Using Information Divergence to Differentiate Deep from Superficial Resemblances among Discourses

Zachary K. Stine[1[0000-0001-5211-0111]], James E. Deitrick[2], and Nitin Agarwal[1[0000-0002-5612-4753]]

[1] University of Arkansas at Little Rock, Little Rock AR 72204, USA
[2] University of Central Arkansas, Conway AR 72035, USA
zkstine@ualr.edu, deitrick@uca.edu, nxagarwal@ualr.edu

Abstract. In comparative analyses of discourses that reflect particular cultural identities, it is often necessary to differentiate superficial distinctions that arise primarily as cultural markers from deeper distinctions that arise from differences in cultural structures. In this paper, we build on previous work in order to operationalize this distinction between deep and superficial relationships between discourses using computational methods. To do so, we draw on the notion of divergence from information theory to measure the extent to which lexical items from a discourse act as signals of one cultural identity over another. We carry out a series of three types of comparisons between the discourses of fourteen English-language online discussion communities primarily focused on religion and spirituality. In the first type of comparison, discourses are compared at the level of individual words and their frequencies. In the second type, they are compared at the level of word-usage patterns learned from topic models. In the third, they are also compared at the level of word-usage patterns, but from topic models trained on their discourses after removing highly distinguishing terms that represent superficial distinctions between them. Our results indicate that, while some discourses share close resemblances both superficial and deep, others may appear to share close resemblances only superficially or may only share close resemblances after accounting for their superficial differences. These findings suggest that the approach we describe may be of use to researchers studying language in a variety of comparative contexts.

Keywords: Natural Language Processing, Cultural Analytics, Information Theory, Comparative Religion, Digital Religion.

1 Introduction

A significant obstacle for comparative analyses of cultures is differentiating cultural expression that is only superficially distinct or similar between cultures being compared from cultural expression that is similar or distinct at a deeper level. In linguistic comparisons, distinctions between culturally specific lexical items may mask deeper cultural resemblances. For example, Prothero [1] argues that the adult religious life of Henry Steel Olcott—a well-known early American convert to Buddhism—was ex-

pressed through a Buddhist, South Asian cultural lexicon, but ultimately reflected American Protestant cultural structures at a deeper level. Another example of this distinction is used by Deitrick [2] in arguing that the social ethics of American Engaged Buddhism is structurally similar to a liberal, Protestant social ethics despite being expressed through a Buddhist lexicon.

In this paper, we are interested in using a quantitative approach to reduce the prominence of superficial distinctions between discourses in comparative analyses as a complement to existing qualitative approaches. We draw on concepts from distributional semantics and information theory to create representations of discourses that lack culturally specific lexical items while still retaining their underlying semantic structures.

This work builds on previous research that frames comparative cultural analysis as a meta-clustering problem wherein discourses are compared indirectly via their latent organizational schemes [3]. There, we saw that discourse around debates on vegetarianism within a Buddhist discussion community and abortion within a Christian discussion community, while distinct on a more superficial level, exhibited structural similarity as instances of ethically contentious debate. Here, we explore a different approach in which we do not compare the organizational schemes of each discourse, but rather compare discourses within a single organizational scheme reflecting all discourses under comparison and from which culturally specific terms have been removed.

The discourses we consider here are those of several online discussion communities from Reddit that are dedicated to discussions of religious and spiritual topics. This study thus contributes to ongoing scholarship concerning the relationship between social media and religion, often referred to as digital religion studies (see [4] for a recent overview of this scholarship).

We carry out a series of comparative analyses between the discourses of several online discussion communities from Reddit. Each pair of discourses undergoes three modes of comparison, which differ in how the discourses are represented. In the first, discourses are represented by probability distributions of words. In the second, discourses are represented within the latent semantic features derived from topic models trained on all of the discourses. Rather than probability distributions of words alone, the discourses are represented as probability distributions of "topics," the learned latent features. In the third, discourses are also represented as probability distributions of topics, but these topics are learned from a modified version of the corpus from which highly distinguishing terms have been removed.

We find that the resemblances and differences between discourses undergo substantial changes from one mode of comparison to another. Comparisons of word distributions may show a discourse closely resembling others, only for these resemblances to weaken at the topic-level and dissipate at the level of topics learned from the modified corpus. Conversely, we also find that a discourse may appear distinct from many of the others under both word-level and original corpus topic-level comparisons, but may have surprisingly strong resemblances to other discourses under the modified corpus topic-level comparisons. Finally, we find that the resemblances between discourses need not necessarily change between modes of comparisons. As we

will show, three of the discourses we consider retain their close resemblances between each mode of comparison.

In the following sections, we provide background for our work, describe the data and methods used, report our results, and discuss them along with the limitations of the present study and our next steps.

2 Background

2.1 Religious and Spiritual Discourses on Reddit

The discussion communities of Reddit provide interesting sources for text data around a variety of topics including religion. These communities, called subreddits, allow users to author posts (or submissions) and to author comments on posts or other comments, resulting in discussion threads accompanying most posts. Scholarship on Reddit and religion include our previous work on comparative analyses of religious discourses [3], a study of the irreligious rhetoric of the subreddit, *r/atheism* [5], and an analysis of the influence of controversial religious news stories on *r/atheism*, *r/Christianity*, and *r/politics* [6].

Here, we focus our analysis on the following 14 subreddits: *r/Awakened*, *r/Bahai*, *r/Buddhism*, *r/Christianity*, *r/Hinduism*, *r/Islam*, *r/Judaism*, *r/Occult*, *r/Pagan*, *r/Philosophy*, *r/Psychonaut*, *r/Sikh*, *r/Spirituality*, and *r/Taoism*. These selections reflect general discussion communities around the so-called world religions (e.g., *r/Buddhism*, *r/Hinduism*, *r/Islam*), relatively newer religious movements (e.g., *r/Bahai*, *r/Pagan*), and several communities that resist easy categorization as religious or not.

