Analysis of chronic pain experiences based on online reports: the RRCP dataset for quality-of-life assessment

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Abstract

Purpose Validate the applicability of Natural Language Processing (NLP) techniques to reveal, and quantify, qualities of the experience of chronic pain, by means of the novel Reddit Reports of Chronic Pain (RRCP) dataset, aimed at being a standard for future research on this underdeveloped area.

Methods Define and validate the RRCP dataset for a set of pathologies related to chronic pain. For each pathology, identify the main qualities emergent of the consequent experience of chronic pain. Compare the identified qualities for each pathology and validate with clinical research.

Results The RRCP dataset comprises 136,573 Reddit submissions from 12 subreddits related to chronic pain. Macro analysis reveals that pathologies affecting the same or similar body parts result in semantically similar descriptions of pain. Detailed analysis reveals that there are qualities to experiencing chronic pain from a given pathology that are nothing like experiencing it from another pathology, and that some are common to every experience of chronic pain. These allow us to compare subjective experiences of chronic pain (e.g., for the RRCP population, experiencing arthritis is very similar to experiencing ankylosing spondylitis in its various qualities or concerns, whilst experiencing fibromyalgia encompasses the same qualities and others not emergent of the other two pathologies).

Conclusion Our unsupervised semantic analysis of descriptions of chronic pain reflects clinical knowledge on how different pathologies manifest in terms of the chronic pain experience. Our results validate the use of NLP techniques to automatically extract and quantify clinically relevant information from descriptions of chronic pain experiences.

Keywords: chronic pain; language of pain; natural language processing; social media; chronic pain modelling; subjective experience modelling

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Plain English Summary

Chronic pain is recognized as a major health problem, with impacts at the economic, social, and individual levels. It is a private and subjective experience, dependent on the subject’s past experiences, social and cultural environments, as well as emotional and psychological loads. Consequently, it is impossible to externally and impartially experience, describe, and interpret chronic pain in a way that would directly point to the problem and easily eliminate it. The expression of pain, specifically verbal communication, thus, plays an important role for the clinical assessment and management of chronic pain patients. What a patient describes about the experience, and how it is described, reveals qualities about the patient and the experience of pain itself, which can be used to guide the clinical process. In this study, we explore how to computationally model a subjective experience of pain from spontaneous textual descriptions of that experience (from social media posts), and how to evaluate and compare intrinsically private, distinct experiences. Our results show that the computational processing of textual descriptions of chronic pain allows for the modelling of these experiences and that key qualities can be automatically extracted and quantified for comparison with models of other experiences of pain, in a clinically relevant way. We believe that our work paves the way for future computational analysis of the language of chronic pain, and that this will ultimately provide new insights and techniques for the clinical assessment and management of chronic pain patients.

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Introduction

Chronic pain is recognized as a major health problem, with impacts not only at the individual, but also at the social and economic levels. At the individual level, chronic pain dominates a multitude of aspects of the patient's life and is usually accompanied by a chain of alterations at both the somatic and psychological levels. For instance, due to immobility, muscles start to weaken, discouraging further exercise or movement. This cycle can lead to sleep disturbances and a vulnerable immune system, effectively affecting the subject's psychological balance. Consequently, adequate chronic pain assessment determines the quality of its management, which has been identified as a key procedure in improving the quality of life of these patients [1].

The most common expressions of pain are cries, facial expressions, verbal interjections, descriptions, emotional distress, disability, and other behaviors that come as consequences of these, such as lack of social interaction, exercise, movement, and productivity. The use of language to express and describe the personal experience of chronic pain is the object of study of the present work, specifically in the context of social media, where there is an implicit demand for sharing and discussing the shared concerns of the experience. This discussion oftentimes includes valuable information about the bodily distribution of the feeling of pain, temporal patterns of activity, intensity, and others. Additionally, the choice of words may reflect the underlying mechanisms of the causal agent [2], which in turn can be used to redirect the therapeutic processes. Indeed, this forms a specific sublanguage which has been the focus of previous research, such as the structuring of the Grammar of Pain [3], the extension of this work to Greek [4], and the study of its lexical profile, resulting namely in the McGill Pain Questionnaire, which is widely used to characterize pain from a verbal standpoint [5, 6]. However, all these studies relied on manual methods and expensive human evaluation.

