October 2015

Workshop Network Theory

Leibniz-Institut für Wissensmedien

Analyzing Knowledge Construction

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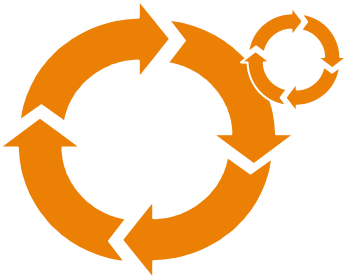
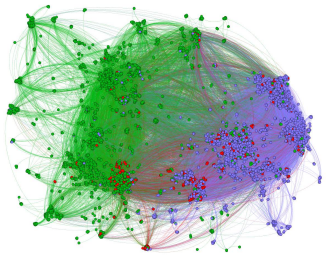
IWM Tuebingen, Germany

Knowledge Construction Lab

OUTLINE

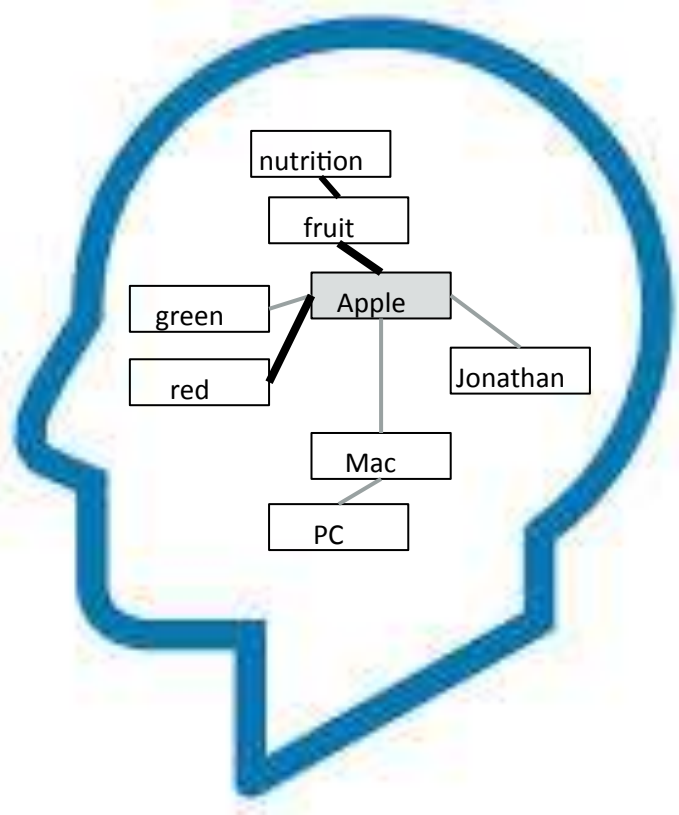
- My theoretical background
- Our co-evolution model about individual learning and collaborative knowledge construction (peer production)
- Typical lab studies
- Studies with Wikipedia log data
- What network theory can provide for the analysis of knowledge construction





MY BACKGROUND

I am a cognitive psychologist



- knowledge as network
- spreading activation
- basis of meaning making

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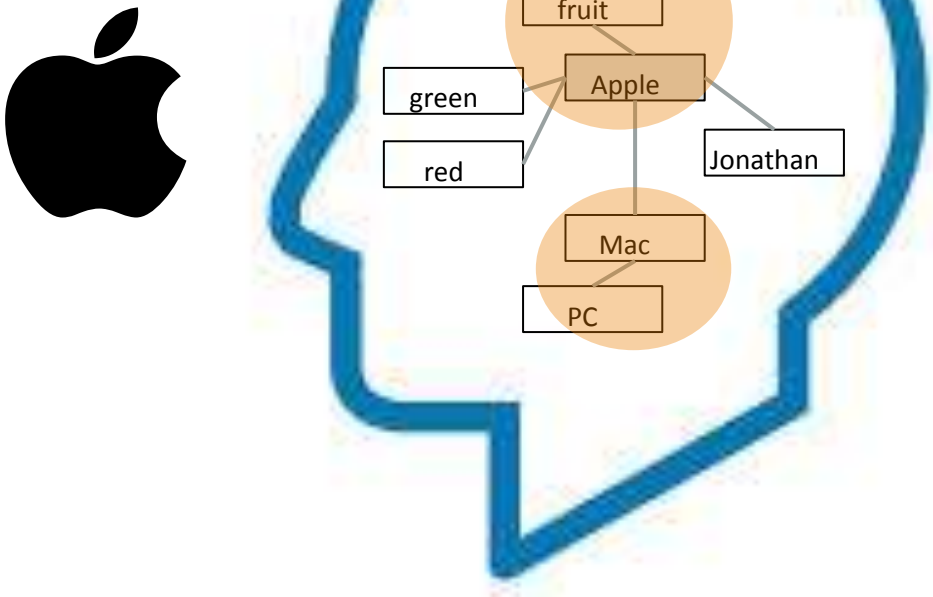

