitter presented as happier, more socially connected, but less reflective.

Since influential accounts have an ever more noticeable impact on society [20–22, 24], another line of research focuses on the way leaders and influences leverage religious discourse. Burge et al. [22] studied how U.S. evangelical leaders used Twitter by analysing more than 85,000 tweets published by 88 American prominent evangelical leaders. The authors found that these leaders use their accounts to communicate with their followers, to disseminate sermons, and to share their events and news.

Political parties also co-opt religious discourse. Bramlett and Burge [20] investigated whether the members of American Congress use religious language in their tweets by analysing about 1.5 million tweets posted by them in April 2018. The authors found that members from both major political parties, i.e. Democratic and Republican, use religious language in their social media accounts.

2.4 Religious Discussions Among Arab Twitter Users

There are relatively few studies of religious discussions between Arabs on social media that do not focus on hate speech or political extremism.

Social media is an important forum of discussions for Muslims who wish to talk about aspects of faith and practice. As Echchaibi [28] notes in her study of blogs, it can be a form of constructive

dissent, where writers develop nuanced positions that promote reform. It can also be a safe space for Muslims to reflect on their own practice in predominantly non-Muslim contexts. An example is the online reaction to the French ban on Burkinis, a swimsuit for Muslim women that incorporates the hijab [30]. In their online spaces, Muslim women develop and elaborate on the meaning of the religious practice of wearing hijab as part of their own identity [35].

Another aspect of discussing religious content on Twitter that should be highlighted here is citing the Quran. A recent study by Abokhodair et al. [3] analysed mentions of the Quran verses in about 2.6 million Arabic tweets. The study shows that users extend their real-life religious practices and worship acts by sharing Quran verses as a form of religious expression.

The study that is most similar to the current work is [6]. In that study, the authors analysed the stance towards religion of 434 Arabic accounts that engaged with a seed list of 80 influential Arabic accounts that discuss religion and atheism. Qualitative analysis of account name, biography, and timeline yielded four main categories of users: atheist, theist, tanweeri and other (no clear position). These accounts are identified starting from 80 seed accounts who believed to be influential users and discuss religions and atheism among Arabs online. Afterwards, about 1.3 million tweets published by these accounts are used to extract the main topics discussed and the network interaction among them. The intermediate categories established by Al-Hariri et al. fit well with the complex landscape of religious and non-religious thought discussed earlier. Although [6] is the first study to shed light on these communities and their contents in the online Arab societies, it is limited due to the size of network and the labelling method, which relies on human annotators identifying the Twitter users' attitude towards religion and atheism. Indeed, some might argue that labelling the contents of accounts might lead to labelling users which clearly affects their privacy. The study also does not consider links between relevant communities.

2.5 Religious Polarisation in Arab Twitter

A form of religious polarisation that has received a lot of attention is religious hate speech. Albadi et al. [8] studied six categories of Arab Twitter users who can be identified as Muslims, Jews, Christians, Atheists, Sunnis, and Shia. The authors found that hateful language was very common in their sample of Arab tweets with religious content. The most targeted groups are found to be Jews, Atheists and Shia.

The study which is perhaps closest to ours is Weber et al.'s [52] quantitative analysis of the polarisation between secular and Islamist Twitter users in Egypt. The authors expanded an initial manually labelled seed list of 22 politicians and prominent users from both groups by using retweeting interaction to have about 7,000 accounts. Then they studied the top topics discussed by the two groups and measured how they are polarised by computing the valence of hashtags used in tweets published by their members. They found that hashtags published by both political sides could be used as polarisation barometer as it coincided with periods of violent events. They showed that followers of accounts on the Islamist side are more likely to use Islamic terms and charitable terms, and were less likely to use derogatory terms and hate speech when talking about followers of other religions.

2.6 Contribution of Present Study

In comparison to the previous literature, and in particular [6] and [52], our study provides an in-depth analysis of network polarisation on Arab Twitter as it relates to religion. While Weber et al.[52] also studied network polarisation between secular and non-secular groups, they did not expand their analysis to non-political contexts, and they restricted themselves to Egypt. In our study, we consider Arab Twitter in general as they discuss topics relevant to their own beliefs whatever their political positions. Unlike [6], we consider accounts that clearly declare their positions, and

study their interactions, paying more attention to influential accounts and those that have been verified by Twitter. We formally analyse the following, retweeting, and mentioning interactions to understand the polarisation between these communities, and sample a wider collection of accounts which give more relevant information about such communities.

3 DATA COLLECTION AND METHOD

Identifying the non-religious community in the Arab countries is difficult, since atheism is either illegal or heavily socially sanctioned in the Arab World. Therefore, it is almost impossible to find representative organisations. However, as we have seen, non-religious Arabs are active on social media, such as Twitter [6, 52]. Therefore, following earlier work, we used seed accounts to identify relevant religious and non-religious communities on Twitter. While Facebook might be more popular in some Arabic countries (especially north Africa), we conduct our study on Twitter, since it is more open platform where data collection of public posts could be easily collected using their API, unlike Facebook, which is highly restricted and data collection is not allowed. In addition, as shown in previous section, most of literature applied to Arabic social media was applied on Twitter, and thus our study here continues in the same direction.

Data collection was performed over two stages. Initially, we identified the relevant accounts that disclose their position towards religion. Then we expanded the data set by adding the accounts that they follow or interacted with.

3.1 Ethical Issues

Discussing non-religion is sensitive, especially in the Arab and Muslim communities. During this study, we took several measures to protect Twitter users' identities. First, we focused on users who clearly stated their religious orientation in their Twitter biographies at the time of data collection. Secondly, we do not perform any statistical analysis to infer information about these accounts, such as gender, that they do not wish to disclose themselves. When we talk about people behind individual accounts, these are either verified by Twitter or well-known figures with a public and social media profile across several platforms. Finally, most sample tweets provided are either slightly rephrased (for English tweets) or translated (for Arab tweets). We only provide original tweets where the user tweeted a headline together with a link to a web page. We also note that individuals' religious beliefs change - accounts may be deleted, Tweets may be deleted, and authors may modify their biographies to highlight changes in belief or loss of belief.

In terms of the positionality of the authors of this paper, the research team consists of Arab Muslims and a non-Arab Christian who has had extensive exposure to Atheism, in particular New Atheism [50].

3.2 Collecting the Seed-list Data Set

In order to answer RQ1 (identifying relevant communities of Twitter users), we searched for Twitter users who explicitly state their position toward religions in the screen names, user names or descriptions (bios) of their Twitter account. To do so, we compiled a list of Arabic terms that can be used to reflect a relevant position towards religions, and refuting or challenging others' beliefs. We considered all the different morphological forms that can be derived of these terms, since Arabic is one of the most inflected languages and one term can have many morphological variations [25]. In addition, we used terms inspired from the study by Hariri et al. [6], such as hashtags عقلانيين (Rationalists) and صناعة_المحاور (Creating_the_interlocutor), which are both used in atheism/religion debates according to [6]. When choosing keywords for theist accounts, we found that using generic terms such as Muslim, Christian, or believer, yielded a large number of

Search term	Translation	Search term	Translation	Search term	Translation
ملحد	Atheist	مسلم سابق	Ex-Muslim	ملاحدة	Atheists
لاديني	No-religion	تنويري	Tanweeri	مستلحد	Extreme-atheist
ربوبي	Deist	عقلاني	Rationalist	الحاد	Atheism

Table 1. Sample of the core terms used to search for profiles. For each term all variations are also used, including the singular/plural and masculine/feminine versions. List on the right are references to atheist usually used by those refuting atheism.

irrlevant accounts, since many Arab Twitter users add their religion in their account descriptions even though they don't talk about their beliefs in their timeline. In total we compiled a set of 118 terms. Table 1 shows few examples of the terms used along with their translations.

This set of 118 terms was then used to search user profiles that has any of them in the profile name or description. We used Followerwonk[1], which is an online tool that allows searching user profiles and screen names, which is a functionality not available through the Twitter API.

Our search process retrieved a set of 5,010 Twitter accounts that use at least one of the selected terms in their profile.

The first author, a native Arabic speaker, analysed profile names and descriptions to exclude irrelevant accounts and assign relevant accounts to one of four categories: Atheist, Theist, Tanweeri, and Rationalist. Irrelevant accounts were retrieved for several reasons. Most of the Arabic tokens are homonyms, in which the same token might give different meanings depending on the context or their diacritics, which is rarely used in Arabic social media text [26]. For example, the Arabic word عقلاني (rationalist) is used in different contexts such as personal names (mainly surnames), sports and football clubs, social relations in addition to the religious context.

