Generative Lexicon: Integrating Theoretical and Distributional Methods

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July 17-21, 2017
1. Introduction to GL and Distributional Analysis
ESSLLI 2017
University of Toulouse

Course Outline

- July 17: Introduction to GL and Distributional Analysis
- July 18: Qualia Structure
- July 19: Event Structure
- July 20: Argument Structure
- July 21: Meaning Composition and Co-composition

Lecture 1: July 17

Introduction to GL and Distributional Analysis

- Basic concepts in GL
  - Notation and Language: typed feature structures
  - Qualia Structure
  - Events and their participants
  - Meaning Composition in GL
- Distributed meaning: Spreading the semantic load
- Polysemy in language
  - Types of contextual variations
  - Detecting copredications in corpora
- Evidence-based linguistics and distributional analysis

Lecture 2: July 18

Qualia Structure

- What is a Quale?
- What motivates Qualia?
- Default Qualia and context updating
- Methodology to identify Qualia
- Data for each Quale
- Qualia and Conventionalized Attributes

Lab on Qualia identification in corpora using SkE

Lecture 3: July 19

Event Structure

- Events as Structured Objects
- Event Types
  - States
  - Transitions
  - Point Verbs
  - Processes
- Events as Labeled Transition Systems
- Dynamic Event Models

Lab on identification of event type properties in corpora

Lecture 4: July 20

Argument Structure

- Argument Types in GL
  - True Arguments
  - Default Argument
  - Shadow Arguments
  - Hidden Arguments
- Argument Structure Representation
  - Semantic Types and Lexical Sets
  - Distributional Approch to Semantic Types
- Arguments and Defaulting
- Dynamic Argument Structure

Lecture 5: July 21

Meaning Composition and Co-composition in GL

- Basic Assumptions
- Simple Function Application
- Coercion
- Subselection
- Co-composition
- Lexical Information and Pragmatics

Studies in evidence-based coercion

Lecture 1: Introduction to GL and Distributional Analysis

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- Lexical Resources need to facilitate compositional processes.

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- Determination of the medium of the situation or event.

Decomposition Strategies: the early history

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4. Bierwisch (1967), Garvin (1967)
5. Dowty (1972, 1979)

Lehrer's Semantic Field of Factors

<table>
<tr><td colspan="10">cook$_1$</td><td>bake$_1$</td></tr>
<tr><td colspan="11">cook$_2$</td></tr>
<tr><td rowspan="3">steam</td><td colspan="3">boil$_1$</td><td colspan="2">fry</td><td colspan="3">broil</td><td></td><td>roast</td><td>bake$_2$</td></tr>
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Table 2.3: *Lexical field of cooking words*, Lehrer (1974)

Lehrer's Semantic Field of Factors

	Water	Oil or fat	Vapor	Amount of liquid	Kind of source of heat	Cooking action	Special utensil	Special additional purpose	Cooking speed
boil$_1$	+	-	-						
boil$_2$	+	-	-			[Vigorous]			
simmer	+	-	-			[Gentle]			
stew	+	-	-			[Gentle]		[To soften]	[Slow]
poach	+	-	-			[Gentle]		[To preserve shape]	
braise	+	+	-	[Small]			(Pot with lid)		
steam	+	-	+				(Rack, sieve)		
fry	-	+	*				(Frying pan)		
sauté	-	+	*	[Small]					[Fast]
French fry deep fry	-	+	*	[Large]					
broil	-	-	*	*	[Radiant]	*			
grill	-	-	*	*	[Radiant]	*	(Grill, griddle)		
barbecue charcoal	-	-	*	*	[Radiant (Hot coals)]	*			
bake	-	-	*	*	[Conducted]	*	(Oven)		
roast	-	-	*	*	[Radiant or conducted]	*			

Table 2.5: *Lexical field of cooking words, componential analysis*, Lehrer (1974)

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- Decompositional processes are compositional in nature

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Pustejovsky 1995

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- Solution: (a) Distribute the components of meaning; (b) underspecify functional behavior:
  - Enrich the semantics of nouns: e.g., what doors, books, and bottles are for;
  - Encode what one does with an object: e.g., coffee, sandwich, movie;
  - Generalize the meaning of verbs: e.g., frying is a manner of cooking.