The computational analysis of syntactic and semantic structures of the language of chronic pain may yield correlations between the content of the descriptions and other relevant medical and non-medical aspects of the painful experience, allowing for a systematic and quantifiable way of characterizing pain and disease manifestations on a linguistic level. This, in turn, has the potential to aid health professionals with the clinical assessment and management of these patients. Social media, specifically online forums with a focus on a given topic, provide a platform for people to express themselves and share their experience with others. Moreover, in these forums, people suffering from chronic pain and other pathologies are encouraged to share their experiences with others, so that they can contextualize their sufferings and help others contextualize theirs. In some ways, this allows chronic pain patients to take back some control over their pain. In terms of computational analysis, this also means that there is a substantial amount of textual descriptions and discussion of chronic pain on these forums, which can be computationally analyzed to extract the same findings previous manual works did, and others that may only be accessible through the processing of thousands of instances.

In this work, we present the Reddit Reports of Chronic Pain (RRCP) dataset, which comprises social media textual descriptions and discussion of chronic pain experiences. We propose a semantic modelling of the latent space, as given by the body of textual submissions to the Reddit platform. By taking each intrinsic group of documents as the discussion of one possible way of experiencing chronic pain, we characterize each of those specific experiences in some semantic space. Then, by analyzing the layout of that semantic space, we can find the similarities between the different experiences of chronic pain, and the differing points. Findings may be useful to better understand what it is like to experience chronic pain as manifested from each pathology, either from the shared points as a baseline for comparison, or from the differing points identifying the unique aspects of that specific experience. Finally, we argue that our unsupervised, semantic analysis of descriptions of chronic pain correlates to clinical knowledge on how different pathologies manifest in terms of chronic pain experience, and the quality of life of these patients.

Our work contributes to show that:

- Textual descriptions of experiences of chronic pain, from public social media posts, can be systematically processed to reveal and quantify clinically relevant semantic patterns;
- The shared chronic pain experience for a given base pathology can be modelled after these textual descriptions, concretely revealing, and quantifying, the core qualities of that experience;
- These models can be compared in terms of coarse- and fine-grained similarity, making explicit exactly which qualities of the compared experiences are shared, and which are exclusive;
- These models allow for a systematic evaluation of an inherently subjective experience, in terms of the extracted and quantified qualities.

Background

The chronic pain experience is characterized by its persistent state, lasting for more than a few months, in extreme cases even a lifetime. The organism arrives at this state when the original damage overwhelms the healing processes, preventing the nervous system from restoring itself to the original state, and can be perpetuated and intensified by factors other than the pathological agent, such as stress, environment, culture, and affection [7]. This experience is consequently dependent on the cultural, behavioral, and psychosocial dimensions of the subject in pain [8]. Assessment of persistent pain is,
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therefore, a demanding task, and considering that sometimes there is no identifiable objective pathology, most of the time it must be heavily based on the patient's explicit and implicit communication, with a comprehensive set of methodologies besides the standard pain assessment techniques, including a set of screening and psychological interviews [8] to effectively characterize all dimensions of the pain experience. Despite advances in research, chronic pain assessment and consequent management are still challenging [1, 7, 9, 10].

Language is a key communicator for this task [2, 11]. Similar descriptions might describe similar characteristics of different experiences of chronic pain. Allowing these descriptions to be characterized by their semantic concepts allows us to quantify the relations between different experiences in an abstract semantic space. Also, it may be possible to characterize specific types of chronic pain by their associated semantic concepts. Thus, understanding the language of chronic pain and how it is used for communicating specific types of experiences allows us to build a linguistic model of chronic pain descriptions.

Social media encompasses a large body of informal language use, which has been increasingly more used for linguistics and NLP research. Previous works have focused on extracting mental health features from social media texts [12, 13], showing that informal language can be used to accurately classify social media users as having or not mental health problems.