More drastically, some accounts used the term atheism in the sport context. For example, some accounts' descriptions state that "Atheism in football is to deny the historical leadership of a specific football club".

After this process, a set of 2,356 (47.02%) accounts remained as relevant. We then collected the network of the 2,356 accounts, which was defined as all accounts that these users followed and interacted with by retweeting, replying, or mentioning. We then searched the profiles of those accounts for any of our 118 terms to be sure that nothing might have been missed by FollowerWonk. We retrieved 520 accounts which belonged to one of the four categories.

From this set of 2876 accounts, we removed those that had no tweets in their timelines or not connected to other accounts on Twitter. Our final set of accounts included a total of 2,673 (92.95%) Twitter accounts. We call this set of accounts our *seed list*.

3.3 Network Analysis Methodology

In this section, we present our methodology for constructing and analysing the social media networks of Arab Twitter users from different religious affiliations. In order to answer RQ2 and RQ3, we analysed how our four religious communities interact with each other and the nature of network of influential users each of them is located within.

Constructing the Follow, Retweet, and Mention Networks. According to Aldayel and Magdy [9], there are three types of networks for each social media user:

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[1]https://followerwonk.com

(1) the connection network (CN), which represents the network of accounts the user is connected to;
(2) the interaction network (IN), which represents the network of accounts the user interact with through retweeting and replying;
(3) the preference network (PN), which are the accounts mentioned in the posts (tweets) the user likes.

It was shown that these networks can be predictive to users' views and beliefs [9]. Thus, in our study, we decided to analyse the CN and IN networks of accounts of our dataset. Particularly, we are interested in analysing the accounts that our groups follow (the *follow network*), those they retweet their posts (the *retweet network*), and those they mention/reply in their tweets (the *mention network*). The follow network is part of CN, while the retweet and mention networks are part of IN.

For each of the 2,673 seed list accounts, we collected the list of accounts they follow and their timelines, which contain all the accounts they have retweeted and mentioned/replied. The seed list accounts follow 550,238 Twitter accounts, retweet 142,880 accounts at least once , and mention or reply to a further 142,472 accounts at least once. We call these accounts *network accounts*.

The majority of these network accounts are followed, retweeted, or mentioned by only one of the seed list accounts, which means that the network will be highly sparse if plotted. In addition, an account that only a few of our seed accounts interact with may not be relevant. Finally, very large, sparse networks can be difficult to interpret. Thus, we used thresholds to ensure that the accounts in our follow, retweet, and mention networks are relevant to several of the users in our seed list. For the **follow network**, we included accounts that were *followed* by at least 20 seed list accounts; for the **retweet network**, we included accounts that were *retweeted* at least once from at least 10 seed list accounts; and for the **mention network**, we chose accounts that were *mentioned* or *replied to* by at least 20 seed list accounts.

After applying these restrictions led to filtering out the majority of the accounts in the network, the size of the follow network is 5,150 accounts, the size of the retweet network is 5,404 accounts, and the size of the mention network is 7,707 accounts.

To ensure that the resulting network analysis was not unduly skewed by these thresholds, we performed all analyses both with and without thresholding. Since the clusters generated in both instances were very similiar, we report only the findings generated with thresholding, as they are easier to visualise and interpret.

3.4 Analysing the Follow, Retweet, and Mention Networks

In our analysis, we focus on the nature, influence, and the position of our seed accounts among the follow network, the retweet network, and the mention network.

We apply a graphical network visualisation to our seed accounts and their follow, retweet, and mention networks. We use Gephi[2], which is an open source software for network analysis and statistical measurements for graphs with visualisation capabilities [13]. To generate the network graphs, we use the default values of most of the parameters of Gephi. The layout algorithm that we use is ForceAtlas 2 [34], with setting the scaling and gravity as 10 and 1 respectively. To identify the sub-communities within the follow and retweet networks, we used the modularity algorithm [16]. We conducted several experiments to select the settings that produce reasonable and harmonious communities. To perform that, we manually investigate the resulted sub-communities for each experiment. With harmonious communities we mean maximising the number of nodes in each cluster, minimising the number of clusters, and grouping the majority of public and well known

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[2]https://gephi.org/

accounts within a similar featured group with least modifications for the default parameters of Gephi's functions.

For the *follow network*, we computed the modularity by using different values within the suggested range by the authors, i.e. [0.1 - 2], and studied the resulted communities for these values. We found that a resolution of 0.75 gives us the reasonable communities in which the majority of the large component nodes, i.e. the well connected accounts, in each community share similar characteristics.

For the *retweet and mention networks*, we used the default value for the modularity resolution, that is 1. Experiments show no substantial differences in the result when we used different values to cluster the communities.

The final follow network graph has 0.063, 0.435 and 11 for average clustering coefficient, modularity and diameter, respectively. The mention network graph has 0.058, 0.692 and 14 for average clustering coefficient, modularity and diameter, respectively. Finally, the retweet network graph has 0.035, 0.485 and 19 for average clustering coefficient, modularity and diameter, respectively.

For the three networks we plot the network graph twice, once including our seed accounts only, to measure the connection among them, and another one with their follow, retweet, or mention networks to visualise the distribution of the different clusters of accounts in these networks, as shown in the next section in Figures 2, 3, and 4.

Network Interpretation. The first author interpreted the resulting cluster using a combination of qualitative and quantitative approaches. For the follower and retweet network, he researched publicly available information about account owner, including checking their official web-page, and watching a few of their online video/lectures (where applicable). These systematic observations were distilled into an overall theme for each cluster and checked in supervision meetings with the second and third author.

For the mention network, we were interested in the topics of the tweets where the accounts were mentioned or replied to. Our quantitative and qualitative analysis methodology is different here from previous two networks, where here we inspect the tweets themselves that have the mentions and replies to extract the main topic of discussion and name the cluster accordingly in Table 8. Since there are a large number of tweets in each cluster, we applied a topic extraction using LDA [15]. First, we extracted all tweets by the seed list accounts that mention or reply to a member of the mention network. Tweet texts were pre-processed by removing special characters (except the At-sign and the hash tag sign) and URLs and converted into input for LDA using a TFIDF vectorizer. LDA was performed using the implementation in the Python package GenSim [3] to extract the top five topics for each cluster. Topics were named based on the representative words.

4 RQ1: COMMUNITIES OF TWITTER USERS THAT DEBATE RELIGION

The 2,673 accounts in our seed list data set are distributed among the four religious groups as shown in Table 2. Almost half of the accounts belong to the atheist group while 26% and 21% belong to the theist and the Rationalist groups respectively. The Tanweeri group has the smallest number of accounts, where only 5% of the accounts belong to it. This biased distribution towards atheist accounts could be expected, since most of the search terms we used for collection have focused on the atheism topic. Thus, the theist accounts in our collection are those who mention they refute atheism in specific in their profile.

We further manually labelled the theist accounts to classify their religion. Annotation was based on what users explicitly mention in their profile, or what we can infer from what they share on their timeline (such as verses of Quran or Bible). As shown in Table 2, the vast majority of the

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[3]https://pypi.org/project/gensim/

Belief	N	%		Religion	N	%
Atheist	1304	48.8%		Muslim	644	94.43%
Theist	682	25.5%		Christian	32	4.70%
Rationalist	549	20.5%		Hindu	3	0.45%
Tanweeri	138	5.2%		Jihadi	2	0.30%
Total	2673	100%		Jewish	1	0.15%
				Total	682	100%

Table 2. Distribution of categories (left) and religions represented in the theist group (right) in our seed list dataset.

Group	Bio (Translated)
Atheist	Before #Atheism, I was a miserable, disobedient, passive person, with goalless life and I am eventually going to hell... #Now I am a new person, optimistic #lover_of_life... I will leave my mark and #go_away. #Agnostic
Atheist	I try not to think, but I find myself thinking; how I stop thinking? I insult the religion twice, and atheism once, I belong to humanity, not religion, not belief nor theory.
Theist	I seek refuge in God from every atheist, and I seek refuge in God from anyone who follows other than Islam .. (Guide us to the straight path) Yes, really it is my religion the religion of truth.
Theist	Atheism is a void that must be filled with a religion someday! ... Religion is a human need... there are cities without education, but there are no cities without temples!
Rationalist	A rationalist, interested in science and philosophy, interested in freedom and equality, human rights activist, and freelance writer.
Rationalist	Rational, taciturn, music-loving, sportive.
Tanweeri	Tanweeri religious researcher (masculine). Columnist, I wait for the mind's winning day.
Tanweeri	Tanweeri (feminine)... Before you argue, test your axioms by looking impartially at the opinions of its dissenters.