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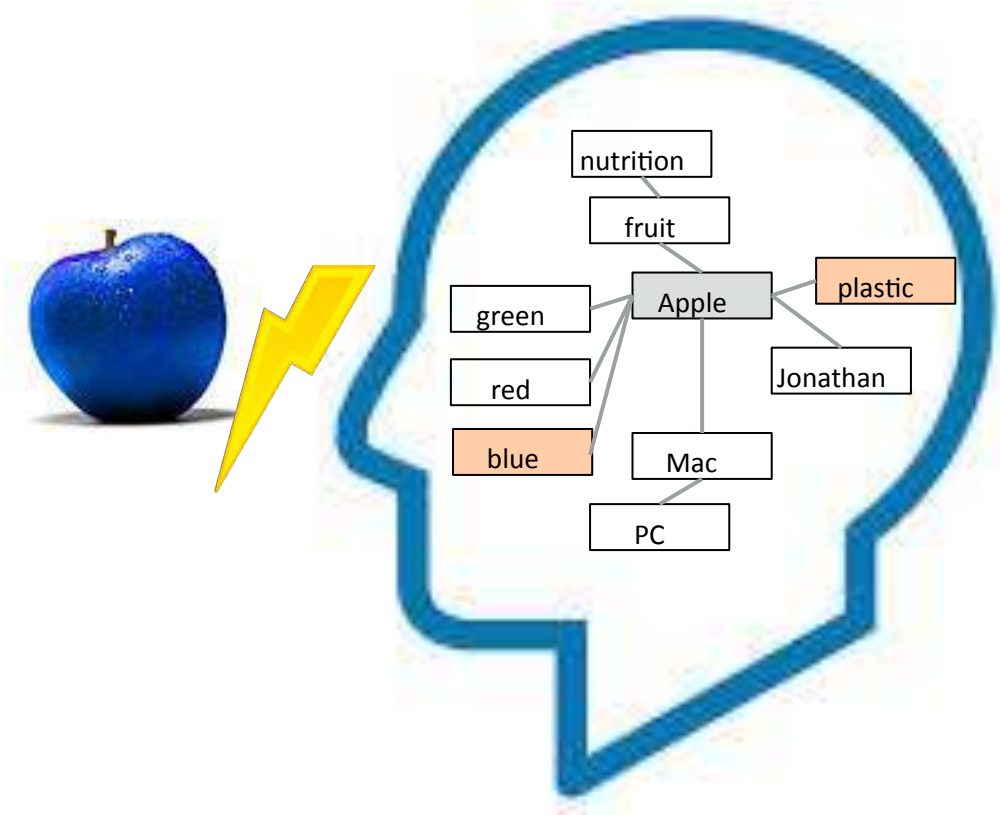
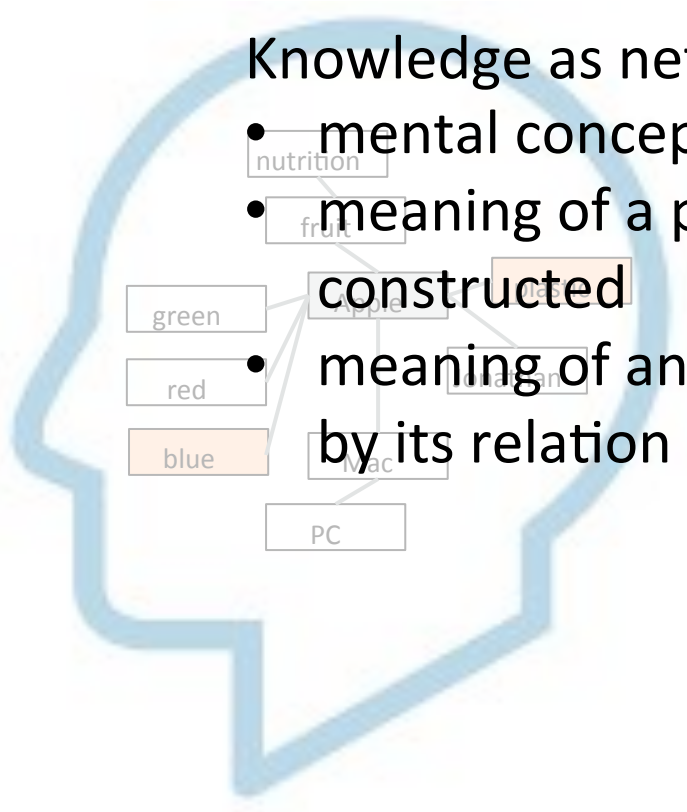


- knowledge as network
- spreading activation
- basis of meaning making
- cognitive conflict: learning through irritation
- learning: new concepts, different link strengths