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  - $\lambda z.A(z)$
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Integrating GL with Distributional Semantics

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   b. John doesn't agree with the new Obama book. (inherent)
2. a. Mary left after her cigarette. (selection as coercion)
   b. Mary left after her smoking a cigarette. (pure selection)

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c. Complex types: Concepts integrating reference to a logical coherence relation between types from the other two levels.

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   If all you have for composition is function application, then you need to create as many lexical entries for an expression as there are environments it appears in.
2. True Compositionality: Enrich the mechanisms of making larger meanings by taking advantage of all espressions in the phrase; type coercion, qualia exploitation, co-composition.

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ii. *Introduction*: wrapping the argument with the type required by the function.

Notation and Language: typed feature structures

$$\begin{bmatrix} \alpha \\ \text{ARGSTR} = \begin{bmatrix} \text{ARG1} = x \\ \ldots \end{bmatrix} \\ \text{EVENTSTR} = \begin{bmatrix} \text{EVENT1} = e1 \\ \text{EVENT2} = e2 \end{bmatrix} \\ \text{QUALIA} = \begin{bmatrix} \text{CONST} = \textbf{what } x \textbf{ is made of} \\ \text{FORMAL} = \textbf{what } x \textbf{ is} \\ \text{TELIC} = e_2\textbf{: function of } x \\ \text{AGENTIVE} = e_1\textbf{: how } x \textbf{ came into being} \end{bmatrix} \end{bmatrix}$$

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- Evidence-based approach.

Context and lexical meaning

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- The next costumer, the next slide ...

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- This is the standard way dictionaries and **resources** used for NLP tasks (i.e. WordNet for word sense detection etc.) are put together.

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Pustejovsky and Jezek 2012 *Introducing Qualia Stucture*

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Pustejovsky and Jezek 2008, Jezek and Quochi 2010, Pustejovsky et al. 2010 SemEval-2010 Task 7 Argument Selection and Coercion.

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Pustejovsky and Anick 1988 (later "Qualia roles"; data from Pustejovsky and Jezek 2012).

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Cruse 1995's *nouns with facets*, Asher's 2011 *dual aspect nouns*.

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    'Once completed, the translation may be uploaded in a special section of the site'.
    Jezek and Melloni 2011, 27

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Distributional analysis of copredication in Jezek and Vieu 2014, Vieu, Jezek and VanDeCruys 2015.

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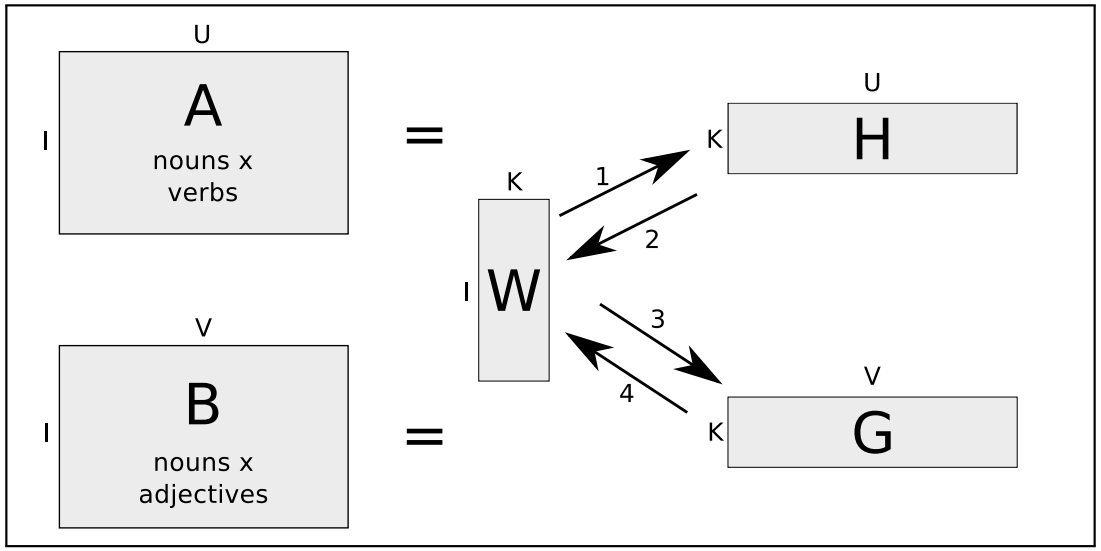
  - NMF: Non-negative matrix **A** is factorized into two other non-negative matrices:

$$A_{i \times j} \approx W_{i \times k} H_{k \times j} \tag{1}$$

where k is much smaller than i, j (Lee, 2001)

Semi-automatic predicate extraction

- Extension of NMF to jointly induce latent factors for 3 modes (N, V, Adj) in the co-predication pattern [V [Det N Adj]] by interleaved factorizations



- Exploits syntactic constraints to obtain semantic similarity, not just topic similarity.

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- Select dimensions and take their first 20 items.
  Yields 4 lists of predicates VPhys, AdjInfo, VInfo, and AdjPhys
  Two alternative methods:
  - Manually review the 15 dimensions most associated with the 10 Info•Phys **seed nouns** to pick between 2 and 5 dimensions for each list (DimsN).
  - Automatically pick the 5 dimensions most associated with 10 **seed predicates** (manually chosen) for each list (DimspP).

Verbs	Adjectives	Nouns
narrare (narrate)	*antico* (ancient)	*leggenda* (legend)
raccontare (tell)	*greco* (Greek)	*favola* (fable)
imparare (learn)	*volgare* (vulgar)	*fiaba* (fable)
conoscere (know)	*latino* (Latin)	*storia* (story)
inventare (invent)	*crudele* (cruel)	*latino* (Latin)
evocare (evoke)	*medievale* (medieval)	*greco* (Greek)
apprendere (learn)	*saggio* (wise)	*dialetto* (dialect)
credere (believe)	*triste* (sad)	*mito* (myth)
sognare (dream)	*medioevale* (medieval)	*antico* (ancient)
insegnare (teach)	*romantico* (romantic)	*mestiere* (profession)
recitare (recite)	*napoletano* (Neapolitan)	*eroe* (hero)
sapere (know)	*italico* (Italic)	*poesia* (poetry)
tradurre (translate)	*eroico* (heroic)	*lingua* (tongue)
parlare (talk)	*nobile* (noble)	*poeta* (poet)
amare (love)	*parlato* (spoken)	*danza* (dance)
ispirare (inspire)	*indiano* (Indian)	*arabo* (Arab)
dipingere (paint)	*popolare* (popular)	*comico* (comic)
adorare (adore)	*orientale* (eastern)	*accento* (accent)
diventare (become)	*moderno* (modern)	*spagnolo* (Spaniard)
vivere (live)	*cinese* (Chinese)	*dramma* (drama)

A dimension picked for both VInfo and AdjInfo

Verbs	Adjectives	Nouns
compilare (compile)	*cartaceo* (of paper)	*fotocopia* (photocopy)
allegare (attach)	*elettronico* (electronic)	*copia* (copy)
spedire (send)	*allegato* (attached)	*certificato* (certificate)
corredare (equip)	*inviato* (sent)	*documento* (document)
inviare (send)	*apposito* (specific)	*ricevuta* (receipt)
inoltrare (forward)	*modulistico* (of form)	*modulo* (form)
stampare (print)	*leggibile* (readable)	*questionario* (questionnaire)
copiare (copy)	*firmato* (signed)	*autocertificazione* (self-certification)
archiviare (file)	*informatico* (of computer)	*pdf* (pdf)
ricevere (receive)	*digitale* (digital)	*documentazione* (documentation)
modulare (modulate)	*valido* (valid)	*informazione* (information)
certificare (certify)	*scaricabile* (downloadable)	*E-mail* (e-mail)
trasmettere (transmit)	*On-line* (on-line)	*dato* (datum)
consegnare (deliver)	*telematico* (telematic)	*posta* (mail)
depositare (deposit)	*redatto* (written)	*verbale* (report)
reperire (find)	*disponibile* (available)	*originale* (original)
redigere (write)	*lino* (of linen)	*scheda* (card)
sottoscrivere (sign)	*postale* (postal)	*certificazione* (certificate)
pervenire (reach)	*reperibile* (available)	*autenticazione* (authentication)
munire (provide)	*identificativo* (identifying)	*formato* (format)