Table 3. Samples of biography description of the Twitter accounts from the four groups in our dataset

theist group belongs to Islam with two out of them mentioning in their profiles that they are Jihadi; 32 accounts are Christians, three Hindus and one Jewish.

The most frequently mentioned terms in the biographies of the atheist group include atheism, non-religious, humanist, rationalist, secularist, ex-Muslim, and Liberal. The rationalist group use both terms that are relevant to their belief about rationalism in general, suhc as thoughts, thinker, and logic, as well as more passionate and emotional terms such as lover, love, hate, and poet. A few members of this group also show their support of certain Arabic football clubs. Tanweeri accounts use more terms relevant to enlightenment (as verb and noun forms). They often use the terms liberal, society, world, educated, Saudi, parody, religion, and peace. The most frequent terms used by Theist accounts are atheists (plural form in specific, especially the version الملاحدة, which is a sarcastic plural version of atheists in Arabic, unlike the normal version الملحدون), atheism, Islam, صناعة_المحاور (Creating_the_interlocutor, an online academy that teaches how to refute atheism and non-religiosity), Christian, Jesus and conservative.

Table 3 shows a sample of the bios (translated to English) of the accounts in our seed list data set along with their corresponding category.
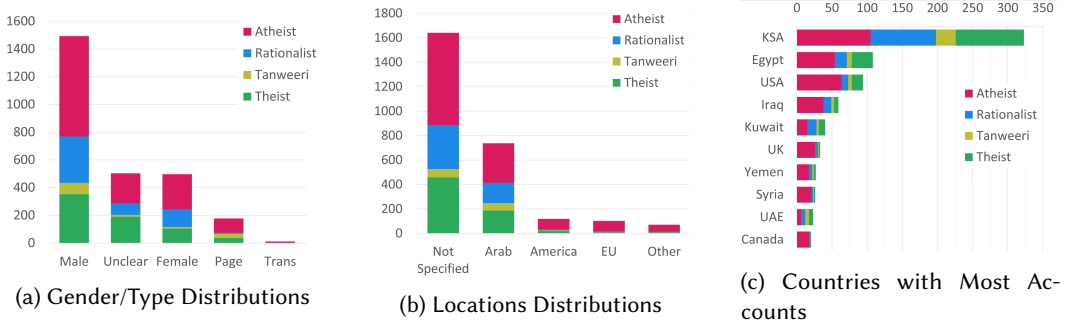
(a) Gender/Type Distributions

(b) Locations Distributions

(c) Countries with Most Accounts

Fig. 1. Distributions for Dataset Accounts

Demographics. We extracted information about account type, gender, and location from the account descriptions. We used gender and location information specified by the Twitter users themselves, even though we are aware that they may be misleading, since giving a false gender or location might be a conscious, privacy-preserving choice. The type of the account is either a person or a page, where page accounts includes those that represent companies, organisation, campaigns or groups of interest, such as accounts for groups promoting or refuting religion/atheism. When the account looks to be representing a person, we label the gender of the person if it is clearly stated in the account's description and/or name as male, female or transgender; otherwise, it will be labelled as unclear, such as accounts using nicknames.

Location is identified by using the location field of the account profile, if it exists and indicates a meaningful location. Many accounts have empty location field or meaningless locations (e.g. "hellfire") [33]. When the account mentions multiple locations in their profile (e.g. "Saudi Arabia and USA"), we consider the Arab country or the first mentioned one.

Figure 1 summarises the demographics of our seed list. As shown in Figure 1a, the majority of the accounts holders in our collection are male (55%), while less than 20% are female. This ratio is almost consistent across all account groups. Three of the atheist accounts mentioned they are transgender in their profiles. The remaining accounts (around 20%) do not provide clear gender information in their profile. Around 200 of the accounts are pages, mainly promoting atheism, while a small percentage of those are refuting atheism or representing rational and Tanweeri groups.

As shown in Figure 1b, the majority of the accounts (over 60%) do not share their location. For those who have stated a meaningful location, the majority of them are living in Arabic countries, which is expected since we focused on Arabic terms when searching for those accounts. Small percentage were found to be living in North America and Europe. Figure 1c lists the top 10 countries identified for the accounts. Saudi Arabia (KSA) has the largest number of accounts, followed by Egypt, USA, Iraq, and Kuwait. It can be noticed that the atheist accounts have lower percentage in KSA, Egypt, and UAE, unlike the general distribution of those accounts in our collection and in the other locations. This might be due to several factors, such as restrictive laws, stigma against atheism in these countries. It is also possible that atheists living in these countries prefer not to share their location.

5 RQ2 AND RQ3 ECHO CHAMBERS, BRIDGES, AND NETWORK STRUCTURES

In this section, we describe the network analysis results for the follow network, the retweet network, and the mention network. For each network, we describe the nature of the clusters that constitute
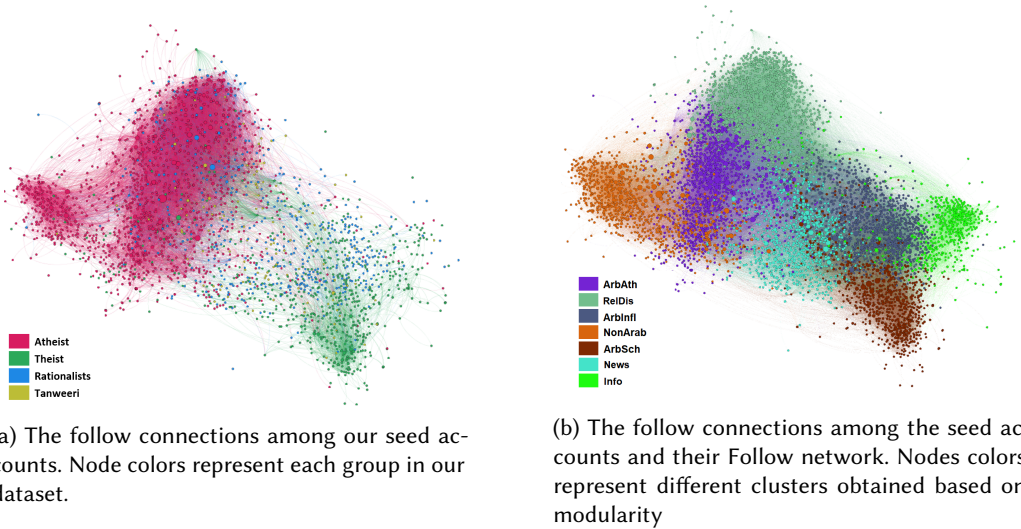
(a) The follow connections among our seed accounts. Node colors represent each group in our dataset.

(b) The follow connections among the seed accounts and their Follow network. Nodes colors represent different clusters obtained based on modularity

Fig. 2. Visualisation of the follow connections among our data set and their network, including only accounts followed by 20 or more of the seed list. Description of cluster names is provided in Table 4

the network and identify echo chambers and bridges. We conclude by discussing the intersection between all three networks.

5.1 The Follow Network

Figure 2 shows the network representation of the follow network among our seed list (2a), and among our seed list and their follow network (2b).

Network Clusters. Seven clusters emerged from the analysis. The characterisation of each cluster is summarised in Table 4. Below, we describe each cluster in more detail.

ArbAth: Arab Atheists. Most of the seed list accounts in this group are Arab atheists. Overall, the accounts in this group promote atheism, view religions as irrational, and criticise traditions, and cultural values of Arab religious communities. They tend to follow Arab and non-Arab atheists from the groups RelDis and NonArab. The personal accounts in this group tend to use names that show their origins or affiliations such as mol7d_Arabi[4] (meaning: An Arab atheist), _PROMETHEUS_1[5], ArabIrreligious, and so on. Also, the screen names of non-seed list accounts tend to reflect atheist affiliations and stances such as CurseOfIslam, AngryEgyptian1 and BigLieReligon. Some accounts criticise religions, and promote secularism without reflecting their affiliation such as aba_akrama, or with declaring their position such as Liberal_Infidel.

This cluster also tends to follow accounts which tweet about science, knowledge and exploration without mentioning any affiliation in their timeline such as youssefalbanay from Kuwait, and ScientificSaudi from Saudi Arabia. There are some non popular theist users that follow atheist accounts whether to criticise atheism or to criticise other religions such as SaudiChrstian93 and SaudiChristian who describe themselves as ex-Muslim Christians and criticise Islam. This cluster

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[4]This name written by using Arabizi which is a form of writing Arabic in Latin letters, numbers and punctuation rather than Arabic letters
[5]Prometheus is the name of one of Titans which is believed to be one of the supreme tricksters in Greek religion, and a god of fire [41].

