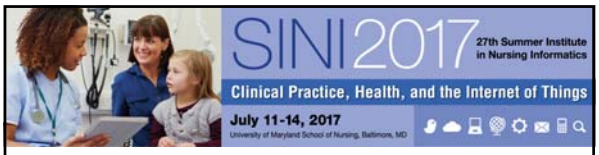

Consumer health, the internet and decision making

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DISCLOSURE

The views and opinions expressed do not necessarily state or reflect those of the U.S. Government, and they may not be used for advertising or product endorsement purposes.

Dina Demner Fushman has no relevant financial relationships with commercial interests

Outline

- Health consumers' online behavior
  - Sharing information
  - Seeking health-related information
  - Asking questions
- Online decision support resources
- Automated decision support
  - Proactively providing tailored actionable information
  - Question Answering

Sharing personal health information

The social life of health information

Among internet users in each group, the % who have interacted with their health online in the following ways

In the past 12 months, have you...	No chronic conditions (a)	1 chronic condition (b)	2+ chronic conditions (c)
Signed up to receive email updates or alerts about health or medical issues?	8	15[a]	14[a]
Read or watched someone else's commentary or experience about health or medical issues online?	25	29[a]	21
Gone online to find others who might have health concerns similar to yours?	15	19[a]	13
Downloaded forms online or applied for health insurance online, including private insurance, Medicare, or Medicaid?	11	12	13
Posted a health-related question online or shared your own personal health experience online in any way?	6	9	11[a]
Used the internet to do any of these	40	45	39

Source: Pew Internet Health Tracking Survey, August 07 – September 06, 2012. N=3,014 adults ages 18+. Interviews were conducted in English and Spanish and on landline and cell phones. Margin of error is +/- 3 percentage points for results based on all internet users.
Note(s): Rows marked with a superscript letter ('a') indicate a statistically significant difference between that column and the column designated by that superscript letter. Statistical significance is determined inside the specific section covering each row and column grouping in that row.

http://www.pewinternet.org/2013/11/26/part-two-sources-of-health-information/

Types of health information shared

- Drug adverse events discussed in the same post as a drug
  - on Twitter, 6,441,679 events (702 unique) were discussed between October 2012 and October 2014; in Facebook, 15,650,108 (946 unique) events were discussed.
- Foodborne illness
  - Yelp reports identify restaurants at high risk for health code violation
- Quality of care
  - Hospitals with lower rates of 30-day hospital-wide unplanned readmissions have higher ratings on Facebook than hospitals with higher readmission rates.

Powell et al. Social Media Listening for Routine Post-Marketing Safety Surveillance. Drug Saf. 2016 May;39(5):443-54.

Schomberg et al. Supplementing Public Health Inspection via Social Media. PLoS One. 2016 Mar 29;11(3):e0152117.

Glover et al. Hospital Evaluations by Social Media: A Comparative Analysis of Facebook Ratings among Performance Outliers. J Gen Intern Med. 2015 Oct;30(10):1440-6.

Seeking health information online

- Idealized consumer health information seeking model:
  - an informed decision maker weighing conflicting choices in consultation with a doctor (Spink et al., 2004);
- Reality:
  - Many patients do not want to be presented with choices or conflicting information (Rimal, 2001)
  - the pragmatic limits of an eight minute consultation in the U.S. health care systems make the model unattainable (Henwood, Wyatt, Hart, & Smith, 2003).
- Most information seekers are inadequately trained and as likely to come to erroneous conclusions as to correct ones (Johnson & Case, 2012).

Johnson JD. Health-related information seeking: Is it worth it?, Information Processing & Management, Volume 50, Issue 5, 2014, Pages 708-717

Seeking health information online is ubiquitous and could be dangerous

- 35% of U.S. adults have gone online to figure out a medical condition; of these, half followed up with a visit to a medical professional
- 72% of the internet users looked online for health information, of these, 77% began at a search engine such as Google and 13% began at a site that specializes in health information.

Fox S, Duggan M. Pew Research Center's Internet & American Life Project http://www.pewinternet.org/files/old-media/Files/Reports/PIP_HealthOnline.pdf

- Biases in search engines can:
  - interact with biases in searchers decision making;
  - increase searchers anxiety;
  - lead to incorrect answers around half of the time;
  - increase the demand for medical services (White & Horvitz, 2014).