COGNITION

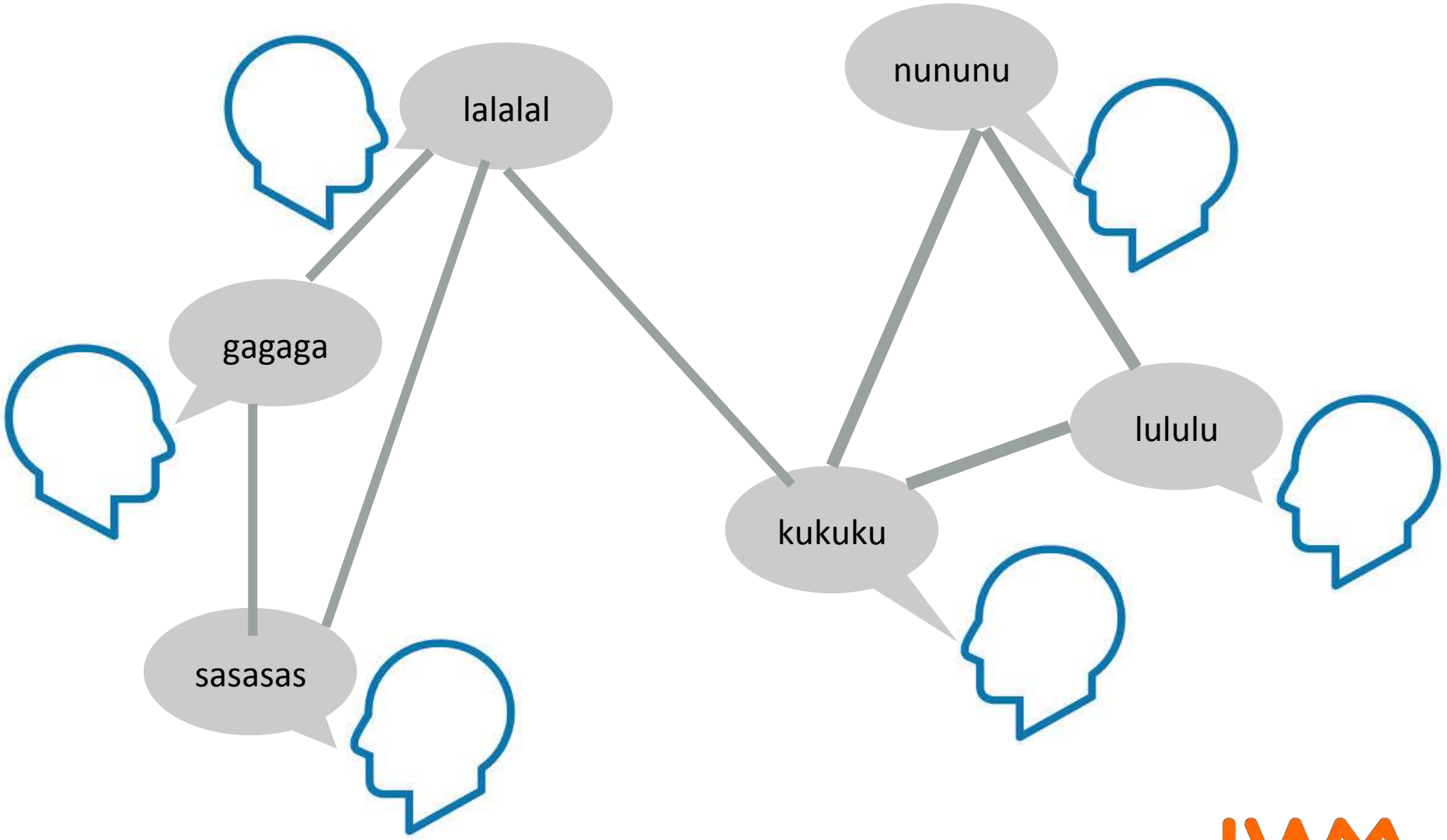
-



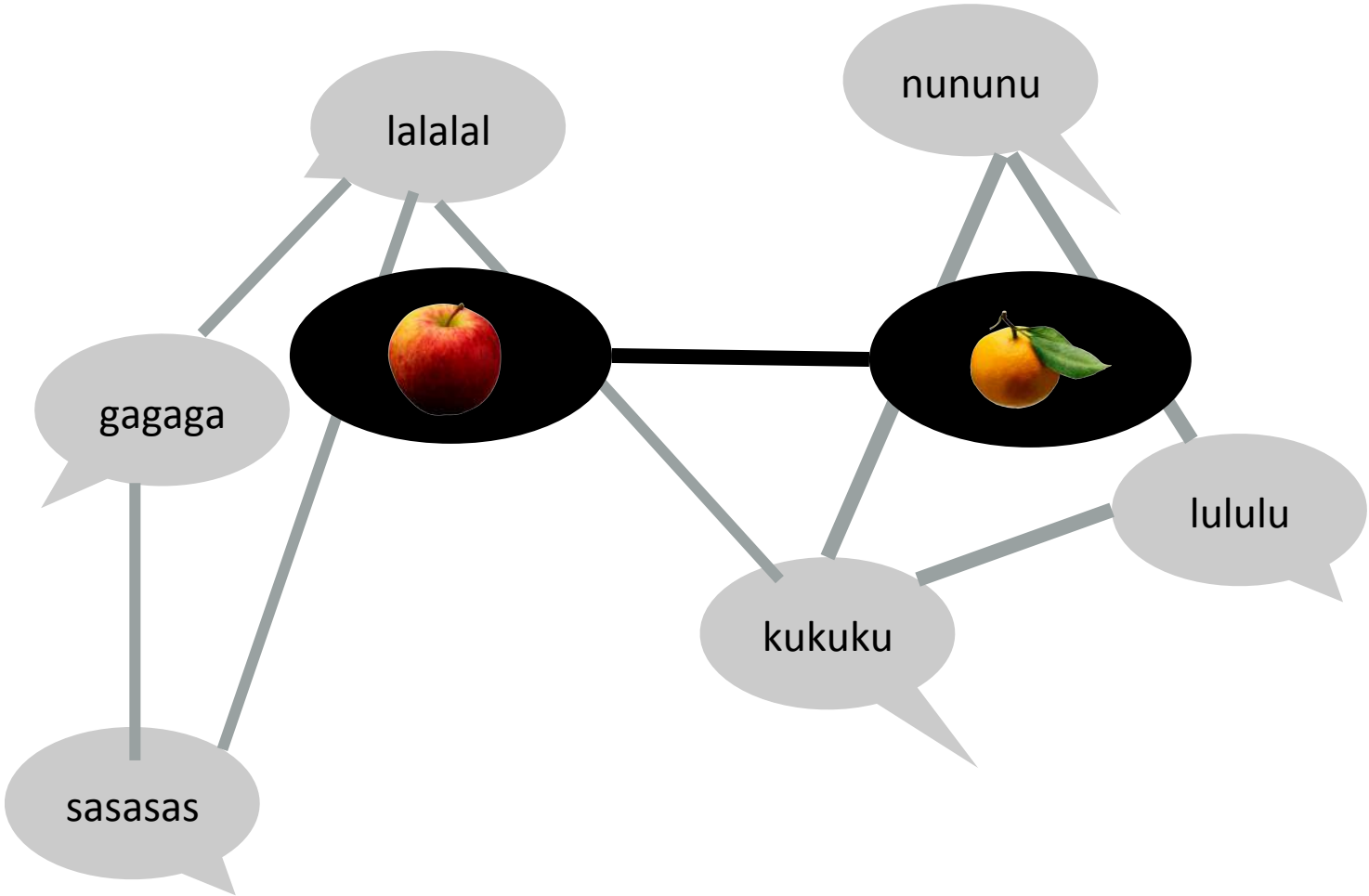
Knowledge as network

- mental concepts
- meaning of a perception is constructed
- meaning of an entity is defined by its relation to other concepts