Cluster	Theme (name)	Description
ArbAth	Arabic Atheists	Arab atheists and secularists tied more strongly to non-Arab atheists
RelDis	Discussion of Religion	Arab atheists and secularists group, linked more strongly to non-religious Arabs
ArbInfl	Prominent Arabic Accounts	Most influential Arabs
NonArab	Non-Arabic & Western	Non-Arabic accounts that are critical of religion
ArbSch	Arab & Islamic Scholars	Arab accounts that promote religion
News	News & Journalists	International public figures, politics, singers
Info	Infotainment	Regular non-influential Arabs and entertainment personalities

Table 4. Cluster Themes for the Seven Groups in the Follow Network

Cluster	Total Size	Seed list				Non-Seed list
		Atheist	Rationalist	Tanweeri	Theist	
ArbAth	941	**447 (47.5%)**	29 (3.1%)	15 (1.6%)	59 (6.3%)	391 (41.6%)
RelDis	910	**299 (32.9%)**	9 (1.0%)	11 (1.2%)	68 (7.5%)	523 (57.5%)
ArbInfl	850	17 (2.0%)	92 (10.8%)	26 (3.1%)	**182 (21.4%)**	533 (62.7%)
NonArab	733	**316 (43.1%)**	25 (3.4%)	3 (0.4%)	10 (1.4%)	379 (51.7%)
ArbSch	649	8 (1.2%)	**269 (41.4%)**	25 (3.9%)	25 (3.9%)	322 (49.6%)
News	634	**116 (18.3%)**	55 (8.7%)	21 (3.3%)	84 (13.2%)	358 (56.5%)
Info	433	15 (3.5%)	**96 (22.2%)**	7 (1.6%)	39 (9.0%)	276 (63.7%)

Table 5. Distribution of Accounts Followed by dataset Accounts

also contains some controversial personal accounts such as MaysAlsuwaidan, HsnFrhanALmalki, TurkiHAlhamad1 and MadawiDr, who usually discuss sensitive topics related to secularism that grab public attention and create online debates. While all of these accounts demand secular communities, some of them strongly support their governments such as TurkiHAlhamad1, others criticise it and demand political reforms such as MadawiDr.

RelDis: Discussion of Religion. As for ArbAth, atheists are the majority in RelDis and theists are a minority. The majority of this group tend to be actively promoting atheism and criticise religions such as DrTalebJawad, SherifGaber and hamed_samad. Also, in this cluster we found some Israeli accounts who tweet in Arabic such as IsraelArabic and EdyCohen. This group also actively campaigns for secular societies founded on rationalist principles. Some accounts do not declare their personal affiliations. Some of these accounts show their belonging to or solidarity with the LGBTQ community, such as LGBTQarabic.

A good example of a RelDis account is Na9eR_Dashti, which is the account of Naser Dashti, a well known Kuwaiti secular activist who actively discusses his point of view with others with respecting their rights to practice whatever they want as that does not harm others. In an interview[6], Dashti states that he is a secularist and that he believes in the logic of reasoning and science in the areas of science, culture and even politics; but, according to him, faith is a spiritual experience for individual. While this group have well-known accounts who discuss religions and atheism, such as jaafarAbdulKari, hamed_samad and DrTalebJawad, it includes some satirical accounts that mock principles of religions, mainly Islam, such as OwaisMaqdesi, TwiceThinker, Suhaibfather, and shikh_elroibda.

Like ArbAth, RelDis includes science accounts by known scientists such as NidhalGuessoum, a verified account of an ex-researcher in NASA and tweets a lot about science and astronomy; and

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[6]https://www.youtube.com/watch?v=63wURurp3hI

other unknown such as SciTalk2U, IBelieveInSci, NasaInArabic and Arabic_Nasa. The latter two accounts tweet in Arabic about exploration news from NASA but they are not verified by Twitter nor officially linked to NASA.

ArbInfl: Influential Arabic Accounts. The third group, ArbInfl, contains accounts of non popular seed list accounts. and the majority are rationalists; atheist accounts are the minority. In additon to theist members, there are Tanweeri of two spectrums, religious and social reformers. These seed list accounts tend to follow well known figures in the Arab communities and mainly from Arabian peninsula (i.e. Arab Gulf countries, Yemen) and Iraq. This group includes number of accounts that belong to members of royal families such as KingSalman, MohamedBinZayed and abdullahthanii, popular individuals such as ministers from Saudi Arabia (AdelAljubeir), and Emirates (AnwarGargash), journalists, writers, actors and shows presenters such as OlaAlfares and OthmanAlomeir; the Saudi TV presenter nadinealbdear, which is one of the first Saudi women TV presenter who demanded liberal society; poets (yasseraltwaijri), and singers (AhlamAlShamsi).

The cluster also contains official news sources such as spagov and AlArabiya_KSA; unofficial news sources (ajlnews and AjelNews24); magazines, (Saco_KSA) and well known Saudi football clubs exist in this group such as Alhilal_FC and AlNassrFC.

The scholars in this group are Islamic scholars or figures mainly from KSA and UAE such as SalehAlmoghamsy and Waseem_Yousef, who are known with their support to Arabic governments; academic members such as HatoonALFASSI and Abdulkhaleq_UAE; and some controversial tanweeri accounts such as Dr_Mhd_Shahrour, DrAdnanIbrahim and salrashed. While the first two provide what they call new readings of Quran and Islamic principles, the latter discuss social reforms and personal development topics.

NonArab: Non-Arabic and Western. Almost 75% of our seed list accounts in NonArab group are atheist accounts such as CEMB_forum, ExmuslimsOrg and Bassamius. This group consists mainly of Arabs and non-Arab ex-Muslims who are based in the West, who established or joined organisations that aligned to their cases, and tweet about religions in Arab countries, Iran, Pakistan and India. Oprah, and BillGates in addition to many others, and some non-Arabic media sources such as AJEnglish and Reuters.

The accounts in this cluster include non-Arabic atheists/agnostics speakers and show presenters (e.g. SamHarrisOrg), Western atheists/agnostics scientists (e.g. RichardDawkins), Arab immigrants residing in the West (e.g. Ayaan), non-Arab Ex-Muslim immigrants who live in west (e.g. MaryamNamazie), non-Arab secular Muslim immigrants (e.g. MaajidNawaz), former presidents of the United States (e.g. BarackObama and realDonaldTrump), non-Arabic religious person such as DalaiLama (The highest spiritual leader of Tibetan Buddhism) and benshapiro, international official organisations (hrw) and non-official organisations (HumanistsInt), Western popular figures such as (JustinTrudeau); Israeli politics (netanyahu and IsraeliPM); US organisations (NASA and FBI); Technology companies (Microsoft and Facebook); and entertainment series such as GameOfThrones.

ArbSch: Arab and Islamic Scholars. The general theme of the cluster ArbSch is promoting religion and refuting atheism. Interestingly it does not include many of the theist accounts in our seed list. It contains verified accounts for famous Muslim scholars such as MohamadAlarefe; women academics and Islamic scholars such as rokaya_mohareb_; Quran reciters such as Alafasy, poets such as Dr_Ashmawi, Muslim academics, intellectuals, and thinkers of different topics such as LoveLiberty (a specialist in political communication), Talhabeeb (consultant in psychiatry), MidoAlhajji (social and behavioural science), TareqAlSuwaidan, (historian and specialist in management), drjasem (social, educational and behavioural patterns specialist), mshinqiti (specialist in Islamic political thought and ethics); and DrAlnefisi (Political thinker); political and social activists, members of

parliaments, and whistleblowers from different backgrounds and different Arab countries that demand political and social reforms such as saadalfagih, nasser_duwailah and mujtahidd; Islamic studies centres, institutions, and programs that promote Islam and discuss or criticise atheism such as takweencenter, Almohawer_T, and Wesal_TV. Also, this group contain some official Arabic news source (AJABreaking), non-official news source (3ajel_ksa), infotainment accounts (naizaktv), and Arab journalists and TV presenters such as Jkhashoggi and MousaAlomar.