The latter group comprises *r/Awakened*, *r/Occult*, *r/Psychonaut*, and *r/Spirituality*. These subreddits may draw on aspects of religion, but do not explicitly associate themselves with particular religious institutions. While the religiosity of these subreddits (or lack thereof) may be unclear, we can examine their resemblances to the other subreddits in order to gain a clearer picture of how their discourses are situated relative to the others. Despite their differences, each of these communities are marked by commitments to gaining wisdom, truth, insight, etc. outside the bounds of traditional religions. *r/Psychonaut* and *r/Occult* may be plausibly read as focused on certain technologies for insight, whether through the use of psychoactive substances in the former or magick in the latter, while *r/Spirituality* and *r/Awakened* are more general in their approaches. In particular, *r/Spirituality* presents an interesting case study given the emergence of the so-called spiritual-but-not-religious identity and the scholarship around it (e.g., [7-10]).

Finally, we include *r/Philosophy* to provide a point of contrast given that, while religious topics are certainly relevant in the community, we suspect that its discussions are motivated by distinct reasons from the other subreddits and that it is structurally quite dissimilar to the other subreddits we analyze.

A critical point to bear in mind is that these subreddits should not be viewed as samples of larger populations from which we can easily extrapolate conclusions; on

the contrary, each subreddit should be viewed as its own population. In other words, there is little reason to suspect that conclusions about *r/Spirituality* will easily map onto spirituality writ large. Despite this, these subreddits constitute interesting cultures themselves that still offer insights into the landscape of popular English-language culture.

2.2 Latent Dirichlet Allocation

Latent Dirichlet allocation (LDA), a kind of topic model, provides a method for learning a set of latent features from a collection of text that reflect patterns of word-usage [11]. LDA has been used in various contexts to provide semantically richer representations of text including a comparative analysis of Confucian texts [12], a study of mind-body holism in medieval Chinese thought [13], and a comparative analysis of different natural language processing conferences' proceedings [14].

After training on a corpus, LDA provides these latent features, called "topics," in the form of probability distributions over the vocabulary of the corpus. Additionally, the trained LDA model can draw a distribution over the topics for each document. With both a document's distribution over topics and each topic as distribution over words, each token in a document can be probabilistically assigned to a topic. As discussed in [3], an LDA model trained on a discourse can be usefully thought of as representing a discourse's latent organizational or conceptual scheme.

The features learned by LDA—the probability distributions over the vocabulary—do not typically correspond to what we colloquially think of as "topics," and can be better thought of as contexts of language usage [15]. The number of topics to be learned, k, must be defined. While the selection of k may influence the resulting model, it likely acts as something like a dial on topic specificity [16]. Therefore, different selections of k may not be better or worse than others in any straightforward way, but may simply offer different yet equally plausible views into the corpus. For a thorough discussion of evaluating LDA models, see [17].

LDA is an unsupervised machine learning algorithm, meaning that it learns topics (or contexts) without them being pre-specified or other external guidance. The way LDA learns "meaningful" topics can be related to the notion of distributional semantics, the idea that something of a word's meaning can be glimpsed based on how the word is distributed among other words across documents. This notion is relevant for our work as we will be removing certain terms from the vocabulary while preserving the overall distributional semantic structure of the corpus. Previous research into a similar problem suggests that the semantic structures of a corpus are resilient to the removal or subsampling of certain terms [18].

2.3 Information Divergence and Comparative Analysis

To facilitate our comparisons of discourses, we use information divergence to measure the dissimilarity (and implicitly, the similarity) between representations of the discourses as probability distributions of linguistic features. From the divergences

between discourses, we can also identify how strongly each feature of the discourse contributes to the discourse's overall dissimilarity from another.

We use two related measures of divergence, the Kullback-Leibler divergence (KLD) and the Jensen-Shannon divergence (JSD). While most measures of difference correspond to distance within some space (e.g., Euclidean, cosine), the KLD is better understood as an epistemic measure of surprise [19]. Given an expectation based on one probability distribution and a newly observed distribution, the KLD from the expectation to the newly observed distribution provides a measure of how surprising the observed distribution is relative to the expectation. It is an asymmetric measure—the KLD from Q to P is not necessarily the KLD from P to Q. Thus between any two distributions, there are two directions in which the KLD between them can be calculated. When the KLD from Q to P is larger than the KLD from P to Q, we can describe their relationship as one of enclosure wherein P encloses Q [19].

The JSD is a symmetrized form of the KLD such that the JSD between distributions P and Q is the mean of the KLD from M to P and the KLD from M to Q (where M is the mean distribution). The JSD is defined for the range [0, 1] and so it can be converted from a difference measure to a similarity measure by subtracting it from one.

Information divergences have been used in a variety of comparative contexts such as an analysis of what features characterize violent versus non-violent trials in a London court [20], an investigation of protestor and counter-protestor discourses [21], a comparison of two online discourses around China [22], and an analysis of language used by politicians of different parties [23]. In our comparative context, these divergences provide an important way of understanding one discourse through understanding how it relates to other discourses. By breaking down the divergences into the per-feature contributions, we can identify lexical markers that mark a discourse as belonging to one subreddit over another.

3 Methods and Data

In this section we describe the collected data and the steps taken in our analysis.

3.1 Data and Preprocessing

We collect text data from 14 subreddits from their earliest submissions through the end of 2019. For each subreddit of interest, we collect all available submission IDs from the Pushshift Reddit database [24] and then use Reddit's API to collect the text for all available submissions. For each submission, we collect the text of the submission along with the text of all comments in the submission's comment threads. The collected text is primarily English-language. An overview of these data is provided in Table 1.

Table 1. Overview of subreddit data ordered by the number of documents after preprocessing.

Subreddit	Date of Earliest Document	Documents Collected	Documents after Pre-processing
r/Christianity	2008-01-25	412,930	274,724
r/Islam	2008-03-05	205,914	83,907
r/Psychonaut	2008-12-08	110,012	73,657
r/Philosophy	2008-01-25	148,794	61,810
r/Buddhism	2008-03-25	87,792	61,339
r/Occult	2008-03-23	75,973	53,969
r/Judaism	2008-06-11	88,233	47,246
r/Spirituality	2008-03-23	41,475	20,510
r/Awakened	2012-06-17	23,021	16,411
r/Hinduism	2008-11-08	28,487	11,722
r/Sikh	2010-01-09	17,314	11,206
r/Pagan	2010-03-30	13,945	8,596
r/Taoism	2008-03-23	8,540	6,231
r/Bahai	2008-05-27	6,667	4,248

All collected text undergoes simple preprocessing. All text is tokenized into lowercase strings with a minimum length of three characters and with internal punctuation preserved. We remove a set of 78 highly frequent stopwords. For each subreddit, we additionally remove all words that occur in fewer than 50 submissions from that subreddit. Of the remaining terms from a subreddit, the ten thousand most frequent are kept as that subreddit's vocabulary. After doing this for each subreddit, the final vocabulary consists of the union of each subreddit-specific vocabulary, resulting in 22,742 total word types.