Johnson JD. Health-related information seeking: Is it worth it?, Information Processing & Management, Volume 50, Issue 5, 2014, Pages 708-717

Asking health-related questions

- At community website where questions are posed and answered by consumers
  - Yahoo! Answers, WebMD Community
- Curated website where consumers submit questions to be answered by a health professional, free or for a fee
  - DoctorSpring, First Opinion
- Writing to NIH
  - Genetic and Rare Diseases Information Center, NLM customer services

Questions sent to NLM

- Information about a "known disease"
  - crossed eye or Strabismus
  - Hi. i am woundering about this illness if it is possible to geneteticly inheritate in second degree from a grandmum or grandfather to possible a grandchild. on other words (im getting married from a girl that both her mom and uncle are crossed eyes while she is not. What is the possibility for our future kids to have this illness. Can somebody get tested the genes before? if yes where around in San Francisco CA? how long does it take to get the resultats? Please answer in easy words no medical terms and looking forward to hearing from y soon.
- Diagnosis for given symptoms
  - I am growing what looks like a pimple in my mouth what does this mean?
- Information about procedures & medications
  - SUBJECT: colonoscopy. MESSAGE: how often needed?
  - My B12 level is greater than 1500... is it too high? too low? what is it supposed to be?

GOOD-QUALITY ANSWERS TO CONSUMER HEALTH QUESTIONS

Are answers available in NIH consumer-health resources?

- Research Question:
  - Can we retrieve answers to consumer health questions using the main points extracted from the question?
  - What are the best sources for question answers?
  - Do we send customers to the same page they were already on?
- Approach: Create a corpus of 300 manually annotated consumer health questions with manually retrieved answers using a structured search protocol

Structuring consumer-health questions

- Need to fix my cross eyed
- Evidence Based Medicine-like structure:
  - What is the question about (focus)?
    - cross eyed
  - What intervention is of interest (question type)?
    - Fix → treatment
- Focus and type provided for 300 questions

Search Protocol

Stage	Search Location	Search String
1.	MedlinePlus	Question focus
2.	MedlinePlus	Focus and Type
3.	MedlinePlus	Any terms from the subject or question
4.	MedlinePlus	Any terms
5.	Google	Any terms

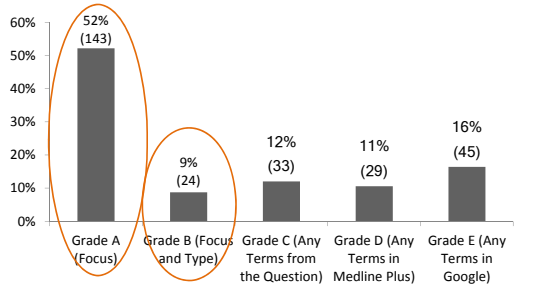
For each stage, look at top five results only, then move to next stage if answer not found.

Answer Grades

Grade	Result	Notes
1	In MedlinePlus	Included on a MedlinePlus topic page or an A.D.A.M. encyclopedia page.
2	One link away	The answer was retrieved on a source linked from MedlinePlus
3	Authoritative, not linked	The answer was found in an authoritative source that was not found via MedlinePlus
4	Not Authoritative	The answer was located but the site is not authoritative.
5	No Information	No information, whether authoritative or not, could be located online

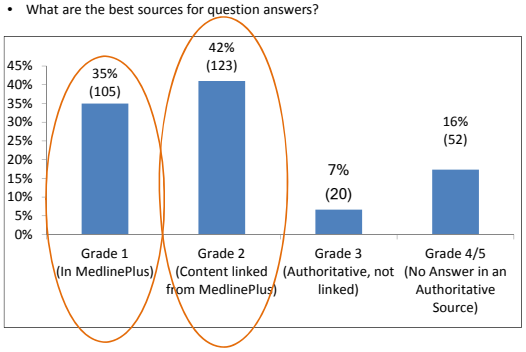
Search Results

- Can we retrieve answers to consumer health questions using the focus and the type?



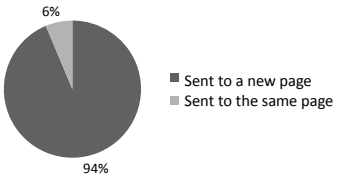
Answer Locations

- What are the best sources for question answers?



Comparing Locations

- Do we send customers to the same page they were already on?



Easy vs. Difficult to Answer Questions

- Requests for general information are easier to answer in MedlinePlus
- Specific questions about associations and relations are generally harder to answer in MedlinePlus
  - Are ear lobe creases always heart disease and 100% heart attack pending? What are other causes?

Authoritative Vs. Non Authoritative Answers

- Questions about treatments and susceptibility are more likely to result in authoritative answers
- Questions about finding support organizations and interest groups are more likely to result in non-authoritative answers.