In addition, there are personal accounts that impugn atheism and promote religious views including popular Arab scholars (Dr_EyadQun, FadelSoliman, abosaleh95, and AhmadyuAlsayed), or some pseudonymous accounts (Ex_AtheistGirL); We noticed some accounts that belong to Arab political writers and activists (YZaatreh and EHSANFAKEEH), and specialists in technology who use their social media to raise technological awareness among Arab users (CyberkovCEO and Abdulaziz_Hmadi). The most interesting religious account in this cluster is PvGovSa, which is the verified account of the Committee for the Promotion of Virtue and the Prevention of Vice in Saudi Arabia.

News: News and Journalists. The majority of seed list accounts in the News group are atheists, while both theists and tanweeri accounts are minorities. However, there are some noticeable theist and rationalist accounts such as BrotherRasheed, an Ex-Muslim Christian who criticises Islam, and hanyfreedom, who define himself as an atheist from Christian background. BrotherRasheed is well known for his TV shows Let's Be Clear and Daring Questions.

Where ArbInfl consisted of Arab influential figures and public accounts that are mostly followed by theists, News represents those influential figures and public accounts that are mostly followed by atheists. Specifically, the group consists of Arabic news sources and TV channels (AJArabic and AlArabiya), and non Arabic media (CGTNOfficial). It also includes some Muslim scholars (alqaradawy and DrAliGomaa), presidents and royal family members (TamimBinHamad, KingAbdullahII, AlsisiOfficial, MuhammadMorsi and Israelipm_ar), Arabic political thinkers (abdelbariatwan and AzmiBishara), public Arab figures (walidjoumblatt, and ElBaradei), journalists, writers and TV presenters (kasimf and FatimaNaoot), and symbolic accounts for writers and poets (Mh_Darwish, Wam_Shakespeare).

It also includes some Western and international organisations that tweet in Arabic language such as (USAbilAraby and hrw_ar) famous international professional football players, singers or show presenters (MoSalah, Rihanna, Oprah and elissakh), Arab and international football clubs such as (realmadrid and AlAhly), international football organisations (fifacom_ar), and Israeli accounts (Israelipm_ar and AvichayAdraee).

Info: Infotainment. The last group, Info, has the majority from rationalist seed list accounts, while atheist accounts are the minority. Some of the theist accounts in this group criticise non-religiosity and organise 'electronic attack' against the atheist contents and accounts in Twitter such as (Anti_Godlessnes and SalwaSsee). It seems that they work in groups as most of them share the same hashtags السنه_جيش# (Sunna's Armay) and عمر_ جيش# (Omar's Army). Some theist accounts only show their affiliation without showing any stance towards others such as saudi_raiq.

The accounts in this group tend to follow infotainment accounts such as AQWAL_MATHORA; personal accounts with no direct stances towards affiliation from different Arab countries such as Palestine (MustafAbuZir), Emirates (EMARATI___1), Saudi Arabia (adelmz44), Kuwait (AhmedAbdullahQ8), Yemen (7oppp); and non official news sources such as (aljadidnews). We notice that lots of accounts in this group are suspended or deleted during the study and we find some bots that broadcast Islamic supplications (TasbehEstigfar).
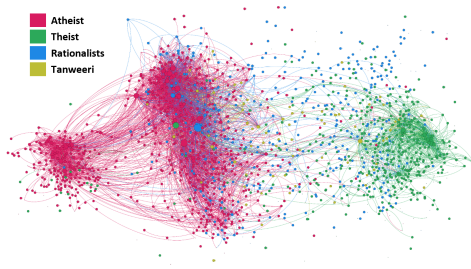
(a) The retweeting interactions among our seed accounts. Nodes colors represent each group in our dataset.

(b) The retweeting interactions among the seed accounts and their Retweet network. Nodes colors represent different clusters obtained based on modularity

Fig. 3. Visualisation of the retweet network among our data set and their network, including only accounts retweeted by 10 or more of the seed list. Description of cluster names is provided in Table 6

Echo Chambers and Bridges. The general observation from Figure 2a is that the atheist group (in pink) and the theist group (in green) are well separated into echo chambers, while the Tanweeri (yellow) and Rationalist (blue) groups are spread between them, acting as a bridge. A small portion of the atheist group is somewhat isolated from the majority, seen in the left part of the graph). Similarly, a small portion of the theist group looks to be closer to the atheist group. This would be better understood from analysing the clusters of communities obtained with the follow network.

When we look at the distribution of our seed list among the seven clusters (c.f. Table 5), a more complex picture emerges The majority of Atheist group has been divided among three main clusters: ArbAth, RelDis, and NonArab. Most of the Theist group, however, is located in one cluster (ArbInfl), and the remaining was split among the other clusters. Similarly, the majority of rationalist group belongs to one cluster, ArbSch. Only the Tanweeri group was spread among all clusters.

In addition to the Tanweeri and Rationalist bridge accounts, there are also Atheist and Theist bridge accounts. For instance, AtheistGhost follows and retweets tweets posted by accounts from groups holding different beliefs. Analysing the timeline content and following relationships for this account shows tweets about supporting Palestine, opposing internal policies and regional relations for some Arab countries, and discussing regional conflicts. Discussing these topics causes huge interactions from supporters and opponents of each topic.

Other accounts that play a bridge role between religious and non religious groups such as z3bdal5l5, arabs_exmus and Fawazintheflesh. The first account claims that it belongs to an ex-Atheist, and the latter two are atheists who argue against religion and mainly criticise the main three monotheist religions Islam, Christianity and Judaism. In addition, the theist group contains some accounts that criticise other religions which again causes intensive interaction from atheists and rationalists with theists.

5.2 The Retweet Network

Here we discuss the retweet network, which includes the accounts that are retweeted by our seed list.

Figure 3 shows the network representation of the retweet network among our seed accounts themselves (3a), and among our seed list and their retweet network (3b). The codes used in Figure 3b are explained in detail in Table 6, where each cluster is described by the main theme characterising the accounts in it. Table 7 shows the distribution of our seed list among the five clusters obtained

Cluster	Theme	Description
TheiPro	Theists and Muslim Scholars	Islamic Scholars and influential Arabs
AthPro	Atheists & Discussion of Religion	Arab accounts with ties to groups that are critical of religion
RelDis	Discussing theists	Prominent Arabs discussing theists and demanding secular communities
ArbInfl	Arab influential accounts	Arab influential users which do not discuss religions/atheism
NonArab	Non-Arabic accounts	Groups with ties to Non-Arabic accounts

Table 6. Maps From Clusters Codes to The Corresponding Theme of Retweeting Community

Cluster	Total size	Atheist	Seed list Rationalist	Tanweeri	Theist	Non-Seed list
TheiPro	1034	5 (0.5%)	**320 (30.9%)**	16 (1.5%)	64 (6.2%)	629 (60.8%)
AthPro	963	**213 (22.1%)**	4 (0.4%)	16 (1.7%)	67 (7.0%)	663 (68.8%)
RelDis	989	**276 (27.9%)**	15 (1.5%)	16 (1.6%)	81 (8.2%)	601 (60.8%)
ArbInfl	844	20 (2.4%)	67 (7.9%)	23 (2.7%)	**99 (11.7%)**	635 (75.2%)
NonArab	649	**218 (37.1%)**	18 (3.1%)	0 (0.0%)	5 (0.9%)	347 (59.0%)

Table 7. Distribution of Accounts Retweeted by dataset Accounts

in Figure 3b.

TheiPro: Theism promoting accounts. The first cluster group, TheiPro, includes cross Arabs and international Islamic scholars (e.g. alqaradawy, abdulaziztarefe, Dr_alqarnee, and salman_alodah), Muslim priests/activists (e.g. shugairi, AbdullahElshrif, and amrkhaled), political specialists and academies with Islamic backgrounds (e.g. DrAlnefisi, LoveLiberty), Arabic activists (e.g. TawakkolKarman), Islamic institutions that promote Islam and oppose atheism (takweencenter, braheen_center and islam_atheism). Interestingly, this group, while containing many popular Arabic Islamic scholars/activists, does not have many of our Theist seed list, while having the majority of the Rationalist accounts. This shows that Rationalists still retweet a lot of theist (Islamic in specific) content. Despite the emphasis on religious content, the cluster also includes accounts of a more general theme, such as Arabic infotainment accounts (e.g. TheArabHash), Arabic news source (AJABreaking, AJArabic, ajmubasher, RassdNewsN, aa_arabic), Arabic journalists and TV presenters (kasimf and Omar_Almulhem), Academic figures, mainly from Saudi, and Some governmental bodies such as SaudiMOH and Saudi_FDA.