A single document comprises the submission text and all corresponding comment text. Documents with fewer than 35 post-processed tokens were excluded.

3.2 Word Distribution Comparisons

For each subreddit, we calculate the relative frequency of each word in the original unaltered corpus in order to compare subreddits with respect to the word distribution of each. We then calculate the Jensen-Shannon divergence (JSD) between each pair of subreddits' word distributions to measure the differences in word usage between subreddits. Additionally, we calculate the per-word contribution to the Kullback-Leibler divergence (KLD) between each word distribution for words where the KLD is defined (i.e., excluding words that do not occur in the subreddit from which the expectation distribution was formed).

3.3 Removal of Distinguishing Terms

While the JSD between each pair of subreddits reflects how different their word distributions are, the per-word KLD contributions measure how conspicuous a word is in one subreddit relative to another. Since the KLD is asymmetric, a single word type makes two KLD contributions when comparing one pair of subreddits: one for each subreddit's word distribution acting as the expectation distribution and then as the observed distribution. The larger a word's KLD contribution is, the more strongly it signals the observed distribution relative to the expectation distribution. Therefore, the larger a word's KLD contribution, the more it acts as a subreddit's distinct cultural lexicon by providing a stronger signal of that subreddit over the other.

In order to understand the relationships between the subreddits' discourses that persist after their more superficial differences are ignored, we create a second version of the corpus from which certain words are removed based on how strongly they act as signals of one subreddit over another based on per-word KLD contributions. Prior to this, we remove any words that do not occur at least once in each subreddit. This results in the removal of 7,400 words or almost a third of the original vocabulary.

Additional words are removed based on how well they distinguish one subreddit from another. To identify words for removal, we define a threshold for the per-word KLD contributions. If a word's KLD contribution is greater than this threshold within any pairwise comparison of the subreddits' word distributions, it is removed from the new corpus. After manually examining words removed based on different per-word KLD thresholds, we use a threshold of 0.001 bits. This results in an additional 1,473 words removed from the vocabulary of this new corpus. In addition to the previously removed words, this results in the modified corpus having 8,873 fewer words in its vocabulary than the original corpus, a reduction of 39%. A similar problem is explored in [18] within a different statistical framework.

3.4 Latent Dirichlet Allocation

We train topics models via latent Dirichlet allocation (LDA) in order to learn corpus features that are semantically richer than individual word types. Models are trained using the implementation of LDA in Gensim [25]. For each model that is trained, the relative frequencies of each topic in each subreddit are calculated by probabilistically assigning each token from the subreddit to a topic. We follow the method used in [18] for estimating each token's topic assignment for EM-based implementations of LDA.

Because the highest probability words in a topic are not often sufficient for interpreting the topic, we interpret topics of interest by reading a variety of exemplar documents for each topic in order to better understand how they relate to the topic's high-probability words.

Original Corpus Models. Fifteen models are trained on the original corpus. This includes all documents from each subreddit with the exception of *r/Christianity* and *r/Islam*. From these subreddits, 75,000 documents are sampled for model training in order to prevent them from dominating the model features. Five samples are drawn

and combined with all documents from the remaining subreddits. For each of the five corpus samples, we train three models: one with 20 topics, one with 100 topics, and one with 250 topics.

Modified Corpus Models. We train fifteen additional models on the modified corpus. All documents from each subreddit that have at least 50 tokens are used for model training with the exception of *r/Christianity*, from which 75,000 documents are sampled due to it having many more documents even within the modified corpus. As was done for models trained on the original corpus, five samples are drawn with a 20-topic, 100-topic, and 250-topic model being trained on each sampled corpus.

3.5 Topic Distribution Comparisons

From the frequencies of token-topic assignments, the topic distributions of each subreddit are calculated and compared in a similar manner as the word distributions. Both the JSD and KLD are calculated between each pair of subreddits for all of the LDA models. Per-topic contributions to both the JSD and KLD are also calculated. For all models trained on the same version of the corpus, original or modified, and for the same number of topics, the mean JSD and KLD are calculated in order to summarize divergences across corpus samples.

Topics that are salient for a subreddit are identified as those with relatively large per-topic contributions to the KLD from others to that subreddit across comparisons.

4 Results

In this section, we describe our results and findings across the three modes of comparison: between word distributions, topic distributions from the original corpus, and topic distributions from the modified corpus from which words have been removed if they distinguish subreddits from each other. We illustrate each mode through examples from *r/Spirituality* and its relationship to the other subreddits. For brevity, we limit our results from topic distribution comparisons to models with 250 topics.

Importantly, we find that the relationships between subreddits have substantial differences between the different modes of comparison. The starkest change occurs between the word-level comparisons and the modified corpus topic-level comparisons. When comparing the similarity rank of each subreddit pair—such that the most similar pair of subreddits (excluding self-similarity) is ranked 1st and the least similar pair is ranked 91st—the sum of absolute rank differences across pairs from comparisons on word distributions to topic distributions from the modified corpus is 1,958, compared with 1,158 for word-level to topic-level comparisons in the original corpus, and 1,074 for original to modified corpus topic distributions.

4.1 Word Distribution Comparisons Results

Comparisons between the word distributions of each subreddit indicate how different or similar the proportion is of each word between subreddits. Of the 91 pairwise comparisons of the 14 subreddits (excluding self-comparisons), the smallest JSD between two subreddits' word distributions—0.02 bits—occurs between *r/Spirituality* and *r/Awakened*. The largest JSD—0.19 bits—is between *r/Psychonaut* and *r/Sikh*. Interestingly, the word distribution of *r/Sikh* appears to be something of an outlier relative to the other subreddits: the nine largest divergences among all comparisons involve *r/Sikh*. However, as we will see, this will not be the case within other modes of comparisons, suggesting that discussions in *r/Sikh* include many more highly distinguishing terms relative to the other subreddits.