AUTOMATED DECISION SUPPORT

Preventive interventions through social media

- An overview of multi-way communications and group discussions on Twitter, blogs, Facebook, etc.
  - Cancer support
  - Suicide prevention
  - Weight management
  - Cardiovascular disease
- Conclusion: effects of social media interventions are mixed or even small. There is insufficient evidence of the design and implementation

Welch et al. Interactive social media interventions to promote health equity: an overview of reviews. Health Promot Chronic Dis Prev Can. 2016 Apr;36(4):63-75.

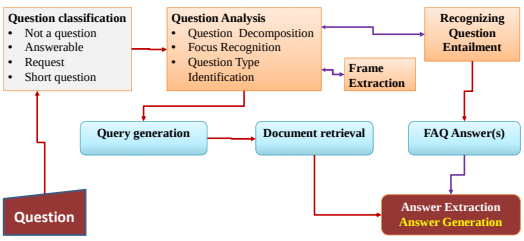
Consumer Health Question Answering

- A prototype system is under in-house evaluation
- Annotated over 1700 short questions submitted to MedlinePlus for training and evaluation of the system
- Organizing a medical subtask for Consumer Health Question Answering at the Text Retrieval Conference (TREC) LiveQA 2017 Challenge

https://sites.google.com/site/trecliveqa2017/

- Ben Abacha A, Demner-Fushman D. Recognizing Question Entailment for Medical Question Answering. AMIA 2016
- Roberts K, Rodriguez LM, Shooshan SE, Demner-Fushman D. Resource Classification for Medical Questions. AMIA 2016
- Mrabet Y, Kilicoglu H, Roberts K, Demner-Fushman D. Combining Open-domain and Biomedical Knowledge for Topic Recognition in Consumer Health Questions. AMIA 2016

Ongoing: CHIQA 0.2 under construction



Three-pronged approach

- Full question frame extraction
  - P = 93% (85%), R=32%(54%), F-1=48% (66% with anaphora resolution)
- Focus and type detection
  - 79% accuracy
- Finding similar questions in FAQs
  - 75% F-1

Kilicoglu H, Fiszman M, Demner-Fushman D. Interpreting Consumer Health Questions: The Role of Anaphora and Ellipsis. Proceedings of BioNLP 2013. Pages 54-62.

Roberts K, Masterton K, Fiszman M, Kilicoglu H, Demner-Fushman D. Annotating question types for consumer health questions. InProceedings of the Fourth LREC Workshop on Building and Evaluating Resources for Health and Biomedical Text Processing 2014 May 31.

Roberts K, Kilicoglu H, Fiszman M, Demner-Fushman D. Automatically classifying question types for consumer health questions.AMIA Annu Symp Proc. 2014 Nov 14;2014:1018-27. eCollection 2014.

Ben Abacha A, Demner-Fushman D. Recognizing Question Entailment for Medical Question Answering. AMIA Annu Symp Proc. 2016 Nov 8;2016

Question understanding: Analysis

- Variety of styles
- Mostly informal language
  - Ungrammatical sentences
  - Inconsistent capitalization & punctuation
  - Abbreviations
  - Misspellings
  - Extraneous information interspersed among questions
  - Abundance of anaphora and ellipses
- Unclear information needs

Challenging NLP–complete problem
Solution: start small, simplify, find regularities

Question analysis: misspellings

- Misspellings can hinder automatic question understanding

My mom is 82 years old suffering from anixity and depression for the last 10 years was dianosed early on set deminita 3 years ago. Do yall have a office in Greensboro NC? Can you recommend someone. she has seretona syndrome and nonething helps her.

- Third-party spelling correction tools are not adequate
  - Jazzy (F_1=0.21)
  - ESpell (F_1=0.25)

Kilicoglu H, Fiszman M, Roberts K, Demner-Fushman D. An Ensemble Method for Spelling Correction in Consumer Health Questions. AMIA Annu Symp Proc. 2015 Nov 5;2015:727-36. eCollection 2015.