AthPro: Atheism promoting accounts. AthPro includes large portion of the atheist accounts in our seed list, and contains other external accounts that promote atheism and criticise religions (mainly Islam) whether they are popular (e.g. hamed_samad); not widely popular individuals (e.g. DrTalebJawad), pages (e.g. AtheismAcademy), and public figures who actively criticise religions without a clear position towards atheism (e.g. NawalElSaadawi1[7]). Also, we find infotainment and news source (e.g. ajplusarabi), Scientific accounts (SciTalk2U, IBelieveInSci), journalists and TV shows presenters Arabs (jaafarAbdulKari), international news source in Arabic (AlarabyTV and BBCArabic), international organisations in Arabic (Unarabic), and few Israeli accounts (e.g. EdyCohen, Israelipm_ar and IsraelArabic).

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[7]It worth mentioning that the holder of this account is a popular Egyptian feminist and has passed away in Match 2021 [47]. Most Atheist accounts and some of the Rationalist and Tanweeri accounts in our seed list have changed their profile picture to her photo in condolences of her death.

RelDis: Discussion of Religion. RelDis group also includes a large potion of the atheist accounts in our seed list, but external accounts that criticise Islam and Muslim communities in specific. It contain Symbolic accounts for a historical sceptical figures (e.g. abn_alrawndi), Non public Atheist users, Saudi feminist accounts (hw_saudiwomen), public figures demand atheist community and criticise revealed religions (squemny), public figures demand secular societies (e.g. Azizalqenaei and ElBaradei [52]), writers and journalists from different Arab countries such as abdelbariatwan (Palestine), FatimaNaoot (Egypt), AhlamMostghanmi (Algeria), Egyptian news source (Shorouk_News, youm7 and AlMasryAlYoum), international news sources broadcast in Arabic (Rtarabic, dw_arabic, cnnarabic and France24_ar), international organisations (hrw_ar), and Israeli account (AvichayAdraee).

ArbInfl: Influential Arabic Accounts. The ArbInfl group includes many Arab influencer accounts with no specific stance towards religion. It includes royal family members from Saudi and Emirate (KingSalman and MohamedBinZayed), Arab government bodies and personnel mainly from Saudi and UAE such as MOISaudiArabia, AdelAljubeir and Dhahi_Khalfan. football clubs (realmadridarab, Alhilal_FC), current and former cross-Arabs football players (MohammedAlDeaye and MoSalah), accounts from different backgrounds such as Arabic official news source (spagov and AlArabiya), Non official Saudi news sources (sabqorg, and News_Brk24), infotainment (TheTopVideo and I_9mile). Interestingly, this cluster has the largest number of Theists accounts from our seed list.

NonArab: Non-Arabic and Western. NonArab group is very similar to the nonArab group from the follow network, where large portion of the atheist accounts in our seed list are in this cluster. It contains mainly popular Western politicans (realDonaldTrump, BarackObama, JustinTrudeau and Nigel_Farage), and persons (BillGates), Arab immigrants to west (Ayaan), Non-Arab atheist immigrants to west (YasMohammedxx and MaryamNamazie), Western atheists (BillNye, SamHarrisOrg), Western organisations and scientific (hrw), Western news sources (dwnews), non-Arab journalists (nailainayat), non-Arabs immigrants to West (TarekFatah, MaajidNawaz), news sources boradcasted in non-Arabic language (AJEnglish, AlArabiya_Eng), and Israeli politicians (netanyahu).

Echo Chambers and Bridges. The general observation from Figure 3a is very similar to the ones from the follow network, where atheist group and the theist group are quite apart from each other, while the Tanweeri and Rationalist groups are spread between them. However, atheist are clearly split into two retweeting groups, each retweet almost exclusively to themselves. In addition, it can be noticed that some rationalist accounts retweet more for atheist group.

5.3 The Mention Network

Finally, in this part we analyse the mention network, that includes the accounts that are mentioned the most by our seed list accounts. The mention interaction means that the screen name of the account is included in a tweet whether as a replied to or mention. This network reflects the discussion within and among groups. Unlike follow and retweet networks which might be more indicative of agreement between connected nodes, mention network can show links between opposing views.

Figure 4 shows the network representation of the mention network among our seed accounts (4a), and among our seed list and their mention network (4b). The colour codes used in Figure 4b are explained in detail in Table 8, where each cluster is described by the main theme characterising the accounts in it. Table 9 shows the distribution of our seed list among the four clusters obtained in Figure 4b.

Table 10 shows the top five discussion topics in each cluster, derived using LDA. In addition, we show samples of tweets from each cluster in Table 11.

(a) The mention connections among our seed accounts. Nodes colors represent each group in our dataset.

(b) The mention network with nodes colors represent different clusters obtained based on modularity
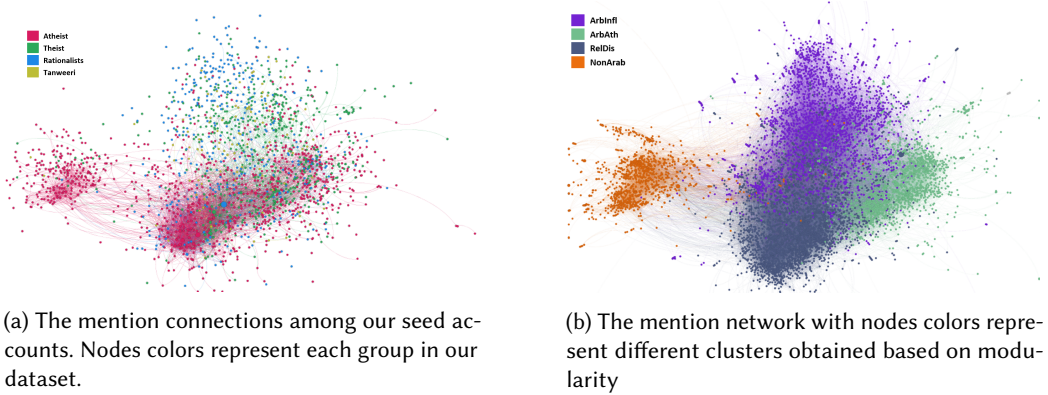
Fig. 4. Visualisation of the mention connections among our data set and their network, including only accounts mentioned by 20 or more of the seed list. Description of cluster names is provided in Table 8

Cluster	Theme (name)	Description
RelDis	Discussion group	Arab theists, atheists and secularists groups, linked more strongly to tanweeri and rationalist Arabs
ArbInfl	Arab influential users	Group includes Arab influential accounts theist promoters (mainly Muslims) and Islamic scholars.
ArbAth	Arabic Atheists	Arab atheists and secularists that interact more with Arab theists
NonArab	Non-Arabic & Western	Non-Arabic accounts in which the majority criticise religions

Table 8. Cluster Themes for the Four Major Groups in the Mention Network

Cluster	Total Size	Seed list				Non-Seed list
		Atheist	Rationalist	Tanweeri	Theist	
RelDis	2291	**243 (10.6%)**	83 (3.6%)	24 (1.0%)	98 (4.3%)	1843 (80.4%)
ArbInfl	2059	106 (5.1%)	152 (7.4%)	40 (1.9%)	**178 (8.6%)**	1583 (76.9%)
ArbAth	1327	**224 (16.9%)**	59 (4.4%)	8 (0.6%)	123 (9.2%)	913 (68.8%)
NonArab	1057	**199 (18.8%)**	1 (0.1%)	0 (0.0%)	19 (1.8%)	838 (79.3%)

Table 9. Distribution of Accounts Mentioned by dataset Accounts

RelDis: Discussion of Religion. The group RelDis includes mainly personal accounts that question religious actions. An account published a tweet 'I will not name my baby as Islamic name such as Muhammad, Omar or Ali, nor Christian name such as George or David. I want him to know God without endorsing any religion'. The main topics discussed with this group are Metaphysics, the religious-legislation and rationalism, social relationships, and religions and atheism. Some of these topics are illustrated in the tweets 13 and 14 which show rejection of religions, 12 which discuss the freedom of choice in Islam, and 15 which is a sample of tweets that discuss legislation.