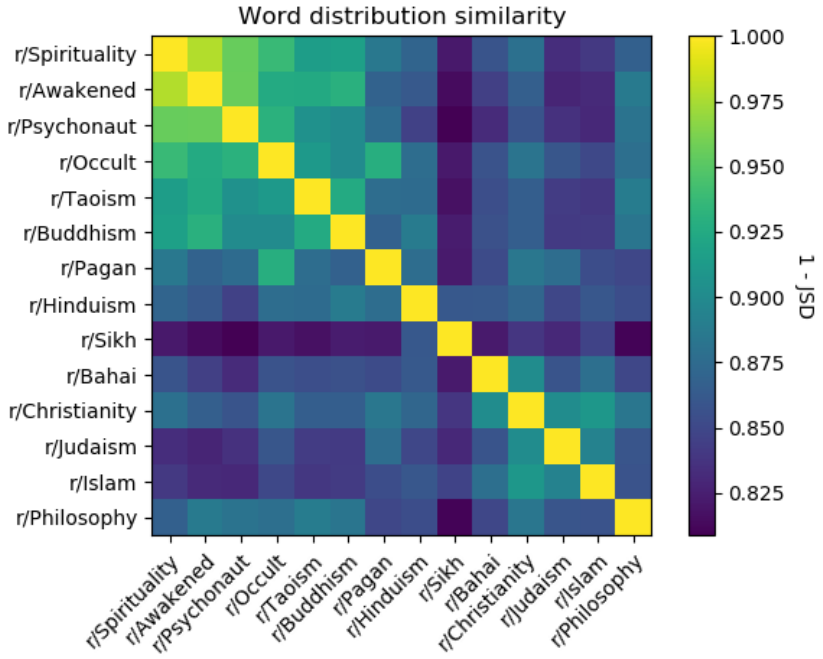

Fig. 1. Similarities between the word distributions of each subreddit where similarity is 1 – JSD.

r/Spirituality, *r/Awakened*, and *r/Psychonaut* all exhibit high similarity between word distributions, accounting for the three smallest divergences among all pairwise comparisons (see Fig. 1). As seen in the similarity network in Fig. 2, they form a densely-connected neighborhood along with *r/Occult*, *r/Buddhism*, and *r/Taoism*. These densely-connected nodes are bridged via *r/Philosophy* and *r/Pagan* to *r/Christianity*, which in turn, acts as the sole bridge to *r/Islam*, *r/Judaism*, and *r/Bahai*.

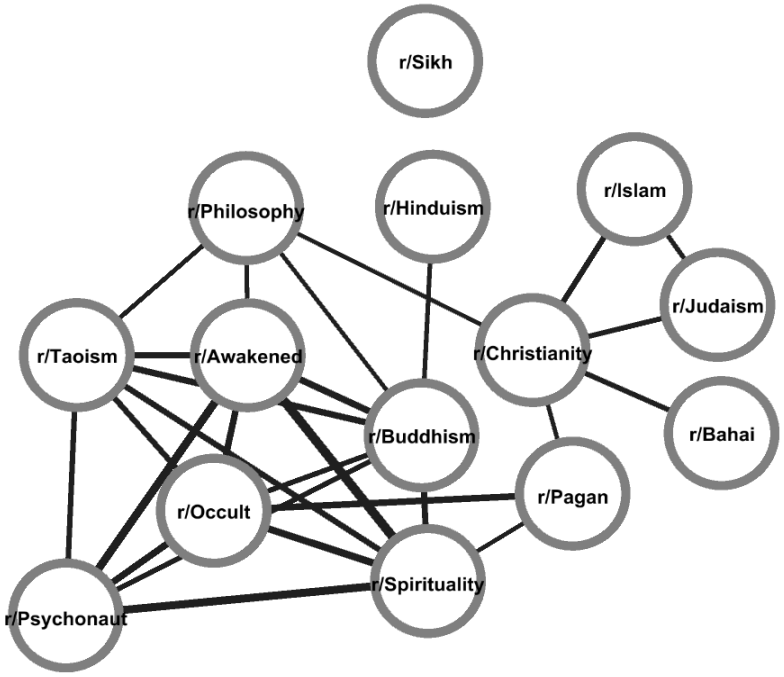

Fig. 2. The word distribution similarity network. Similarity is calculated as one minus the JSD between the word distributions of each subreddit. Edges indicate similarity scores at or above the 70th percentile (0.883). Edge thickness reflects similarity with thicker edges indicating greater similarity.

4.2 Topic Distribution Comparisons Results from the Original Corpus

Despite consisting of the same vocabulary, comparisons of topic distributions from the unaltered corpus produce relationships between subreddits that differ from those derived from word distributions in several ways. Both *r/Hinduism* and *r/Pagan* are more closely connected to the neighborhood of highly similar subreddits described above. However, *r/Christianity* and *r/Philosophy* now appear more dissimilar to several subreddits compared with their relationships under comparisons of the word distributions.

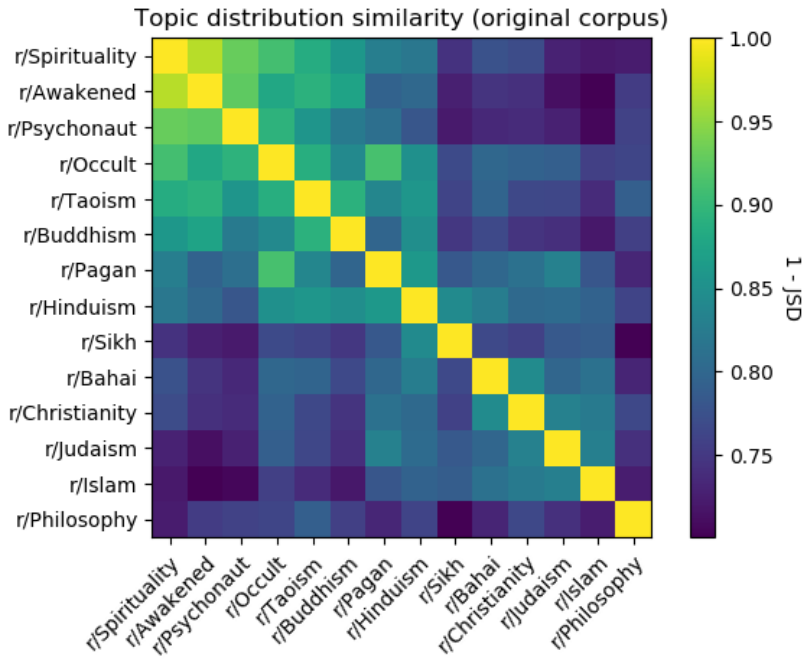

Fig. 3. Mean similarities between the topic distributions of each subreddit where similarity is 1 – JSD and calculated from the 250-topic models trained on the original corpus.