Misspelling types and importance

- 472 requests, more than 1,000 errors (25K tokens)
- Misspelling type
  - NON-WORD (*physians* → *physicians*) (43.3%)
  - REAL-WORD (*leave* → *live*) (15.3%)
  - TO-SPLIT (*knowabout* → *know about*) (31.3%)
  - TO-MERGE (*on set* → *onset*) (4.4%)
  - PUNCTUATION (*Ive* → *I've*) (5.7%)
- Misspelling salience
  - IMPORTANT-FOCUS (*seretona* → *serotonin*) (9.5%)
  - IMPORTANT-FRAME (*dianosed* → *diagnosed*) (13.4%)

Consumer Health Spelling Error Dataset
https://ceb.nlm.nih.gov/ridem/infobot_docs/CHQA_SpellCorrection_Dataset.zip

Dictionary-based spelling correction

- Score suggestions based on:
  - Orthographic similarity to the original spelling (SC_{ORTHO})
    - Token similarity
    - Phonetic similarity
    - Leading/trailing character overlap
  - Frequency in consumer health-related corpora (SC_{FREQ})
    - MedlinePlus, GHR, GARD, etc.
  - Contextual similarity using word embeddings (SC_{CXT})
    - Word vectors calculated from corpora using *word2vec* tool
- Linear-weighted ensemble of scores
  - $0.6 * SC_{ORTHO} + 0.25 * SC_{FREQ} + 0.15 * SC_{CXT}$
- Additional constraints for potential real-word error

Frames work well for simple requests

Are there treatments for trisomy 13?
What is the prognosis?
What is life like for those who have this condition?

Frame 1
Question type: Management
Indicated by: treatments
Theme (problem): trisomy 13
Question cue: are there

Frame 2
Question type: Prognosis
Indicated by: prognosis
Theme (problem): trisomy 13
Ellipsis resolution
Question cue: what

Frame 3
Question type: Manifestations
Indicated by: life like
Theme (problem): trisomy 13
Anaphora resolution

What is the question about?
What is the clinical task?

QUESTION FOCUS AND TYPE

Why do we need a backoff strategy?

- Our frame-based question answering system handles:

What is the treatment for antisynthetase syndrome?

- … and the kind of questions we mostly get:

I have been recently diagnosed with antisynthetase syndrome. Could you please provide me with information on antisynthease syndrome? I am also interested in learning about prognosis, treatment, and clinical trials.

Question Analysis: Classification

- Classification dimensions

Needed for question interpretation and answer resource identification

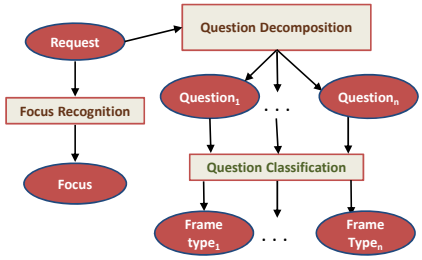
- Who is asking?
  - Clinicians, Patients, Researchers, Administrators, Epidemiologists ….
- Question / answer type
  - Semantic type of an answer / Clinical task, information need based (definition, cause, treatment…)
- Answer resource type
  - Patient-specific (EHR), general knowledge (textbook, MedlinePlus), research (PubMed, PMC)

Roberts K, Rodriguez L, Shooshan SE, Demner-Fushman D. Resource Classification for Medical Questions. AMIA Annu Symp Proc. 2016 Nov 15;2016

Question analysis: question type (clinical task)

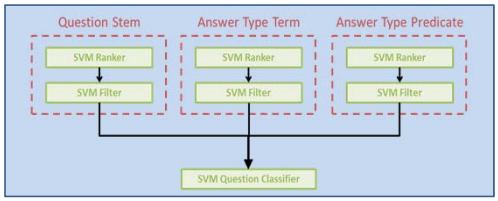
- What health related activity/task pertaining to the question focus is of interest? Defines search strategy. Closely related to answer type.
- First approach: specific to each focus type
  - Handle questions about problems (disorders)
  - Types: Information, Cause, Treatment, Complications, Prognosis…
  - Added questions about drugs and procedures
  - Types: Information, Usage, Indications, Complications, Prognosis...
- Second approach: generic types
  - ACTION, ASSOCIATION, CAUSE, COMPARISON, COMPLICATION, CONTRAINDICATION, COST, DIAGNOSE_ME, DIAGNOSIS, INDICATION, INFORMATION, INGREDIENT, LIFESTYLE_DIET, LOCATION, PERSON_ORGANIZATION, PREVENTION, PROGNOSIS, SUSCEPTIBILITY, SYMPTOM, TIME, TREATMENT, USAGE

Backoff system architecture



Question Type Classification

- Question Stem: "Where can I find a doctor?"
- Answer Type Term: "Which treatment is best?"
- Answer Type Predicate: "How long will she live?"



Focus Recognition

- The focus is the primary **entity** or **event** of interest
- At least one per question, but occasionally multiple when the consumer is interested in the interactions, associations and comparisons

Roberts K, Masterton K, Kilicoglu H, Fiszman M, Demner-Fushman D. Annotating Question Decomposition on Complex Medical Questions. LREC 2014.