ArbInfl: Influential Arab users. The ArbInfl cluster includes accounts of famous Arab influential users from different backgrounds. This includes professionals and academics, Islamic scholars, journalists, government and key government officials and football players, trainers and clubs. By considering the topics extracted with LDA model, as shown in Table 10, we notice that ArbInfl accounts are usually mentioned in the context of ideas and interactions as in tweets 1 and 3 from Table 11, wars and conflicts within countries and mainly in the middle east as shown in tweet 4, social interactions, and women's rights as shown in tweet 3. Tweet 3 might not be clear, but it is a

Topic	ArbInfl	ArbAth	RelDis	NonArab
1	Ideas and interactions	Religions and conflicts	Metaphysics	Bigotry and prejudice
2	Wars and nations	Islam and Islamic rules	Legislation and rationalism	Muhammad and Jesus Christ
3	social life	Freedom	Relationships	Ex-Muslims
4	Middle East and religions	Middle East and religions	Religions[8] and atheism	Rational and secular communities
5	Women's rights	Development of societies	Personal interests	Women's rights

Table 10. The Topics discussed in tweets with the top mentioned members as extracted with LDA

harsh reply to a tweet that complains about a fatwa that allows women to visit graves, which is not permissible in Islam. The complain to the fatwa, which some says it eases the restrictions of women's freedom, was written by a female account; while, the reply, tweet 3, which endorses the fatwa is written be a male account as they both describe themselves.

ArbAth: Arabic Atheists. The vast majority of ArbAth cluster accounts are non-public and personal accounts from different beliefs. The main topics discussed within the tweets that mention accounts from this groups are religions and religious conflicts, Islam and Islamic law, personal freedom, religions in the Middle-East and development of societies. We can see such topics in the sample tweets in Table 11 in addition to other tweets that discuss freedom, and development of societies such as: 'They used to forbid music and photography, and now they both are permissible. They said women will never drive a car, and now women can drive. Now they say secularism is a disbelief, but it is rooted in the culture!'. Another tweet that talks about the conflict in the Middle-East. The tweet 'I never authorise anyone to concede or even to negotiate on behalf of me, my rights and the right of my offspring in this country' which show a position towards the Arab-Israel conflict.

NonArab: Non-Arabic and Western. The main topics of discussion in this cluster are relevant to bigotry and prejudice, the prophet of Islam, Jesus Christ and Christianity, ex-Muslims, rationalism and secularism within the communities, evolution, and women's rights. Tweets in the Non-Arab group are generally part of long threads that discuss these topics, and some of them mention widely known atheists from the West.

Tweet 13 in Table 11 is taken from a discussion of evolution and Islam between two non-Arab accounts, both of which accuse each other of irrationality. The topic related to Ex-Muslims is widely discussed within the non-Arab group including the tweets number 14 and 15. Tweet 14 is part of a thread that claims that it is vital to have more Ex-Muslim atheists, which was instigated by a tweet from Richard Dawkinsm the UK biologist and atheist, about ex-Muslim atheists.

Echo Chambers and Bridges. While the mention network shown in Figure 4a has the fewest clusters (4), it clearly highlights an additional echo chamber that was not as clearly visible in the follow and retweet networks. There is a clear divide between a small portion of the Atheist group, which corresponds to the mention cluster NonArab, and the other three mention clusters, RelDis, ArbInfl, and ArbAth. Indeed, NonArab is almost isolated from any discussion with other Arab groups, including vocal atheists. Within the other three clusters, the atheist and theist echo chambers we saw in the follow and retweet networks become a lot more porous in the mention network. This means that within the Arab world, all four groups clearly interact with and react to each other.

Group	#	src	Tweet
ArbInfl	1	T	@MohamadAlarefe I believe in Allah as I believe a polar bear lives in desert. I am an atheist and I want to discuss with you.
	2	T	@user Here are 10 facts about the universe that are mentioned in the Qur'an; How did Muhammad knew about it?
	3	T	@user @user @SaudiNews50 Hey you! go and bury yourself, the lives of others are not your business.
	4	T	@user @AJArabic Your dream has finished (ISIS), terrorism is in constant loss, now Mosul; and Raqqa in the future.
ArbAth	5	T	@user I am a Saudi, Sunni and Muslim girl from Makkah (Saudi Arabia). My ancestry returns to the cousin of Islam prophet Muhammad. I left Islam because of the discrimination against women in Islam.
	6	T	@user women are the ones who suffer from this religion (Islam).
	7	T	@user @user @user What is the evidence that there is a day of the Resurrection?
	8	T	@user Leaving Islam is an act of sense.
RelDis	9	T	@user @user What a mind? she got out from the rubbish of Islam to enter the rubbish of Christianity. It is better for her to become an atheist.
	10	T	@user It is just a nonsense that intimidate naive people to increase the religion followers.
	11	T	@user The first step to develop your family and country is removing Islam from the legislative process. Legislative process must be based on the rational and ethical thoughts not by a book that was found 1400 years ago.
	12	T	@user @user Music to stay and growing. (criticising ISIS supporters claim 'Here to stay and growing').
NonArab	13	P	@user @user @user I have noticed that when you get stuck, you turn around by claiming that you hate Ahmadiyya. Please leave feelings out of our discussion.
	14	P	@user @RichardDawkins Here I am, an Ex-Muslims
	15	P	@user @user @user @realDonaldTrump Read the book "Why I am not Muslim" by a fellow ex-Muslim.
	16	O	An atheist Muslim on what the left and right get wrong about Islam @aliamjadrizvi

Table 11. Samples of the discussion tweets in each cluster including some of the top mentioned accounts. "T" indicates tweet is translated from Arabic, "P" indicates tweet is in English, but has been paraphrased to protect the user's privacy, and "O" indicates original English tweet is shown

5.4 Summary of observations and intersections among networks

In this part, we present a summary on the connections between our seed list and the clusters of users they connect to for the three networks we discussed earlier. In addition, we examine the mapping between the different obtained clusters in each of the networks. We check the common accounts among these networks to see how each cluster in each of the interaction networks might map to the other clusters in the other ones.

Figure 5 shows the summary of interactions between our seed list and the cluster communities obtained from each network: follow (Figure 5a), retweet (Figure 5b), and mention (Figure 5c). In addition, we show the common accounts between the obtained clusters in each network in Figure 5d.

As could be noticed, especially from Figure 5d, that the religion discussion cluster in the mention network maps mainly to the religion discussion in the follow network with some members of the other clusters as well. Also, it maps mainly to the AthPro cluster in the retweet network and still connects to most of the other clusters. This also applies to the ArbInfl cluster in the discussion that maps to most of the other clusters in the other networks. The general finding here is that

(a) Following Interactions

(b) Retweeting Interactions

(c) Mentioning Interactions
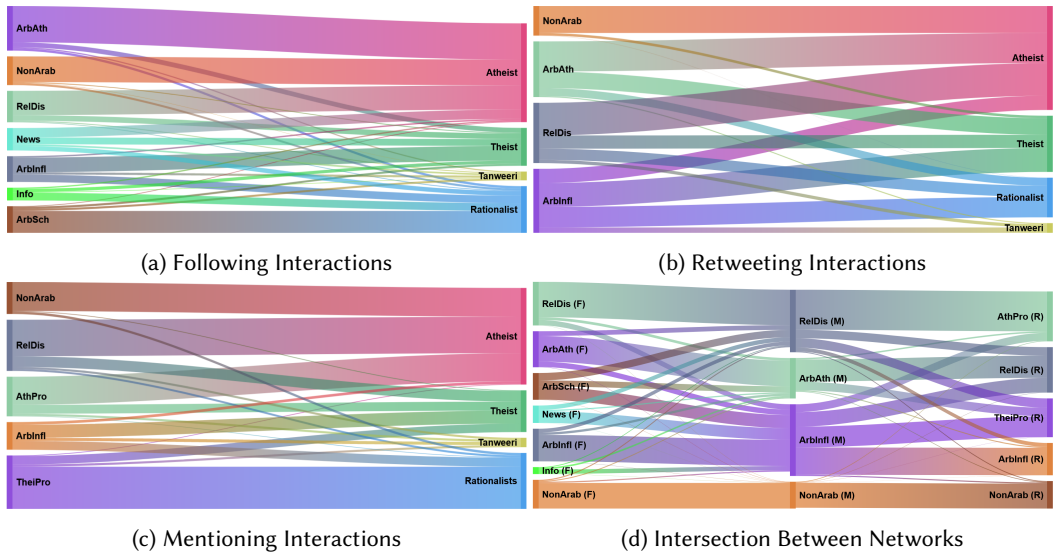
(d) Intersection Between Networks

Fig. 5. Summary of network interactions

while there are echo-chambers in the follow and retweet networks, especially between atheists and theists, the mention network comes to show that these different echo-chambers connects over discussions through mentioning and replying each other.

The very obvious echo-chamber from Figure 5d is in the nonArab cluster in all the three networks that almost fully map to each other. This shows that the Arab atheists that connects to the non-Arab and western accounts follow, retweet, and reply accounts from outside the Arab world and almost has no interaction with the Arab users, including the other Arab atheists.

In the following section we discuss these findings from the network analysis and link it back to the RQs of our study.