Several relationships persist at this mode of comparison from the word distribution comparisons. *r/Spirituality*, *r/Awakened*, and *r/Psychonaut* remain the three most similar subreddits, while the largest divergence now occurs between *r/Awakened* and *r/Islam*, a rank change from the 79th most similar pair to the 91st.

When comparing the magnitudes of change in rank of the most similar pairs of subreddits when comparing topics as opposed to word distributions, the nine largest drops in rank all involve *r/Philosophy* as one of the subreddits in the comparison. The biggest drop in rank occurs in the JSD between *r/Awakened* and *r/Philosophy*, dropping 44 places to the 67th most similar out of 91 pairs. This is reflected in the similarity network in which *r/Philosophy* is an isolated node, having no similarity score at or above the 70th percentile (Fig. 4). Conversely, six of the seven largest increases in similarity rank involve *r/Sikh* with the largest rank increase between it and *r/Pagan*, which is the 49th most similar pair, up 36 places from the word distribution ranking.

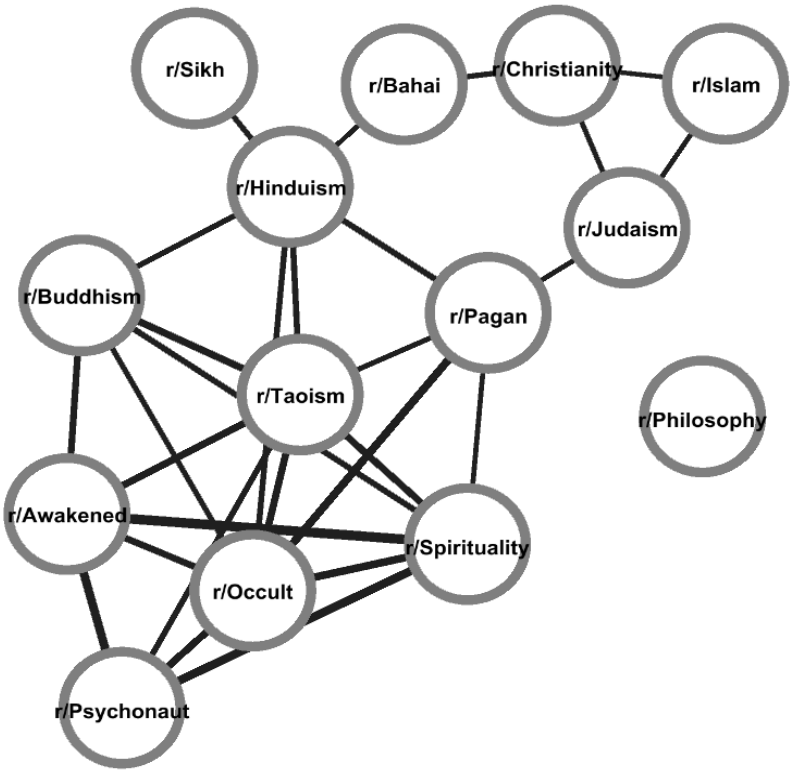

Fig. 4. The topic distribution similarity network from topic models trained on the original corpus with 250 topics. Edge weights are the mean similarity between subreddits where similarity is calculated as one minus the JSD between the topic distributions of each subreddit. Edges indicate similarity scores at or above the 70th percentile (0.825). Edge thickness reflects similarity with thicker edges indicating greater similarity.

4.3 Topic Distribution Comparisons Results from the Modified Corpus

70 of the 91 subreddit pairs (77%) undergo rank changes from word distributions to modified topic distributions that differ only in magnitude, but not in direction, i.e., positive or negative change. In other words, most subreddit pairs change rank in the same way that they did when going from word distributions to original corpus topic distributions. The primary difference between the changes seen in the modified corpus distributions versus the original topic distributions is due to the extent of the rank change: the absolute difference in rank is larger here, but positive changes are still mostly positive and negative rank changes are still mostly negative.

The relationships between subreddits are therefore not an extreme departure from the relationships between them under comparisons of topic distributions from the original corpus. The same group of highly similar subreddits continues to persist as a densely connected region of the similarity network (Fig. 6). *r/Hinduism* and *r/Pagan*

continue to act as bridges between network regions. *r/Philosophy* is still isolated from the others, but now joined by *r/Christianity* as another isolate.

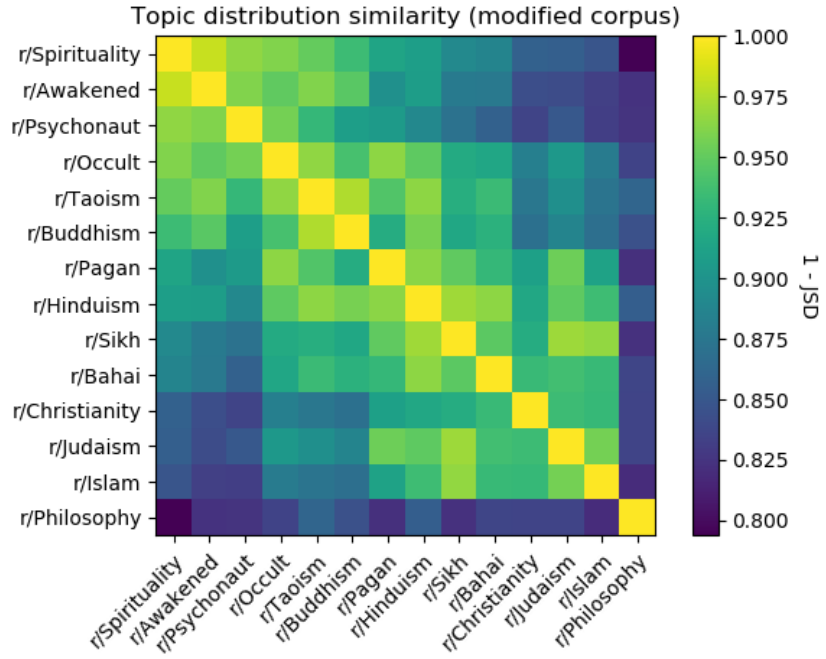

Fig. 5. Mean similarities between the topic distributions of each subreddit where similarity is 1 – JSD and calculated from the 250-topic models trained on the modified corpus.