However, the work presented here is more concerned with text characterization and modelling rather than prediction. The vocabulary space of the corpus is often used as one such (baseline) characterization. Scores such as Bag-of-Words (BoW) or Term Frequency / Inverse Document Frequency (TFIDF) characterize documents by their most important words, respectively, overall, and relative word frequency. The task of topic modelling focuses on extracting implicit (latent) information in a given document from a corpus, explicitly representing it with that information. Additionally, topics can be characterized by themselves when they are attributed with “meaning”, given the context of the problem. These models, such as LDA [14] and NMF [15], take the vocabulary-based representation of the collection (e.g., BoW and TFIDF), and extract topics following probabilistic or matrix factorization approaches, respectively. A topic is a distribution of weights over the vocabulary terms, where the weight indicates the level of relevance that word has in the topic, in such a way that the top relevant words of a topic are syntactically and/or semantically related, given the corpus. By itself, this task provides a new perspective on the documents and the corpus, allowing for new measures of similarity, composition, and aggregation. However, it can also be used to enhance other downstream tasks dependent on document representation, such as document classification, indexing, and clustering.

Methods

The RRCP Dataset

Reddit is a social media platform structured in sub-forums (subreddits), each focused on a given topic. Each subreddit is self-moderated according to its specific rules and topic(s) of discussion, providing an important characteristic for data analysis: discussions are guaranteed to be topic centered. Moreover, considering only public subreddits, any Reddit user can participate in accordance with their rules, and, because Reddit has a large user-base, this results in large amounts of anonymous public data. Finally, Reddit is implicitly anonymous, i.e., users can choose not to disclose their identity without limitations to the usage of the platform, which eliminates an important barrier of public forums, especially when discussing personal aspects of experiencing chronic pain and other pathologies. For these reasons, various previous works have based their exploration on Reddit-based datasets, such as RSDD [12] and SMHD [13], which are both focused on mental health and depression analysis from user-generated text.

For this work, we collected the RRCP dataset, using the Reddit API, with PRAW1 and PSAW2. The objective was to have a large dataset of textual documents relating to descriptions or discussions of what it is like to experience chronic pain from various backgrounds. This dataset is composed of 136,573 Reddit submissions with a body of text, from 12 subreddits, from 2013 to 2020 inclusive. The subreddits and the total number of submissions per subreddit are shown in Tab.1, which also shows the summary of the RRCP dataset regarding the number of submissions and tokens per subreddit. The theme unifying all these subreddits is the experience of chronic pain, i.e., each subreddit is directly related to the topic of chronic pain or is otherwise related to a pathology which patients are known to experience chronic pain as a manifestation of that base pathology. These subreddits were manually selected from a sample of related subreddits. A sample of the data extracted for each submission is shown in Tab.2.

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1 https://github.com/praw-dev/praw
2 https://github.com/dmarx/psaw
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**Tab. 1** Summary of the RRCP dataset regarding textual data, per subreddit. Standard deviation is shown in parentheses

| Subreddit       | Mean posts per year | Total number of posts | Mean tokens per post | Total tokens | Number of users (thousands) |
|-----------------|---------------------|-----------------------|----------------------|--------------|-----------------------------|
| CrohnsDisease   | 3,864.4 (2,107.5)   | 30,915                | 140.1 (162.4)        | 4,332,620    | 35                          |
| migraine        | 3,350.0 (3,051.1)   | 26,800                | 144.9 (147.6)        | 3,882,725    | 73.9                        |
| ChronicPain     | 2,952.0 (1,989.7)   | 23,616                | 200.5 (226.1)        | 4,735,584    | 54.1                        |
| fibromyalgia    | 2,345.1 (2,056.2)   | 18,761                | 153.5 (171.7)        | 2,880,040    | 34.1                        |
| Lupus           | 883.8 (943.8)       | 7,070                 | 151.3 (154.9)        | 1,069,745    | 12                          |
| Interstitialcystitis | 693.9 (833.3)   | 5,551                 | 166.1 (199.9)        | 922,101      | 9.2                         |
| Rheumatoid      | 686.6 (550.7)       | 5,493                 | 148.5 (143.0)        | 815,778      | 12.5                        |
| backpain        | 538.6 (706.2)       | 4,309                 | 167.3 (175.4)        | 720,688      | 15.6                        |
| ankylosingspondylitis | 516.0 (626.3) | 4,128                 | 158.8 (176.5)        | 655,608      | 8.4                         |
| Sciatica        | 508.1 (664.5)       | 4,065                 | 198.4 (231.8)        | 806,668      | 10.1                        |
| ChronicIllness  | 484.3 (694.3)       | 3,390                 | 214.7 (243.3)        | 727,963      | 25.5                        |
| Throse          | 309.4 (206.8)       | 2,475                 | 158.9 (156.2)        | 393,255      | 7.8                         |