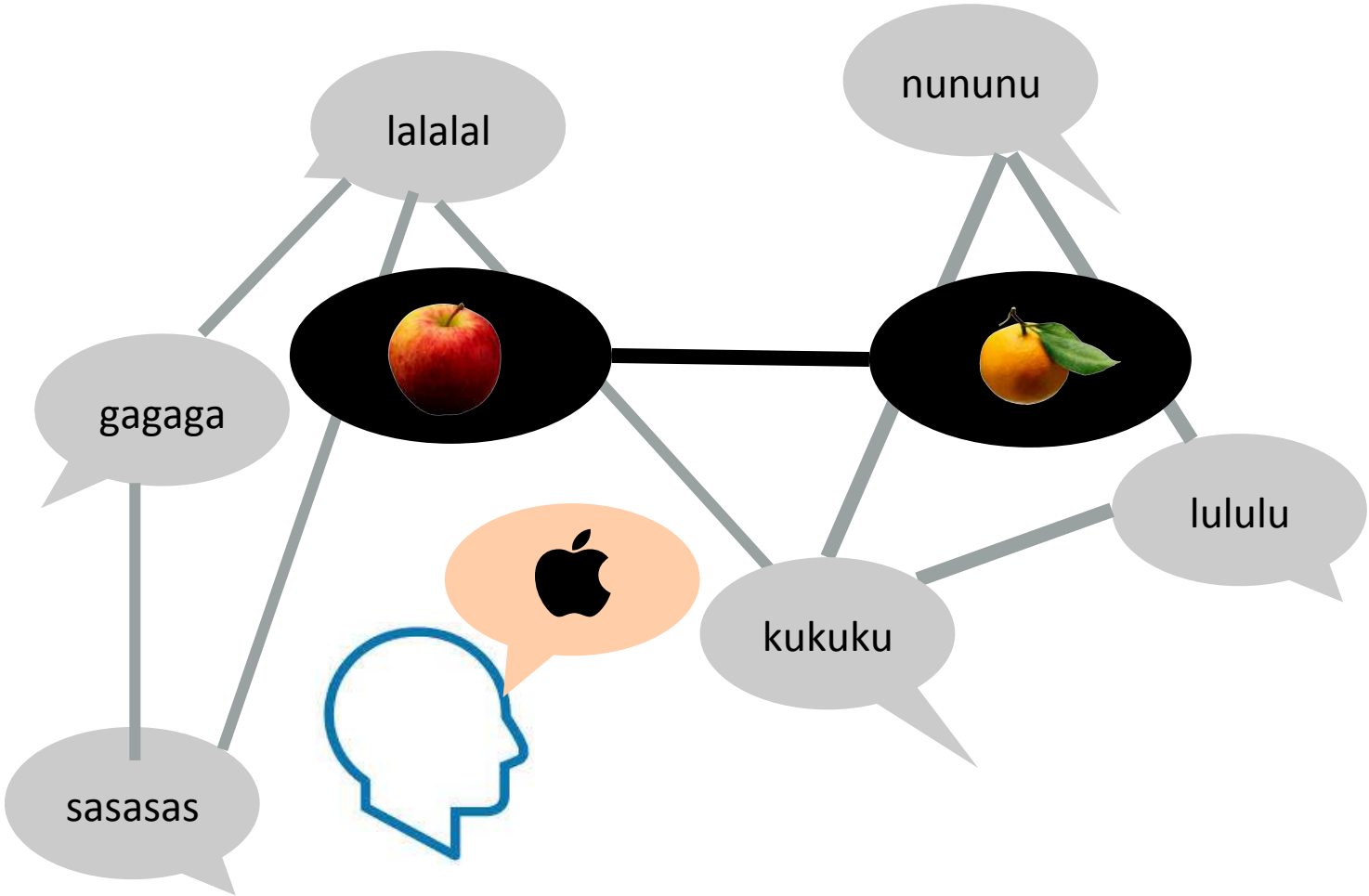
COMMUNICATION



COMMUNICATION



COMMUNICATION



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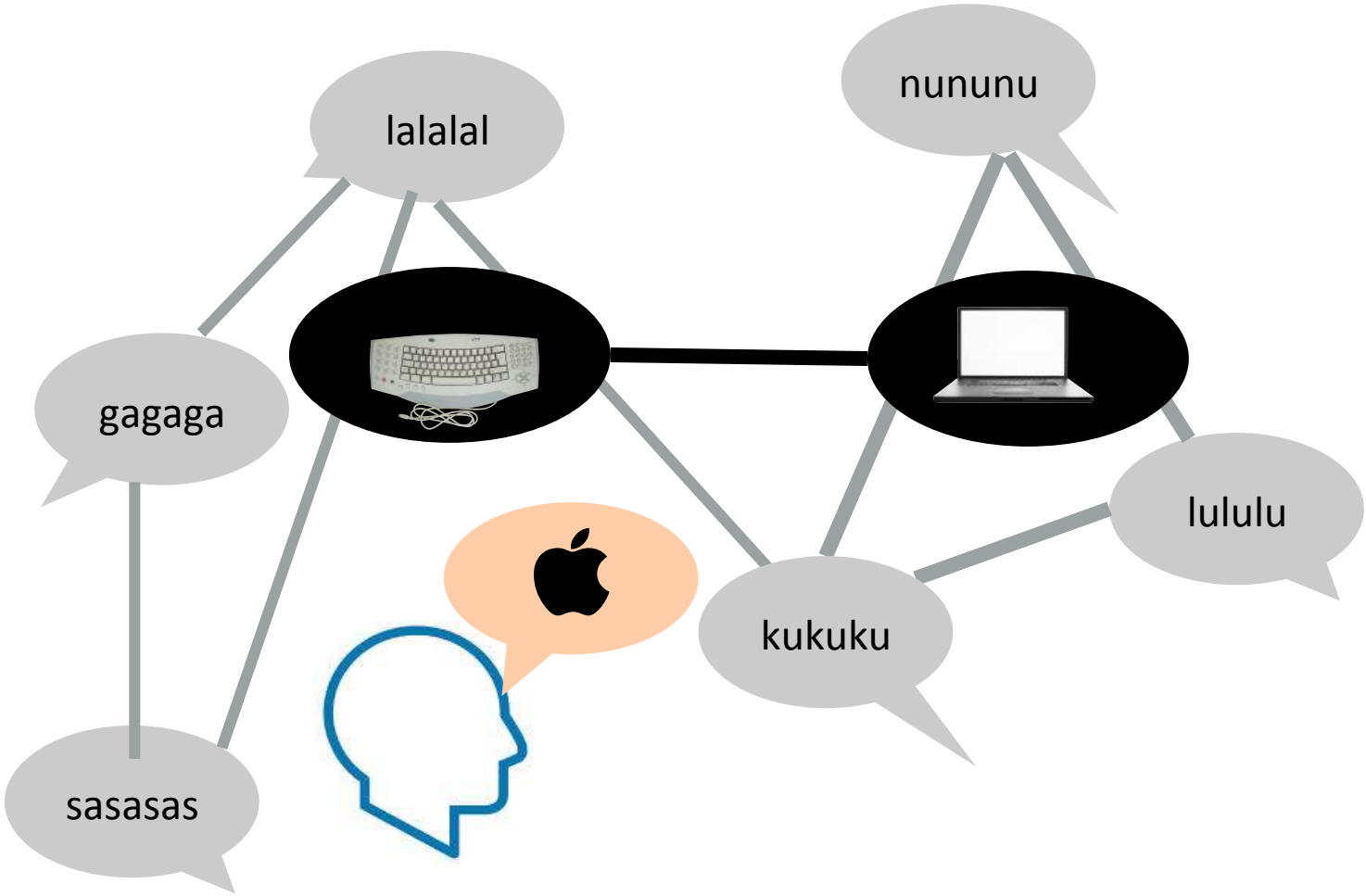