The most notable change at this mode of comparison is the continued increase in similarity between *r/Sikh* and many of the other subreddits (see Fig. 5 and compare with Figs. 1 and 3). The five subreddit pairs with the largest positive changes in similarity rank from word-level to modified topic-level distributions all have *r/Sikh* as one of the subreddits in the pair. Of these, the most extreme case is *r/Sikh* and *r/Judaism*, which are ranked 80th most similar pair under word-level comparisons, but are ranked 4th most similar under modified topic-level distributions; a change of 76 places.

While *r/Spirituality* and *r/Awakened* remain the most similar pair, the 2nd through 6th most similar pairs are different than those in either the word-level or original topic-level comparisons. This is not because the subreddit pairs that previously occupied these rankings are necessarily more different, but because so many other subreddit pairs have become so much more similar under this mode of comparison with the lexical items that most differentiated them removed.

Of the ten largest negative changes in ranking from word-level to modified topic-level comparisons, eight include *r/Philosophy*. In the most extreme of these,

r/Philosophy and *r/Awakened* move from the 23rd most similar pair under word-level comparisons down 64 places to the 87th most similar pair here.

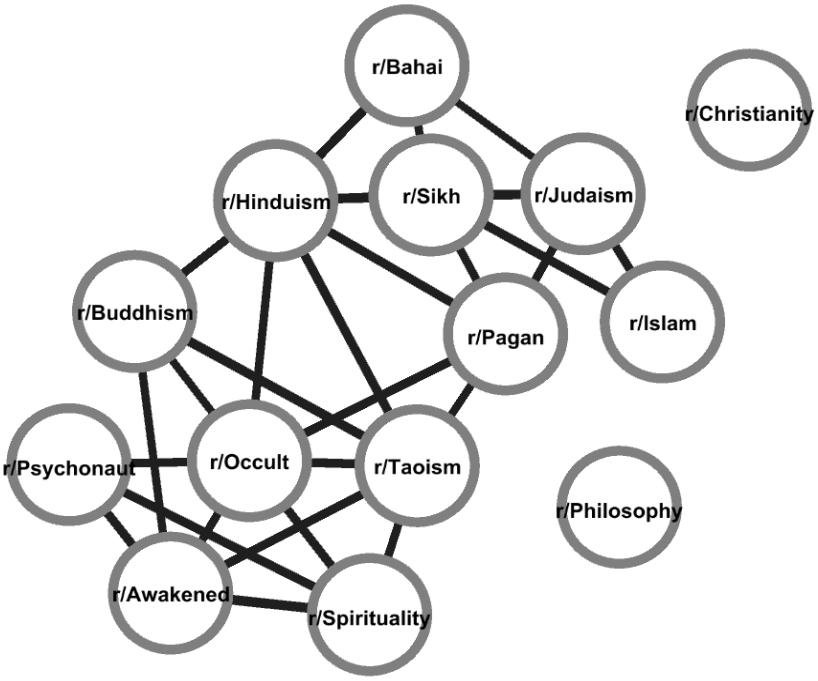

Fig. 6. The topic distribution similarity network from topic models trained on the modified corpus with 250 topics. Edge weights are the mean similarity between subreddits where similarity is calculated as one minus the JSD between the topic distributions of each subreddit. Edges indicate similarity scores at or above the 70th percentile (0.937). Edge thickness reflects similarity with thicker edges indicating greater similarity.

4.4 Examples from *r/Spirituality*

A richer picture of the relationships between discourses can be uncovered through the exploration of which words and topics most differentiate a subreddit from another. Here, we summarize the words and topics which most differentiate *r/Spirituality* from other subreddits as a case study illustrating what linguistic features, both deep and superficial, characterize the discourse of the subreddit relative to the others.

Word-level Comparisons. In comparisons of word distributions, the words from *r/Spirituality* which most distinguish it from the other subreddits include words like *spiritual, life, feel, love, spirituality, energy, yourself, ego, self, experience, mind, soul, consciousness, feeling,* and *meditation*, among others.

Notably, in most comparisons, the words which most distinguish *r/Spirituality* tend to make smaller per-word KLD contributions than the most distinguishing words of the subreddit to which *r/Spirituality* is being compared. In other words, the cultural lexicon of *r/Spirituality* is less distinct than the cultural lexicons of the other subreddits.

For example, the word types which most differentiate *r/Buddhism* from *r/Spirituality* include *buddhism, buddha, buddhist, dharma, practice, dhamma, sutta, mahayana,* and *buddhists,* among others. These example words are much less likely to occur with high frequency in the other subreddits, compared with the less culturally specific terms that distinguish *r/Spirituality*.

Topic-level Comparisons from the Original Corpus. In comparisons of topic distributions based on one of the 250-topic models trained on the original corpus, salient topics for *r/Spirituality* reflect life advice, personal stories and experiences, language about the nature of reality and fundamental truths, meditation, requests for help with difficult situations, the meaning and purpose of life, relationships, mental health, language about energy, vibrations, and auras, and others.

Similar to what was seen for word-level comparisons, *r/Spirituality* appears less distinct from the other subreddits as they do from it. More formally, in each comparison with another subreddit, the KLD from *r/Spirituality* to the comparison subreddit is always greater than the KLD from the comparison subreddit to *r/Spirituality*. In other words, observing *r/Spirituality* (as represented within the topic space) is less surprising relative to all other subreddits than the other subreddits are relative to *r/Spirituality*. The other subreddits are more distinct than *r/Spirituality* in each comparison.

Topic-level Comparisons from the Modified Corpus. In comparisons of topic distributions based on one of the 250-topic models trained on the modified corpus with distinguishing terms removed, several of the salient topics for *r/Spirituality* share similarities with the topics discussed above learned from the original corpus. These include topics reflecting language around struggles, personal stories and experiences, the nature of reality, requests for help, and relationships. Additional salient topics reflect discussions on mental obstacles to personal growth, the nature of suffering, and loneliness.