**Tab. 2** Example of a submission in the RRCP dataset. Some parts were hidden to maintain the anonymity of its author

| title                  | (... looking for any help to manage pain (...)                  |
|------------------------|------------------------------------------------------------------|
| ID                     | redacted                                                         |
| URL                    | redacted                                                         |
| score                  | 3                                                                |
| num comments           | 4                                                                |
| created utc            | redacted                                                         |
| subreddit              | redacted                                                         |
| year                   | 2014                                                             |
| body                   | (... My right side of my face hurts so severely that all I want to do is get a knife and cut off that side of my face. I find myself daydreaming about how fantastic it would feel to just blow that part of my head off during my most painful attacks. I now have no doubt as to why they call it the suicide disease. I know very little about this condition so any advice would be super appreciated. (…) |
| title length           | redacted                                                         |
| body length            | redacted                                                         |

Appendix 1 describes in greater detail the construction of the RRCP dataset and provides an analysis of the statistics of the activity of each subreddit as a whole and by year, so that it can be determined if the activity distribution of all subreddits is comparable. It also describes the text preprocessing and a preliminary analysis of the vocabulary in the corpus as a whole and in each subreddit.

**Experiment 1: Baseline Analysis of Subreddit Similarity**

The overall objective is to gain insights about how the various subreddits are related based on what their users describe and discuss regarding their experiences of chronic pain. For that, the corpus is projected onto a latent space as given by the LDA topic model, with $k = 20$ topics. This number was empirically determined, according to previous experiments. This $20$-dimensional topic space defines the semantic space of the experiments described in this document.

In this experiment, each subreddit is characterized by a single point in the semantic space, called the subreddit centroid, allowing for a coarse-grained analysis. The centroid is given by the average of the document vectors of that subreddit. Thus, in this setting, each subreddit is fully characterized by a single vector of length $k$. This means that all subreddit centroids belong to the same space and can be compared. Subreddit similarity is given by some similarity measure between the subreddits' centroids. In this case, the cosine similarity metric is used, as defined in Eq. 1.

$$
sim(c_i, c_j) = \frac{c_i \cdot c_j}{||c_i|| \times ||c_j||}
$$

Eq. 1 Cosine similarity between two vectors of the same length.

**Experiment 2: Subreddit Semantic Span Similarities**

This second experiment more intricately characterizes subreddits and measures their similarities, in the same $k$-dimensional topic space, allowing for a fine-grained analysis.
There are multiple aspects to experiencing chronic pain, such as bodily pain distribution, variations of intensity, difficulties with the work life, social life, and so on. These examples are somewhat common to chronic pain. However, there may be other concerns, or qualities, which are more specific to certain types of chronic pain experiences. For example, because Crohn's Disease has an important manifestation around the digestive system and its functions, it is conceivable that concerns about diet are a relevant quality to this specific type of experience, which may not be the case for other experiences of chronic pain. Thus, the objectives of this experiment are three-fold: (1) to identify the core concerns, or qualities, of each subreddit, in the semantic space; (2) to determine which qualities are shared among various subreddits and which are specific to only a few; and (3) to attribute meaning to the discovered qualities, so that they can be reasoned about and transferred to the latent pathology.

The core qualities of a subreddit are given by the intrinsic clusters of the document distribution of that subreddit in the semantic space. The clustering algorithm K-Means is used for this. The number of clusters is dependent on the distribution of the documents of each subreddit, and is given according to clustering metrics, specifically, the sum squared distance to the closest centroid (i.e., inertia), Calinski-score [19], and the silhouette score [20]. Thus, a subreddit is characterized by a matrix of cluster centroids of dimensions $c_i \times k$, where $c_i$ is the number of clusters of subreddit $i$. This matrix defines the subreddit's semantic span.