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Results of predicate extraction

- We started with 10 seed nouns (*articolo* 'article', *diario* 'diary', *documento* 'document', *etichetta* 'label', *fumetto* 'comic', *giornale* 'newspaper', *lettera* 'letter', *libro* 'book', *racconto* 'short novel', *romanzo* 'novel').

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Accounting for Missing Arguments

Fillmore (1985), Rappaport and Levin (1988), Jackendoff (1990), Levin (1993), Pustejovsky (1995), Goldberg (2002)

- John swept the dirt$_{material}$.
- John swept the room$_{region}$.

- The man shoveled the snow$_{material}$.
- The man shoveled the driveway$_{region}$.

- Mary translated the book. (the translation)
- They decorated the Christmas tree. (the decoration)
- Cathie sliced the bread. (slices)

Flexibility of Argument Interpretation 1/2

- That book bored me terribly.
- The movie frightened Mary.
- The newspaper article angered the Senator.

- The boy heard a cat.
- They heard a bang / rumor / rain.

- Mary believes the rumor.
- She never believes the newspaper.
- The student regrets his last homework assignment.

Flexibility of Argument Interpretation 2/2

- Mary began her beer / thesis / dinner / bath.
- John enjoyed his coffee / movie / a cigar.

- John knows that the earth is round.
- Mary knows what time it is.
- Mary knows the time.

- Mary told John where she lives.
- John told me how old he is.

- Mary told John her address.
- John told me his age.
- I just realized the time.

Context-sensitive model of lexical semantics

- **Semantic flexibility** is a property of natural language.
- The meaning of each word is expected to vary from occurrence to occurrence as a function of the interaction with the other words it combines with, and of the situation of utterance.
- **Functional notion** of polysemy.
- Generative Lexicon proposes that context-sensitivity is not confined to words with functional roles (traditionally verbs and adjectives), but extends e.g. to nouns (Pustejovsky's Qualia theory, Lecture 2).
- Generative Lexicon spreads the semantic role to all items in the lexicon.

Evidence-based Language Analysis

- Linguistics is now both a theoretical and experimental discipline.
- The scope of observed data for language study and theorizing is richer and broader than ever.
- Linguistic Corpora and captured media datasets will enable contextualized and embodied interpretation of linguistic utterances.
- This will enable the development of more expressive and broader theories of language and communication.

Methods in Linguistics

- Sapir, Bloomfield, Hockett, Wells (Structural analysis)
  Discovery procedure allows for the emergence of grammatical patterns and constructions in a dataset.
- Chomsky, Bar-Hillel (Transformational Grammars)
  Descriptive procedure allows for the generation of grammatical patterns.
- Chomsky (Generative Grammar 1962- present)
  Explanatory model allows for the generation of best grammatical patterns.

1950-1990 - The Absence of Data

- Chomsky liberated the field of linguistics in the 1950s
- Generation through recursive functions allows one to create your own corpus
- Experiment with new datasets that are not attested in actual "found data"

1990-2017 - The Absence of Theory

- Big Data and statistical modeling have largely dominated the fields of CL and AI, both theoretical and applied.
- Deep Learning seems positioned to obviate theory completely.
- This will not happen: machine learning and deep learning make theoretical assumptions in both the data preparation and feature selection and engineering phase of training.
- Theory is more relevant than ever before.