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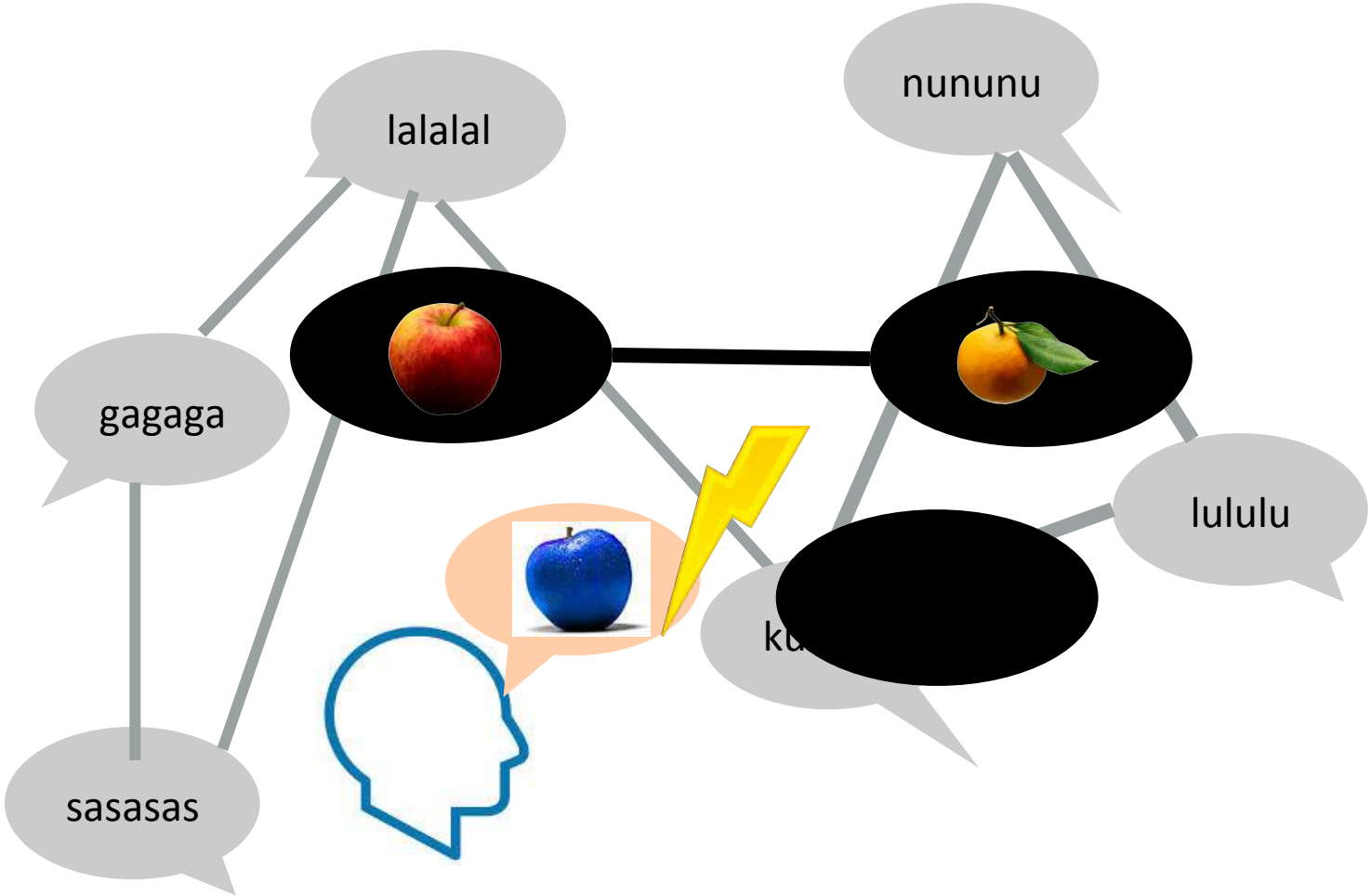


COMMUNICATION

Communication as Network

- people
- utterances
- topics

- meaning of an utterance is constructed
- meaning is defined by its relation to other utterances
- „external knowledge“; artefacts

THEORY DEVELOPMENT

CO-EVOLUTION MODEL

Theoretical papers

- Journal of Computer-Supported Collaborative Learning (2008)
- Knowledge Management Research & Practice (2010)
- AI & Society (2011)
- Journal of the Learning Sciences (2014)
- Educational Psychologist (2015)
- Frontiers in Psychology (2015)

Empirical papers

- Computers and Education (2012; 2013)
- Interacting with Computers (2011)
- Information, Communication and Society (2010)
- Journal of Computer Assisted Learning (2009; 2013)
- Journal of Medial Internet Research (2014)
- Medical Education (2013)
- Computers in Human Behavior (2012)
- PLOS ONE (2014)
- Journal of Computer-Supported Collaborative Learning (2014)

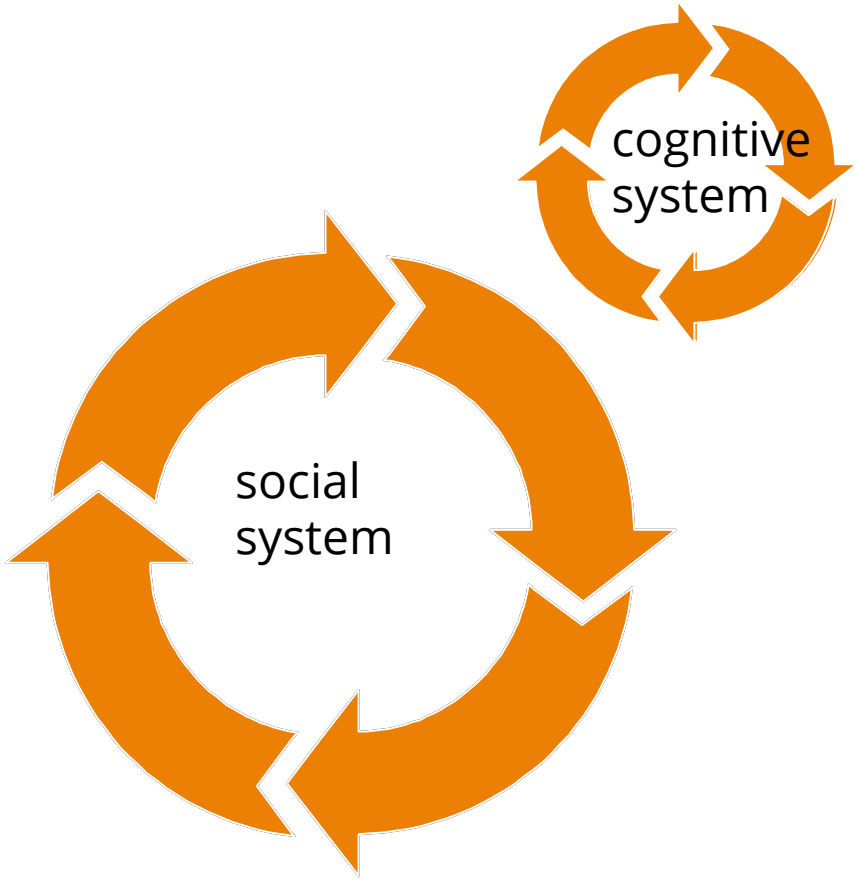
AUTOPOIETIC SYSTEMS (Maturana; Luhmann)