The semantic spans of two subreddits are comparable because they are defined in the same $k$-dimensional space. All subreddit centroids are measured in similarity against all other centroids, as given by the cosine similarity metric in Eq. 1. Projecting these semantic span similarities in a similarity graph, and identifying the (dis)connected components, or sub-graphs, we can identify which parts, or qualities, of the various subreddit semantic spans are shared among all subreddits (cliques), and which are not. Finally, the subset of documents belonging to each sub-graph can be used to attribute meaning to the core qualities of experiencing chronic pain that they represent. As an initial approach, we observe the top-10 words according to their TFIDF score in that subset of documents.

Results

Experiment 1: Baseline Analysis of Subreddit Similarity
The subreddit similarity results are shown in Fig. 1, in the form of a similarity graph, where each node represents one subreddit (centroid), and an edge between two nodes represents them being related (i.e., the cosine similarity is equal to or higher than a threshold empirically determined to identify regions of interest). We observe 7 sub-graphs: 4 disconnected nodes, 2 sub-graphs of 2 nodes each, and a sub-graph of 4 nodes, where only one (rheumatoid) is connected to all other nodes. Although not represented in the figure, the subreddit CrohnsDisease is the least related to any other subreddit.

Experiment 2: Subreddit Semantic Span Similarities
The sequence Fig. 2, 3, and 4 shows the sequential overlap of the semantic spans of 3 subreddits. In Fig. 2 we observe the core qualities of Thrritis. According to the relatedness requirement empirically determined (cosine similarity $\geq 0.7$), these are all unrelated qualities. In Fig. 3 we observe the core qualities of Thrritis and ankylosingpondylitis, overlapped. Clustering metrics determined the number of qualities of both subreddits to be the same (4). As indicated by the graph edges, there is a pairwise relation between all qualities. In Fig. 4 we observe the core qualities of Thrritis,
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ankylosingspondylitis, and fibromyalgia, overlapped. There are 3 more qualities to fibromyalgia than the other two subreddits. Noticeably, according to the graph edges, these three are unrelated to all other qualities considered in the semantic space (i.e., they are disconnected from all other nodes). Fig. 5 shows the similarity graph of the semantic spans of all subreddits. We observe various sub-graphs, both disconnected nodes and cliques, which are of equal importance for our discussion. Finally, Tab. 3 shows the top words, as scored by TFIDF, of select sub-graphs identified in Fig. 5.

Fig. 2 Thritis (green)

Fig. 3 Thritis and ankylosingspondylitis (blue)

Fig. 4 Thritis, ankylosingspondylitis, and fibromyalgia (orange)
Fig. 5 Similarity graph between all subreddit centroids (nodes). Edges between two nodes represent similarities ≥ 0.9, which is a threshold empirically determined from previous experiments. Labeled sub-graphs are further explored in Tab. 3. Nodes are colored by subreddit.

Tab. 3 Top 10 words, as scored by TFIDF, of the subset of documents belonging to each sub-graph, as identified in Fig. 5

| Sub-graph | Subreddits                                                                 | Top-10 TFIDF words                                      |
|-----------|---------------------------------------------------------------------------|--------------------------------------------------------|
| 1         | ChronicPain, Interstitialcystitis, rheumatoid, CronhsDisace, Sciatica, Chronicillness, Thriris, migraine, backpain, lupus, fibromyalgia | work, want, life, people, day, back, need, bad, never, sick |
| 2         | CronhsDisace, Interstitialcystitis                                        | diet, eat, food, foods, eating, good, day, lot, flare, drink |
| 3         | Interstitialcystitis                                                     | bladder, uti, back, urologist, went, first, see, started, pelvic floor, antibiotics |

Discussion

**Experiment 1: Baseline Analysis of Subreddit Similarity**

The 7 sub-graphs shown in Fig. 1 represent the related groups of subreddits, as given by their centroids in the k-dimensional semantic space. These groups are obtained with a very high requisite of similarity (≥ 0.95), which is indicative of their strong relatedness. Attending to Tab. 1 we consider it to be sub-optimal to summarize thousands of documents in a single point (i.e., the subreddit centroid), since this leads to the dilution of meaningful information in the document-topic distribution. Moreover, in determining the similarity between subreddits, there may be specific areas in the semantic space which are very related between two subreddits, and other areas which are very different. This experiment does not capture that information, thus, we consider this approach to subreddit similarity as a baseline. Nonetheless, these results reveal important latent structures in the dataset, which validate the approach of textual analysis to gain insights on the experience of chronic pain. Noticeably, the sub-graphs correlate with clinical research regarding how each of the represented pathologies manifest themselves: Sciatica and backpain partially share the same bodily area of pain, the lower-back; the same applies to the group of rheumatoid, ankylosing spondylitis, Thriris, and lupus, due to manifesting in forms of inflammatory arthritis [17]; even though fibromyalgia is not fully understood clinically, it is thought to manifest in general ways, with a multitude of symptoms, which is understood to be related to generic ChronicPain [18]; and the remaining are clearly distinct from the rest, especially in the areas of the body that they manifest themselves.