Corpora for Linguistic Research

- It is quite typical for researchers to use any collection of texts for linguistic analysis. Often proceed opportunistically: whatever data comes in handy is used.
- However, the term corpus usually implies the following characteristics:
  - sampling/representativeness
  - finite size
  - machine-readable form
  - a standard reference
  - (time-bound)

Limitations of Corpora

1. Existence in corpus ≠ grammatical.
   - **Response:** Intuition is necessary, but existence in corpora can point out new assumptions & reduce some biases next slide)
2. Finite corpus cannot capture all possible sentences.
   - **Response:** A corpus can supplement the sentences your brain can generate (& show appropriate context).
3. Grammaticality is not statistical.
   - **Response:** This point is arguable and grammaticality is not everything (cf. language *use*)
4. Corpora are observational, not experimental
   - **Response:** Both are worth investigating: controlled studies and real-world use.

Advantages

Corpus-based & Intuition-based approaches

Being empirical (i.e., using corpora [& experiments]) has advantages over intuition on its own:

- Intuition can be influenced by ideolect or dialect
  - corpus-based approach is free of overt judgments
- Intuition is based on a conscious monitoring of one's production
  - generated sentences may not be typical language use
- Intuition-based examples are difficult to verify

Additionally, corpus-based approaches can show differences that intuition cannot provide

Representativeness

Representativeness: the extent to which a sample includes the full range of variability in a population

- distinguishes corpora from archives
- allows findings to be generalized to a particular variety of language

A corpus is a sample of language use (i.e., from a particular population)

- balance: types of genres
- sampling: how the text is selected

Diachronic dimension

Should corpora be updated regularly?

- And if not, do they become un-representative?

Two general types of corpora:

- **sample corpus**: static corpus
- **monitor corpus**: dynamic corpus which grows

Multiple sample corpora can also provide a view of language change (e.g., Helsinki, LOB corpora)

Lexical Association Measures

- Pointwise Mutual Information:

$$\frac{\text{observed frequency}}{\text{expected frequency}} = PMI(A, B) = log_2 \frac{f_{AB} N}{f_A f_B}$$

- Association Score:

$$\text{AScore}(w_1, R, w_2) = log \frac{||w_1, R, w_2|| \cdot ||*, *, *||}{||w_1, R, *|| \cdot ||*, *, w_2||} \cdot log(||w_1, R, w_2|| + 1)$$

- t test:

$$\frac{\text{observed frequency - expected frequency}}{\sqrt{\text{expected frequency}}}$$

Corpus Analysis Toolkit – SketchEngine

- Corpus creating, loading, handling environment
- Allows extensive querying over the corpus and results of analysis
- Performs statistics and analytics over corpora
- https://www.sketchengine.co.uk/

Corpus Analysis Toolkit – SketchEngine

SketchEngine | English Web 2013 (enTenTen13) | Prof. James Pustejovsk

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read *(verb)*

English Web 2013 (enTenTen13) freq = 9,135,047 (401.91 per million)

modifiers of "read"		
	1,198,223	0.13
aloud +	19,777	9.01
read aloud		
somewhere +	13,428	8.14
I read somewhere that		
carefully +	16,764	8.04
carefully read		
please +	14,495	7.88
please read		
about +	65,599	7.75
read about		
ever +	38,541	7.54
've ever read		
recently +	21,144	7.36
I recently read		
widely +	10,650	7.30
widely read		
first +	18,088	7.26
I first read		
just +	101,055	7.08
just read		
here +	39,368	7.04
read here		
actually +	28,477	6.89
actually read		
below +	7,064	6.85
read below		
never +	29,207	6.35
never read		
then +	28,750	6.35