Systems

- do not exist per se
- exist through their operations
- operationally closed
- but open for their environments

- like a species in the evolutionary process: adapting to it’s niche

KNOWLEDGE CONSTRUCTION - PEER PRODCUTION



COGNITIVE SYSTEM

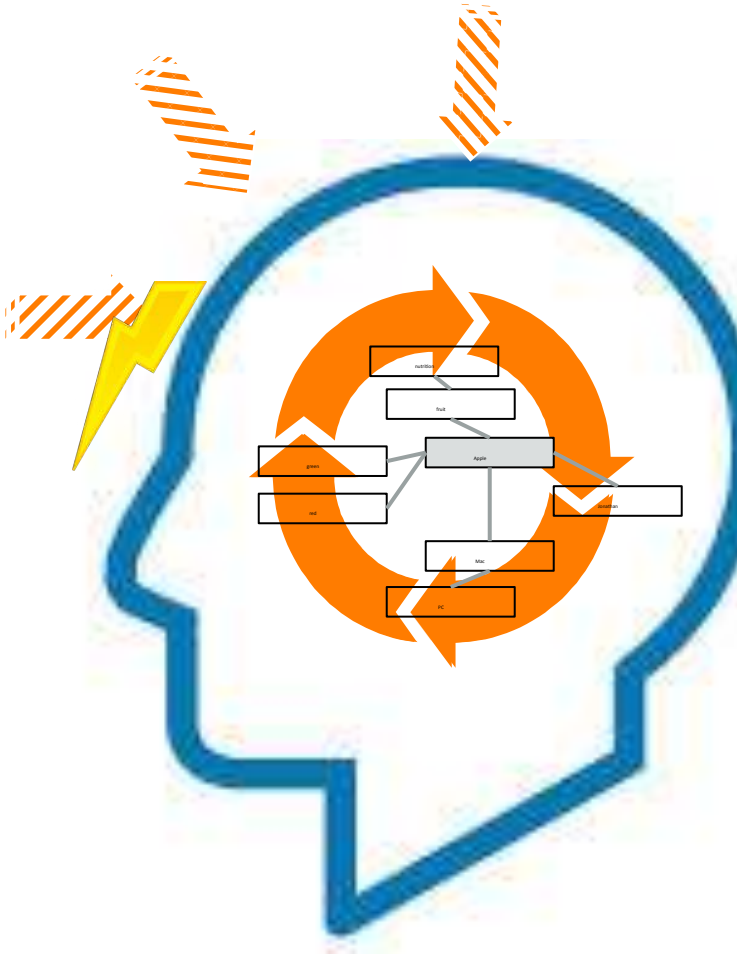
- autopoietic, exists through own operations (cognitions)
- operationally closed
- can be stimulated through its environment
- irritation
- deals with irritation