**Experiment 2: Subreddit Semantic Span Similarities**

Observing Fig. 2, we identify the nodes representing different aspects to what it is like to experience chronic pain as manifested by the latent pathology of arthritis. Because they are all disconnected in the similarity graph, we can conclude that they represent unrelated qualities. Clinical research has found both arthritis and ankylosing spondylitis to manifest in similar ways, especially the focus of pain location on joints and the descriptors used to talk about it, exactly because they are both common forms of inflammatory arthritis [17]. Fig. 3 correlates with these findings. Specifically, the same number
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of qualities was found for each corresponding subreddit, and there is a pairwise relation, which suggests that connected node pairs represent the same, or very related qualities. Thus, these two graphs suggest that experiencing chronic pain from arthritis is very related to experiencing it from ankylosing spondylitis, in each and every captured quality of the experiment. Fig. 4 shows that there are qualities to experiencing chronic pain from fibromyalgia which are related to the other two pathologies. These are connected in triplets. However, it also shows that there are core qualities to this specific type of experience of chronic pain which are nothing like what is experienced from the point of view of arthritis or ankylosing spondylitis. Again, this correlates with clinical research, which suggests that experiencing fibromyalgia encompasses general body ache, physical exhaustion, and cognitive difficulties [18], which are not common for inflammatory arthritis. Importantly, these figures show what Fig. 1 failed to reveal: (1) that there are multiple concerns to a single base pathology, as shown by the various nodes of the same subreddit spread out on the semantic space, (2) that there are shared partial experiences of chronic pain between different pathologies, as shown by the connected nodes, and (3) that there are partial experiences which are exclusive to certain pathologies, as shown by disconnected nodes.

Fig. 5 shows the combined similarity graph of the semantic spans of all pathologies. The high relatedness requisite, empirically determined from previous experiments to identify regions of interest for this setting (cosine similarity ≥ 0.9), suggests that the connected nodes represent the same core quality, which is shared by multiple subreddits (i.e., their latent pathologies). We observe three types of sub-graphs: cliques (e.g., sub-graph 1), disconnected nodes (e.g., sub-graph 3), and anything in-between (e.g., sub-graph 2). The design of this experiment tells us that cliques represent core qualities which are shared between all experiences of chronic pain. Sub-graphs that are not cliques and are not single nodes represent core qualities which are only relevant to a sub-set of experiences of chronic pain, when not all subreddits are represented. Finally, disconnected nodes represent qualities which are exclusive to a specific type of experience of chronic pain, as dictated by the underlying pathology. Tab. 3 shows the top words of the thousands of documents belonging to each sub-graph identified in Fig. 5, i.e., sub-graphs 1, 2, and 3, so that these hypotheses may be put to the test. Even though considering only the top TFIDF scoring words of these sub-graphs is an initial, limited approach to attribute meaning to the concepts being discussed by thousands of documents, it is already possible to discern clinically relevant semantics. Noticeably, as expected, sub-graph 1 appears to be concerned with qualities which are common to any experience of chronic pain, namely, work life, feeling sick (or being sick of), and others. All subreddits share these aspects. Sub-graph 2, only shared between two subreddits, CrohnsDisease and Interstitialcystitis, is concerned with food, drink, and flare ups. Reminiscent of the hypothesis raised in a previous section, it is reasonable that out of the considered subreddits, only these two are concerned with these aspects, exactly because the resulting experiences of chronic pain of their latent pathologies are highly correlated with nutrition quality [21, 22]. Because these aspects are not the most relevant in common experiences of chronic pain, it was unexpected to see these concepts shared by all subreddits. Finally, sub-graph 3, which is a disconnected node, represents core qualities which are exclusively relevant to one subreddit, Interstitialcystitis. Due to the nature of the experience, this observation was expected, i.e., it is not reasonable to expect concepts such as bladder pain and urinary tract infection to be relevant to a common experience of chronic pain.