objects of "read"		
	3,463,987	0.38
book +	341,688	10.82
article +	232,787	10.57
post +	108,274	9.61
blog +	90,960	9.45
review +	85,830	9.36
rest +	65,241	9.02
. Read the rest of this entry		
story +	72,130	8.78
bible +	33,203	8.22
read the Bible		
comment +	39,167	8.19
report +	35,099	7.91
storey +	29,895	7.84
text +	27,936	7.83
page +	30,690	7.70
paper +	26,296	7.67
novel +	23,057	7.67
word +	35,736	7.66
label +	22,937	7.65
letter +	26,827	7.64
newspaper +	21,613	7.61
chapter +	18,873	7.35
magazine +	16,351	7.18
news +	19,248	7.18
email +	17,319	7.09
print +	14,975	7.07
read the fine print		
message +	19,379	7.02

subjects of "read"		
	707,028	0.08
anyone +	24,123	8.30
anyone reading		
continue +	4,469	7.68
... Continue reading the story "		
fun +	5,040	7.44
a fun read		
i +	35,227	7.27
i read		
ive +	3,945	7.26
Ive read		
reader +	4,812	7.09
everyone +	10,555	6.88
statement +	4,007	6.87
statement read .		
sign +	3,428	6.85
sign reads		
min +	2,586	6.85
mins reading time)		
people +	49,234	6.72
people read		
student +	10,469	6.61
students read		
someone +	9,520	6.60
time +	13,379	6.58
time reading		
headline +	2,149	6.55
headline reads		
hour +	3,438	6.52
hours reading		

"read" and/or ...		
	409,895	0.04
write +	68,986	11.34
read and write		
hear +	22,214	10.19
understand +	18,873	9.64
to read and understand		
watch +	11,027	9.27
listen +	10,004	9.13
study +	7,983	8.93
read and study		
see +	11,968	8.73
comment +	5,168	8.54
reading and commenting		
learn +	8,273	8.42
read and learn		
follow +	5,154	8.35
to read and follow		
speak +	5,126	8.22
discuss +	4,704	8.16
read and discuss		
enjoy +	4,837	8.00
read and enjoy		
interpret +	3,391	7.90
to read and interpret		
review +	3,856	7.86
to read and review		
sit +	4,026	7.81
to sit and read		
respond +	3,094	7.72
read and respond to		

prepositional phrases		
	615,601	
"read" about ...	136,992	0.01
"read" in ...	114,644	0.01
"read" through ...	54,402	0.01
"read" on ...	51,404	0.01
"read" from ...	36,399	0.00
"read" by ...	32,859	0.00
"read" for ...	30,399	0.00
"read" to ...	21,754	0.00
"read" at ...	21,572	0.00
"read" of ...	18,864	0.00
"read" with ...	18,105	0.00
"read" as ...	16,589	0.00
"read" like ...	15,533	0.00
"read" between ...	9,952	0.00
"read" over ...	8,752	0.00
"read" into ...	7,976	0.00
"read" during ...	2,639	0.00
"read" before ...	1,986	0.00
"read" so ...	1,355	0.00
"read" than ...	1,301	0.00
"read" without ...	1,232	0.00
"read" after ...	935	0.00
"read" below ...	751	0.00
"read" within ...	713	0.00
"read" until ...	600	0.00

Corpus Analysis Toolkit – SketchEngine

SketchEngine | English Web 2013 (enTenTen13) | Elisabet

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- Search
- Word list
- Word sketch
- Thesaurus
- Sketch diff
- Corpus info
- My jobs
- User guide

- Clustering
- Save

read *(verb)*
English Web 2013 (enTenTen13) freq = 9,135,047 (401.91 per million)

Lemma	Score	Freq
write	0.515	9,209,491
learn	0.467	8,933,221
think	0.455	21,650,907
speak	0.441	4,829,660
talk	0.439	5,399,739
know	0.438	29,229,869
give	0.436	22,289,988
hear	0.434	6,078,870
present	0.429	3,390,837
tell	0.429	11,428,601
say	0.423	39,839,420
understand	0.422	6,215,980
want	0.413	21,635,056
receive	0.410	7,099,321
create	0.410	11,463,028
provide	0.410	16,231,340
see	0.410	29,777,567
need	0.407	21,424,720
like	0.406	8,924,162
make	0.405	51,256,256
show	0.404	10,492,472
mean	0.403	9,118,407
feel	0.403	12,463,798