As observed in the other two modes of comparison, the KLD from another subreddit to *r/Spirituality* is always less than the KLD from *r/Spirituality* to the other subreddit. Even after removing the terms which most distinguish each subreddit, the remaining features of *r/Spirituality* continue to be less distinct relative to the other subreddits.

5 Discussion

Through our results, we have described the changes undergone by the relationships between the subreddits' discourses across the three modes of comparisons. We have seen that some close resemblances persist across modes, most notably observed in the relationships between *r/Spirituality*, *r/Awakened*, and *r/Psychonaut*. The distinctive lexicon of *r/Psychonaut* (i.e., words that tend to make the largest contributions to the KLD from other subreddits to *r/Psychonaut*) include words such as *trip, psychedelics, lsd, tripping, psychedelic, dmt, shrooms, mushrooms, acid, trips*. At a superficial level of comparison, we might be surprised then to see that *r/Psychonaut* has such close resemblances to *r/Spirituality* and *r/Awakened* at each mode of comparison. *r/Psychonaut* resembles the discourses of *r/Spirituality* and *r/Awakened* because, in a sense, it is ultimately about the exploration and attainment of knowledge about oneself and reality, as reflected in the salient topics of the three subreddits learned from the modified corpus. For example, the topics from the modified corpus with the smallest KLD contributions between *r/Spirituality* and *r/Psychonaut* reflect discussions about life and death; depression, anxiety, and mental health; and the nature of reality, among others. Through the different modes of comparison, the relationships between these three subreddits is continually amplified as their superficial distinctions are ignored.

We have also seen several stark changes occur over the modes of comparison. The discourse of *r/Philosophy*, while appearing relatively similar to several other subreddits at the word level, appears considerably distant at the more structural level of modified corpus topic distributions. While there is overlap in the usage of individual terms among *r/Philosophy* and other subreddits such as *r/Taoism*, *r/Awakened*, *r/Buddhism*, and *r/Christianity*, these resemblances appear mostly superficial—when comparing patterns of word-usage in topic models trained on the original corpus, these resemblances shrink and do so even more severely when comparing topics from the modified corpus. Opposite to the trajectory of *r/Philosophy*, *r/Sikh* appears structurally more similar to several subreddits when comparing topics from the modified corpus than when comparing word distributions or even topics from the original corpus. Thus *r/Sikh* provides an example of a discourse whose relationships to other discourses are quite different between the two topic-level modes.

Given some of the similarities between the two modes of topic-level comparisons, it seems that simply comparing discourses within a topic space already results in more structural comparisons than is the case in the word-level comparisons. However, as noted above in the case of *r/Sikh*, it is not the case that the topic distributions from the modified corpus only provide an amplified (and therefore redundant) picture of the topic distributions from the original corpus. While the directions, positive or negative, of rank changes among 77% of the subreddit pairs are the same in both topic-level modes of comparison, the configuration of the subreddits is considerably different under the modified corpus topic comparisons. While the absolute divergence between subreddits is necessarily less overall under topics from the modified corpus compared to the original corpus, the characterizations we have provided have focused on the

relative changes, such as the change in similarity rank or only including edges in the network visualizations for similarities at or above the 70th percentile.

Finally, we have also shown that *r/Spirituality* comprises less distinctive features in comparisons with the other subreddits. In the terminology of [19], we could say that *r/Spirituality* "encloses" the other discourses—it is more general and is always less surprising relative to expectations set by the others. Interestingly, these enclosure relationships are unchanged, even at the deepest level of comparison between topics learned from the modified corpus. In other words, *r/Spirituality* is less distinctive even after forcing all other discourses to be less distinctive as well, implying that it is thematically broad, encompassing, or non-specific at a structural level by comparison.

The current study has several limitations. While we have chosen to investigate one per-word KLD threshold for removing distinguishing terms, a more thorough analysis of how the relationships between discourses change across a range of thresholds would yield more robust insights into the effects this threshold has. Additionally, while the distributional semantics underlying a corpus may remain relatively stable as words are removed, an open question remains to be answered about how much modification a corpus can undergo before its semantic structures become instable and incongruent with its original structure. These limitations will be explored in future work. Additionally, our next steps will include broadening this analysis to a larger set of subreddits to map out the larger religious landscape of Reddit.

6 Conclusion

We have presented an approach to comparative discourse analysis that removes superficial distinctions between discourses in order to facilitate comparisons of their deeper, structural aspects. Our findings suggest that both types of topic-level comparisons we explore offer fundamentally different views into the relationships between discourses compared to word-level comparisons. While similarities exist between comparisons of discourses within the space of LDA models trained on the original corpus and a modified corpus (from which highly distinguishing terms have been removed), the relationships between discourses within the modified corpus topics are substantially different. This suggests that the removal of highly distinguishing terms may uncover differences and similarities between discourses that would be otherwise hidden behind such superficial distinctions.

Acknowledgements. This research is funded in part by the U.S. National Science Foundation (OIA-1946391, OIA-1920920, IIS-1636933, ACI-1429160, and IIS-1110868), U.S. Office of Naval Research (N00014-10-1-0091, N00014-14-1-0489, N00014-15-P-1187, N00014-16-1-2016, N00014-16-1-2412, N00014-17-1-2675, N00014-17-1-2605, N68335-19-C-0359, N00014-19-1-2336, N68335-20-C-0540, N00014-21-1-2121), U.S. Air Force Research Lab, U.S. Army Research Office (W911NF-17-S-0002, W911NF-16-1-0189), U.S. Defense Advanced Research Projects Agency (W31P4Q-17-C-0059), Arkansas Research Alliance, the Jerry L. Maulden/Entergy Endowment at the University of Arkansas at Little Rock, and the

Australian Department of Defense Strategic Policy Grants Program (SPGP) (award number: 2020-106-094) to the third co-author, Nitin Agarwal. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding organizations. The researcher gratefully acknowledges the support.