Conclusions

In this work we presented the RRCP dataset, which comprises 136,573 Reddit submissions, from 12 subreddits either related to chronic pain directly, or to a pathology which is known to be accompanied by chronic pain. We presented two experiments that attempted to reveal the underlying structure and concepts being discussed in the corpus, in order to model descriptions and discussions of chronic pain on social media, and possibly obtain insights about this subjective experience. Both experiments correlate with clinical knowledge. However, the second more intricately reveals exactly which concepts are being discussed, and which subreddits are concerned with which concepts. Our approach captured common concepts, such as work life, to be shared by all subreddits, and other concepts, such as diet and urinary infections, to be exclusive to specific subreddits. Since the considered subreddits are topic-moderated, these findings can be transferred to the corresponding pathology without loss of relevance. This work lays the ground for future research by making the RRCP dataset available and validating the semantic analysis with clinical research.

As future work, we point to more intricate approaches to the semantic modelling of the corpus, namely probability-based clustering methods. Not only do these allow for soft definitions of clusters, instead of hard boundaries as given by the presented work, but also provide descriptions of the data process generators, by interpreting the corresponding distribution parameters, and inserting them into the similarity judgements. Notably, similar interpretations could be made with the presented approach, however these would have to be inferred from Euclidean metrics. Additionally, the identified sub-graphs were given meaning by the top-10 words of their corresponding documents, which is a baseline approach. Others should be considered, such as multi-document summarization. Moreover, even though the semantic space was defined as the latent topic space, other spaces should be taken into consideration, namely those of pre-trained word-embeddings.

Finally, the exploration of the presented dataset and the experience of chronic pain as reported on social media is not limited to the semantic modelling approach presented in this work. Possibly interesting tasks include symptom extraction from user-generated text, recognition of pain descriptors (for the qualification of pain), and intensity estimation based on keywords (for the quantification of pain). Discarding the possibility of annotating thousands of entries for each of these tasks, all of these must be based on unsupervised methods, which is an interesting challenge.
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Declarations

Conflict of interest
The authors have no relevant financial or non-financial interests to disclose.

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Informed consent
This work includes a novel dataset, comprising public textual social media (Reddit) posts of descriptions and discussions of various forms of chronic pain experiences. Every single entry included in this dataset belongs to the public domain and was collected by means of the public Reddit API.

Data availability
We plan on making the RRCP dataset publicly available upon the acceptance of the paper.

Abbreviations
BoW: Bag of words  
LDA: Latent Dirichlet allocation  
MPQ: McGill pain questionnaire  
NLP: Natural language processing  
NMF: Non-negative matrix factorization  
RRCP: Reddit reports of chronic pain  
RSDD: Reddit self-reported depression diagnosis  
SMHD: Self-reported mental health diagnoses  
TFIDF: Term frequency / inverse document frequency