- UMLS entities → SVM → boundary adjustment → focus
  - 56% (73% inexact) F_1

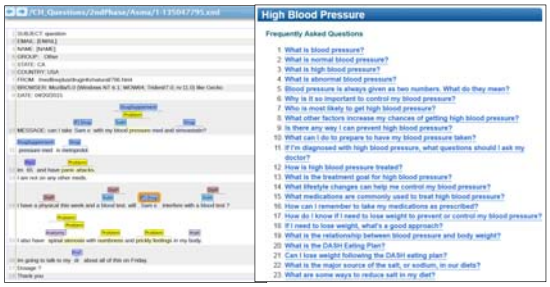
Mrabet Y, Kilicoglu H, Roberts K, Demner-Fushman D. Combining Open-domain and Biomedical Knowledge for Topic Recognition in Consumer Health Questions. AMIA 2016 Annual Symposium, Chicago, IL, November 12-16, 2016.

- KODA → SVM
  - 66% F_1 (P ~ 70%, R ~ 62%)

NIH FAQs come with high-quality answers

FINDING SIMILAR QUESTIONS

How to find similar questions?



From Textual Entailment to Question Entailment

- Textual Entailment is a directional relation between two text snippets called text (T) and hypothesis (H), expressing the fact that the meaning of T is contained in the meaning of H.
- Recognizing Textual Entailment (RTE) from questions

Question A entails Question B if every answer to B is also an exact or partial answer to A

Ben Abacha A, Demner-Fushman D. Recognizing Question Entailment for Medical Question Answering. AMIA 2016 Annual Symposium, Chicago, IL, November 12-16, 2016.

Recognizing Question Entailment (RQE)

RQE: Question A entails Question B if every answer to B is also an exact or partial answer to A.

A1 → B1 (An exact answer)
- **A1 (CHQ):** Hi I have retinitis pigmentosa for 3years. Im suffering from this disease. Please introduce me any way to treat mg eyes such as stem cell ....I am 25 years old and I have only central vision. Please help me. Thank you
- **B1 (FAQ):** Are there treatments for RP?

A2 → B2 (A partial answer)
- **A2 (CHQ):** Can sepsis be prevented? Can someone get this from a hospital?
- **B2 (FAQ):** Who gets sepsis?

Semi-automatic Construction of Test Data

302 question pairs of consumer health questions (CHQs) and NIH FAQs (**43% positive pairs**), constructed using two methods:

1) 300 CHQs and 349 NIH FAQs pairs that have the same focus annotated into positive and negative examples (70 pairs).

2) negative pairs selected at random from FAQs found using CHQ as query.

```
<pair id="66" type="Part1" value="FALSE">
    <t> recovery after stroke?. what is the pattern of recovery after stroke? </t>
    <h> Is there any treatment for Stroke and Atrial Fibrillation? </h>
  </pair>
```

Evaluation of ML algorithms for RQE

Algorithm	Precision	Recall	F-measure
SVM	**75.0**	**75.2**	**75.0**
Logistic Regression	74.7	74.8	74.7
Naive Bayes	73.1	72.5	71.5
J48	70.9	70.2	70.3

RQE for Question Answering (QA)

- **Experiment to study the RQE coverage for CHQA:**
  - Goal: Find FAQs corresponding to **390 CHQs** about **diseases** containing **566 individual questions**
  - Matching: Based on the focus and the question type
  - Resource: **22k NIH FAQs**
- **Results:** Corresponding FAQs are available for:
  - **60%** of individual questions
  - **47%** of consumer health requests

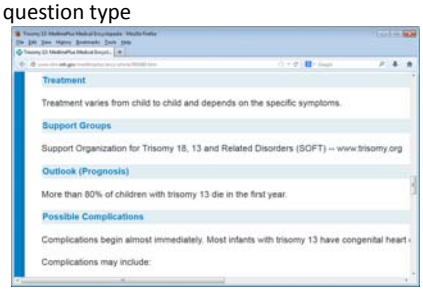
ANSWER EXTRACTION

Answer sources

45

Using structured questions in search queries

- Search for the theme (focus) in titles
  - If found, return an appropriate section for question type



Selecting the best answer

- Rank articles and sections
- From the best sections, select paragraphs containing more answer type indicators
  - trim long paragraphs
- Ranked answers to the trisomy 13 prognosis question:
  - Due to the presence of several life-threatening medical problems, many infants with trisomy 13 die within their first days or weeks of life. Only five percent to 10 percent of children with this condition live past their first year. (GHR)
  - More than 80% of children with trisomy 13 die in the first year. (MedlinePlus)