→ LEARNING

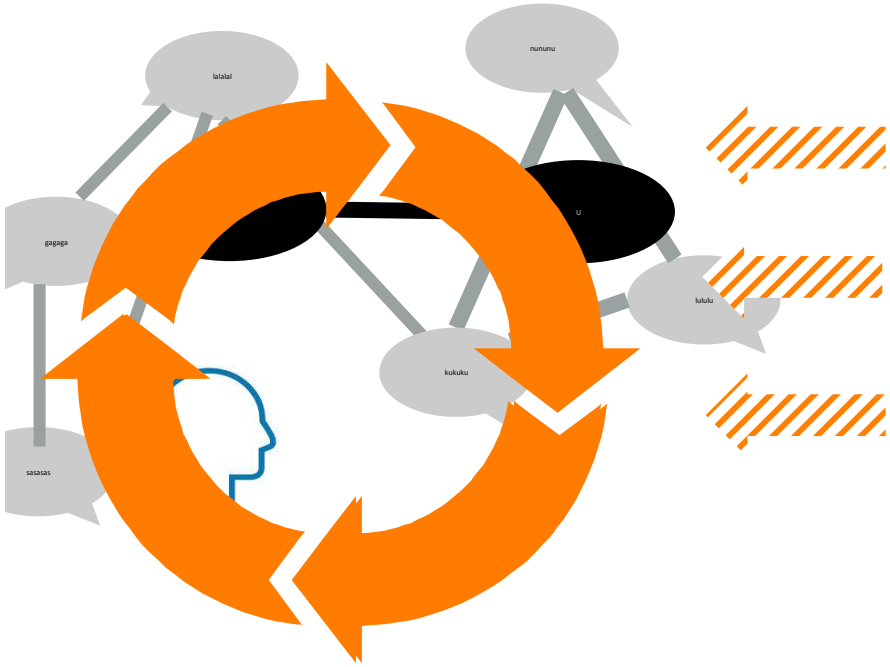
more facts

deeper understanding, deeper knowledge

change in attitude



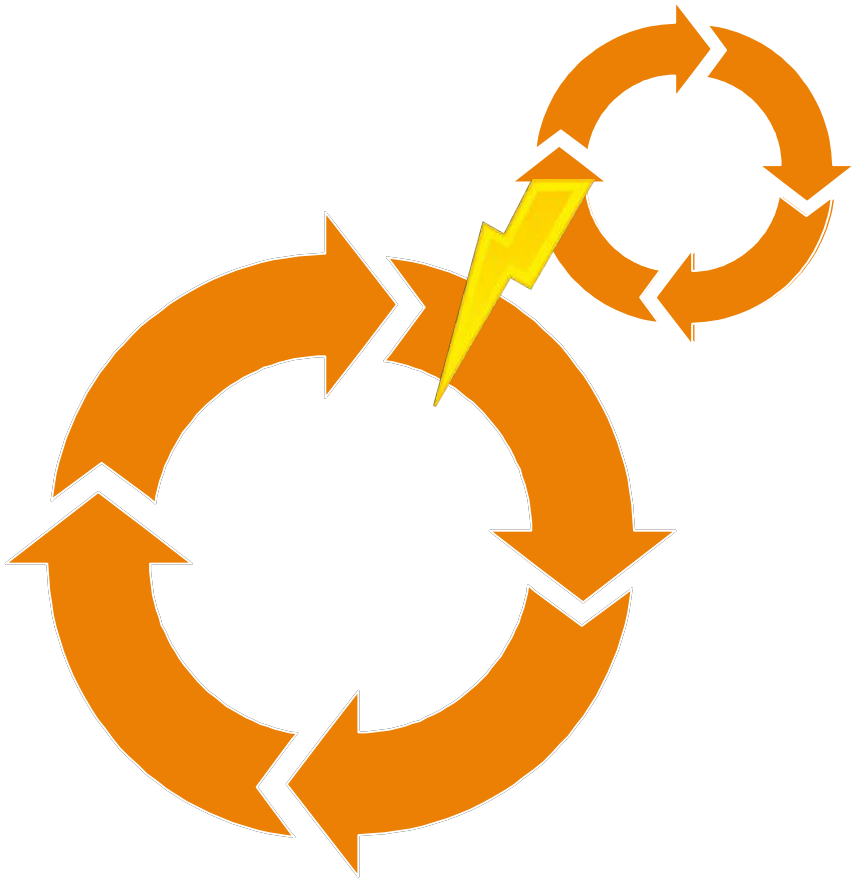
SOCIAL SYSTEM



- autopoietic system
- operates through communication
- operationally closed
- develops rules, norms, culture
  - Wikipedia
  - Metapedia
- can be stimulated through its environment
- develops through operating on irritations

→ KNOWLEDGE CONSTRUCTION

STRUCTURAL COUPLING



- both systems operate
- each system is environment for the other
- each one can stimulate/irritate the other
- incongruity leads to co-evolution
- the systems develop (drift)
  - learning
  - knowledge construction

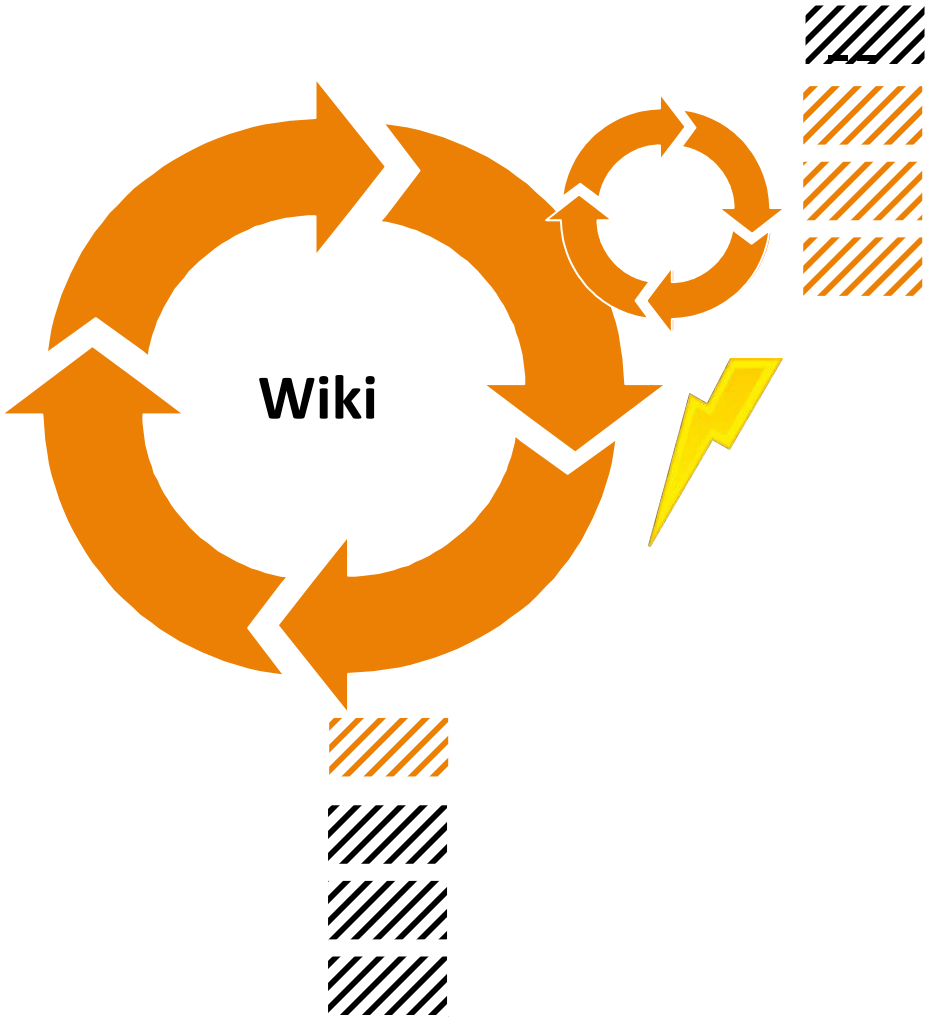
EMPIRICALLY ANALYZING THESE DYNAMIC PROCESSES

- controversial domains
- analyzing individual learning (internal)
  - individual expertise / interests / behaviour / attitude
- analyzing knowledge construction (utterances; artefact)
  - communication thread (quality, quantity)
  - uptakes
  - topical/conceptual development
- analyzing coupling / co-evolution

TYPICAL (PSYCHOLOGICAL) STUDIES

- Studies with Wikis/Wikipedia
- Studies with social tagging systems, Internet forums, design patterns, knowledge platforms