References
[1] Fink, R. (2000). Pain assessment: the cornerstone to optimal pain management. Baylor University Medical Center Proceedings, 13(3), 236-239. https://doi.org/10.1080/08982820.2000.11927681
[2] Wilson, D., Williams, M., Butler, D. (2009). Language and the pain experience. Physiotherapy Research International, 14(1), 56–65. https://doi.org/10.1002/peri.424
[3] Halliday, M. (1998). On the grammar of pain. Functions of Language, 5(1), 1–32. https://doi.org/10.1075/fol.5.1.02hal
[4] Lascaratou, C. (2007). The language of pain: expression or description? John Benjamins. ISBN: 9789027292056
[5] Katz, J., Melzack, R. (1999). Measurement of pain. Surgical Clinics of North America, 79(2), 231–252. https://doi.org/10.1016/S0039-6109(05)70381-9
[6] Sullivan, M. D. (1995). Pain in language: from sentience to sapience. Pain Forum, 4(1), 3-14. https://doi.org/10.1016/S1082-3174(95)80068-1
[7] Loeser, J. D., Melzack, R. (1999). Pain: an overview. The Lancet, 353(9164), 1607-1609. https://doi.org/10.1016/S0140-6736(99)10311-2
[8] Dansie, E., Turk, D. C. (2013). Assessment of patients with chronic pain. British Journal of Anaesthesia, 111(1), 19–25. https://doi.org/10.1093/bja/aet124
[9] Breivik, H., Borchgrevink, P., Allen, S., Rosseland, L., Romundstad, L., Breivik Hals, E., Kvarstein, G., Stubhaug, A. (2008). Assessment of pain. British Journal of Anaesthesia, 101(1), 17–24. https://doi.org/10.1093/bja/aen103
[10] Azevedo, L. F., Costa-Pereira, A., Mendonça, L., Dias, C. C., Castro-Lopes, J. M. (2012). Epidemiology of chronic pain: a population-based nationwide study on its prevalence, characteristics and associated disability in Portugal. The Journal of Pain, 13(8), 773–783. https://doi.org/10.1016/j.jpain.2012.05.012
[11] Melzack, R., Torgerson, W. (1971). On the language of pain. Anesthesiology, 34(1), 50-59. https://doi.org/10.1097/00000542-197101000-00017
[12] Yates, A., Cohan, A., Goharian, N. (2017). Depression and self-harm risk assessment in online forums. Proceedings of the 2017 Conference on Empirical Methods in Natural Language Processing, 2968–2978. https://doi.org/10.18653/v1/D17-1322
[13] Cohan, Arman and Desmet, Bart and Yates, Andrew and Soldaini, Luca and MacAvaney, Sean and Goharian, Nazli (2018). SMHD: a large-scale resource for exploring online language usage for multiple mental health conditions. Proceedings of the 27th International Conference on Computational Linguistics, 1485-1497.
[14] Blei, D., Ng, A. Y., Jordan, M. I. (2003), Latent Dirichlet allocation. Journal of Machine Learning Research, 3(Jan), 993–1022. https://doi.org/10.1162/153244303322655993
[15] Lee, D. D., Seung, H. S. (1999). Learning the parts of objects by non-negative matrix factorization. Nature, 401, 788-791. https://doi.org/10.1038/44565
[16] Rehurek, R., Sojka, P. (2010). Software Framework for Topic Modelling with Large Corpora. ELRA, May, 45-50.
[17] Kaarela, K., Jantti, L., Kotaniemi, K. (2009). Similarity between chronic reactive arthrits and ankylosing spondylitis - a 32-35-year follow-up study. Clinical & Experimental Rheumatology, 27(2), 325. PMID:19473576
[18] Häuser, W., Ablin, J., Fitzcharles, M. A., Littlejohn, G., Luciano, J. V., Usui, C., Walitt, B. (2015). Fibromyalgia. Nature Reviews Disease Primers, 1(1), 1–16. https://doi.org/10.1038/nrdp.2015.22
[19] Calinski, T., Harabasz, J. (1974). A dendrite method for cluster analysis. Communications in Statistics-theory and Methods, 3(1), 1–27.
[20] Rousseuw, P. J. (1987). Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. Journal of Computational and Applied Mathematics, 20, 53–65. https://doi.org/10.1016/0377-0427(87)90125-7
Main Body

[21] Jones, V. A., Workman, E., Freeman, A., Dickinson, R., Wilson, A., Hunter, J. (1985). Crohn’s disease: maintenance of remission by diet. The Lancet, 326(8448), 177–180. https://doi.org/10.1016/s0140-6736(85)91497-7

[22] Friedlander, J. I., Shorter, B., Moldwin, R. M. (2012). Diet and its role in interstitial cystitis/bladder pain syndrome (ic/bps) and comorbid conditions. British Journal of Urology International, 109(11), 1584–1591. https://doi.org/10.1111/j.1464-410X.2011.10860.

Statements and Declarations

Conflict of interest
The authors have no relevant financial or non-financial interests to disclose.

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Informed consent
This work includes a novel dataset, comprising public textual social media (Reddit) posts of descriptions and discussions of various forms of chronic pain experiences. Every single entry included in this dataset belongs to the public domain and was collected by means of the public Reddit API.

Data availability
We plan on making the RRCP dataset publicly available upon the acceptance of the paper.