6 DISCUSSION

In this paper, we investigated three research questions:

(1) What are the relevant communities of Twitter users, and where do they fall on the spectrum of religiosity?
(2) Do these communities form echo chambers or they have bridges between them?
(3) What is the nature of the networks that each of these religion-related communities interact with?

To answer the first question, we investigate how Arabs from different religious backgrounds use Twitter to reflect their beliefs, promote it or criticise other beliefs, and if they participate in religious discussions. To this end, we created a list of seed accounts that openly mention their belief or non-belief in their account name or Twitter bio. We used four categories to describe user groups, Theist (regardless of religious affiliation), Atheist (including agnostics and Deists), rationalists (both religious and non-religious) and Tanweeri. These groups differ not only by their attitude to organised religion, but also by their epistemological positions. While most users are committed to either atheism or theism, overall, we observe the full spectrum of religiosity and non-religiosity that the literature would lead us to expect.

To answer the second and third question, we investigated the follow network (i.e., network of accounts followed by the seed accounts), the retweet network (i.e., network of accounts retweeted by the seed accounts), and the mention network (i.e., network of accounts retweeted by the seed accounts). Surprisingly, the clearest divide across all three networks is not between theists and atheists, but between atheist Twitter users who mainly interact with Western accounts and Twitter users of all four groups that have strong links to Arab Twitter in general. When looking at the follow and retweet networks, we find additional clear evidence for polarisation along the expected religious lines. Atheists and theists tend to follow and retweet accounts that have similar attitudes to religion.

In the follow and retweet networks, atheists split into three groups. In addition to those that mainly engage with Western accounts (NonArab), there are atheists who engage in active debate with theists and argue for secularisation (RelDis), and atheists who mainly engage with atheists in their own community (AthPro, ArbAth). Theists tend to follow, retweet, and mention accounts that are well known and influential in the Arab world, including government, news sources, and popular figures.

The atheist-dominated clusters that focus on the Arab community also include public figures, news sources, sports clubs, international organisations, and accounts that talk about science. In the Follow network, atheist, theist and rationalist accounts are connected almost equally to ArbInfl and News.

In all three networks, Rationalists and Tanweeri act as a bridge. These accounts are distributed between the main two communities with more accounts on the atheist end of the spectrum. Notably, rationalists are the group that is most likely to engage with Islamic scholarship.

6.1 Implication for HCI and CSCW

The social and cultural norms and practices of religions are often deeply embedded in the lives of those that practice them, and affect every part of life, from wellbeing [58] to engagement with technology [49, 55]. They will also affect those that live in areas where these religions are dominant. Indeed, the lens of religious practice and discourse has been used to critique dominant discourses in HCI [11].

Our findings illustrate that the study of religious polarisation cannot be separated from culture. Regardless of their attitude to religion, Rationalist, Tanweeri, Theist, and many Atheist users are deeply rooted in their communities. They pay attention to (follow network), amplify (retweet network) and interact with (mention network) local news, journalists, political figures, sports clubs (in particular football) and other public figures. This is also reflected in the topics extracted using LDA. The three groups that are rooted in the Arab world, ArbInfl, ArbAth, and RelDis, feature at least one topic that is relevant to society and life in general, whereas the discussion topics of NonArab (including bigotry and prejudice) are focused clearly on religion-related issues.

The interactions between theist accounts and those whom they follow and retweet indicate a space where Muslims can safely discuss issues linked to practising their religion in the context of the modern world [4, 35, 51]. Non-religious Arab accounts indicate a space where those practices themselves are critiqued and reforms can be pushed and argued for. We suggest that analyses of online discussion of contentious topics, such as women's rights, might benefit from a nuanced classification of the religious stance of the accounts involved. We hypothesise that rationalist accounts, which, as we have shown, engage deeply with relevant scholarship, might play an important role in making such discussions productive. Openly Tanweeri accounts may indicate which relevant religious and secular reforms are currently being discussed in the Arab world.

Online polarisation in Arab communities has previously mostly been studied in the context of politics and radicalisation (e.g. [52]). While there is often an overlap between political stance and

attitude to religion [20], it is counterproductive to reduce religious affiliation to political stance, and vice versa. The Rationalist and Tanweeri groups on Arab Twitter provide important bridges between the theist and atheist communities that might link discussions of reform in the atheist context to communities who might be open to adopting such reformed practices. When considering existing work on political polarisation, the role of these two groups highlights the importance of designing techniques to bridge echo chambers between [31, 32].

Since religion is so intimately tied to people's values and practices that it can affect uptake of e.g. health interventions [58], the detailed network analysis performed here can be helpful when researchers seek to leverage social media data to understand how people react to technology-mediated services and products. The analysis may also be informative for those who seek to design for user groups that differ in religious belief.

Finally, our analysis is strongly contextualised within Arab culture. In this, we follow recent calls for HCI that acknowledges and incorporates cultural differences [7, 40]. The cultural knowledge contributed by the Arab authors of this paper allows us to characterise the position of prominent figures in the community, interpret the tweets within the discourse conventions of the Arab world, and acknowledge the varied strands of thought that are often not seen from a Western perspective which focuses on conflict and radical Islam.

In fact, our results show why cultural contextualisation is important. We identified an entire subset of atheist discourse within Arab Twitter that is almost unmoored from the debates that are going on in the rest of the Arab world. By interacting with Western atheist accounts, those Arab atheists position themselves within the wider debate between Muslim theists and atheists that goes beyond the Arab world itself. In order to understand this wider debate, however, we argue that we need more studies which focus on specific Muslim majority and minority countries and regions. The political and social situations in Turkey, India, Pakistan, Bangladesh, Nigeria, or Indonesia, to mention only a few countries with large Muslim populations, are quite different from each other. Our study shows that online debate of religion versus non-religion benefits from the same in-depth study that we afforded to the Arab world here. It would be interesting to see whether there are similar differences between an atheist group that mainly interacts with the Western world and atheist groups that interact with local communities, and whether there is evidence of theist and atheist groups in dialogue across national and regional boundaries in the Muslim world.

6.2 Limitations

For reasons of protecting people with atheist leanings that are not public about it, our initial sample was based only on public information that people publish online, i.e. the biography. However, some of this information may be false. There are also parody accounts, which huge volume of interactions. We also followed people's self-description even in cases where their timeline might have led us to a different judgement.

Most accounts have removed content whether by the account holder or by Twitter. Studying the discussions, timelines contents and networks interaction in real-time would be richer and more informative, but would not respect the Twitter users' right to control which parts of their timeline are accessible to the public or preserved as part of a putative research record. Removed content, suspended and protected accounts cause a lot of incomplete discussions. Investigating those requires a sensitive, qualitative approach, because account holders may have deleted this information due to potential negative consequences for themselves.

Due to available resources, we limited the network analysis to accounts that had more than a set number of followers or retweets. While this produces a cleaner data set that is easier to interpret, it is possible that there are smaller sub-structures which we failed to detect due to lack of data.

We acknowledge that due to our focus on atheism, the sample of Theist accounts is comparatively small. We also did not divide Theist accounts according to the branch of Islam to which they belong. We acknowledge that polarisation between Theists and Atheists on Arab Twitter needs to be carefully contextualised within general religious discussion on Arab Twitter, but performing such an analysis is unfortunately outside the scope of this study and remains as potential future work.

Finally, we focused on people's attitudes towards religion, but we did not classify them according to their own spirituality, and spiritual practices. This means that we were unable to accurately represent Twitter users who are spiritual, but not religious; such people might fall into the Atheist and Rationalist categories in this study.

7 CONCLUSION AND FUTURE WORK

In this paper, we have shown how an in-depth network analysis can be used to develop a nuanced understanding religious polarisation between atheists and theists on Arab Twitter. We have highlighted both religious and cultural divides, and shown the importance of reformist (Tanweeri) and Rationalist users in fostering productive discussion despite strong polarisation. In addition, we have shown that analysing the mention/reply networks of users might give additional insights about interactions between polarised online communities that might not been captured in their retweet and follow networks.

While we have begun to examine the content of discussions between people with different attitudes towards religion using LDA, the logical next step is a detailed content analysis. This would allow us to see to what extent debates address current political and social issues in the Arab world, and would also allow us to surface humour and satire, which clearly play a part in the discussion. We also require a closer reading to identify references to spirituality or "personal religion", and its relationship to organised religion in Arab Twitter. This work is being planned in collaboration with sociologists of religion, so that we can place our findings in the wider context of adherence to religion and spiritual beliefs and practices.

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