References

1. Prothero, S.: The White Buddhist: The Asian Odyssey of Henry Steel Olcott. 1st. edn. Indiana University Press, Indianapolis, IN (1996).
2. Deitrick, J.E.: Engaged Buddhist ethics: Mistaking the boat for the shore. In: Queen, C., Prebish, C., Keown, D. (eds.) Action Dharma: New Studies in Engaged Buddhism, pp. 252-269. 1st edn. RoutledgeCurzon, New York, NY (2003).
3. Stine, Z.K., Deitrick, J.E., Agarwal, N.: Comparative religion, topic models, and conceptualization: Towards the characterization of structural relationships between online religious discourses. In: Karsdrop, F., McGillivray, B., Nerghes, A., Wevers, M. (eds.) Proceedings of the Workshop on Computational Humanities Research (CHR 2020). CEUR Workshop Proceedings, vol. 2723, pp. 128-148. Amsterdam, Netherlands (2020).
4. Campbell, H.A., Evolvi, G.: Contextualizing current digital religion research on emerging technologies. Human Behavior and Emerging Technologies 2(1), 5–17 (2020). DOI: https://doi.org/10.1002/hbe2.149
5. Lundmark, E., LeDrew, S.: Unorganized Atheism and the Secular Movement: Reddit as a Site for Studying "Lived Atheism." Social Compass 66(1), 112–129 (2019). DOI:10.1177/0037768618816096.
6. Sanders, W.S., Ferré, J.P.: Reader Responses to Religion News: Discussions about Ark Encounter on Reddit. Journal of Religion, Media and Digital Culture, 9(1), 107–130 (2020). DOI: https://doi.org/10.1163/21659214-bja10008.
7. Fuller, R.C.: Spiritual, But Not Religious: Understanding Unchurched America. 1st edn. Oxford University Press, New York, NY (2001).
8. Mercadante, L.A.: Belief without Borders: Inside the Minds of the Spiritual but not Religious. 1st edn. Oxford University Press, New York, NY (2014).
9. Drescher, E.: Choosing Our Religion: The Spiritual Lives of America's Nones. 1st edn. Oxford University Press, New York, NY (2016).
10. Jain, A.R.: Peace Love Yoga: The Politics of Global Spirituality. 1st edn. Oxford University Press, New York, NY (2020).
11. Blei, D.M., Ng, A.Y., Jordan, M.I.: Latent Dirichlet allocation. Journal of Machine Learning Research 3, 993–1022 (2003).
12. Nichols, R., Slingerland, E., Nielbo, K., Bergeton, U., Logan, C., Kleinman, S.: Modeling the Contested Relationship between Analects, Mencius, and Xunzi: Preliminary Evidence from a Machine-Learning Approach. The Journal of Asian Studies, 77(1), 19–57 (2018). DOI: 10.1017/S0021911817000973.
13. Slingerland, E., Nichols, R., Neilbo, K., Logan, C.: The Distant Reading of Religious Texts: A "Big Data" Approach to Mind-Body Concepts in Early China, Journal of the American Academy of Religion 85(4), 985–1016 (2017). DOI: https://doi.org/10.1093/jaarel/lfw090
14. Hall, D., Jurafsky, D., Manning, C.D.: Studying the history of ideas using topic models. In: Proceedings of the Conference on Empirical Methods in Natural Language Processing (EMNLP '08), pp. 363–371. Association for Computational Linguistics, USA (2008).

15. Allen, C., Murdock, J.: LDA Topic Modeling: Contexts for the History & Philosophy of Science. 2020 preprint of a chapter to appear in Ramsey, G., De Block, A. (eds.) The Dynamics of Science: Computational Frontiers in History and Philosophy of Science. Pittsburgh University Press; Pittsburgh (forthcoming).
16. Nguyen, D., Liakata, M., DeDeo, S., Eisenstein, J., Mimno, D., Tromble, R., Winters, J.: How We Do Things with Words: Analyzing Text as Social and Cultural Data. Frontiers in Artificial Intelligence 3, (2020). DOI:10.3389/frai.2020.00062
17. Roberts, M.E., Stewart, B.M., Tingley, D.: Navigating the Local Modes of Big Data: The Case of Topic Models. In: Alvarez, R.M. (ed.) Computational Social Science: Discovery and Prediction, pp. 51–97. 1st. ed., Cambridge University Press, New York, NY (2016).
18. Thompson, L., Mimno, D.: Authorless topic models: Biasing models away from known structure. In: Proceedings of the 27th International Conference on Computational Linguistics, pp. 3903–3914. Association for Computational Linguistics, Santa Fe, NM, USA (2018).
19. Chang, K.K., DeDeo, S.: Divergence and the Complexity of Differences in Text and Culture. Journal of Cultural Analytics 4(11), 1–36 (2020). DOI:10.22148/001c.17585
20. Klingenstein, S., Hitchcock, T., DeDeo, S.: The civilizing process in London's Old Bailey. PNAS 111(26), 9419-9424 (2014). DOI: https://doi.org/10.1073/pnas.1405984111
21. Gallagher, R.J., Reagan, A.J., Danforth, C.M., Dodds, P.S.: Divergent discourse between protests and counter-protests: #BlackLivesMatter and #AllLivesMatter. PLoS ONE 13(4), (2018). DOI: https://doi.org/10.1371/journal.pone.0195644
22. Stine, Z.K., Agarwal, N.: Comparative Discourse Analysis Using Topic Models: Contrasting Perspectives on China from Reddit. In: International Conference on Social Media and Society (SMSociety'20), pp. 73–84. Association for Computing Machinery, Toronto, ON, Canada. DOI:10.1145/3400806.3400816
23. Sloman, S.J., Oppenheimer, D.M., DeDeo, S.: Can we detect conditioned variation in political speech? Two kinds of discussion and types of conversation. PLoS ONE 16(2), (2021). DOI: https://doi.org/10.1371/journal.pone.0246689
24. Baumgartner, J., Zannettou, S., Keegan, B., Squire, M., Blackburn, J.: The Pushshift Reddit Dataset. In: Proceedings of the International AAAI Conference on Web and Social Media, vol. 14, pp. 830–839. (2020).
25. Řehůřek, R., Sojka, P.: Software Framework for Topic Modelling with Large Corpora. In: Proceedings of LREC 2010 workshop New Challenges for NLP Frameworks, pp. 46–50. University of Malta, Valletta, Malta (2010).