STUDIES WITH WIKIs



controversal topic

pro argument

con argument

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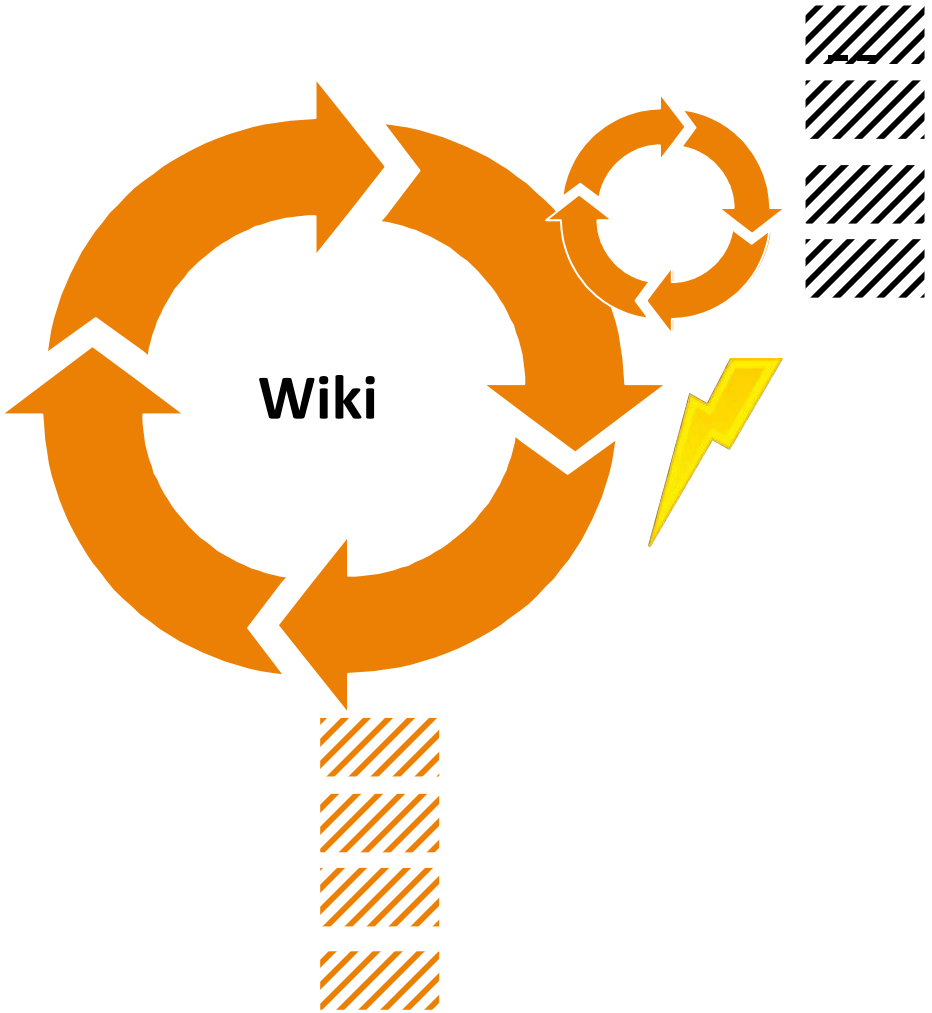
STUDIES WITH WIKIs



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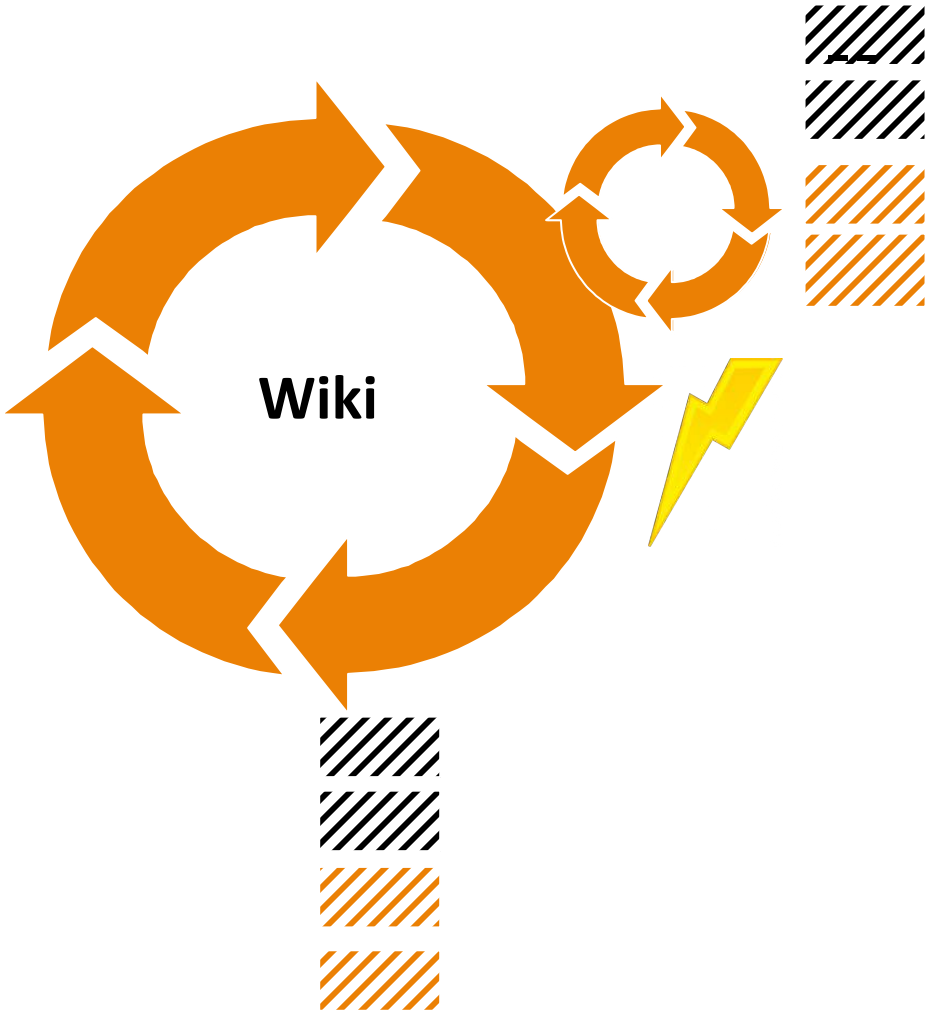


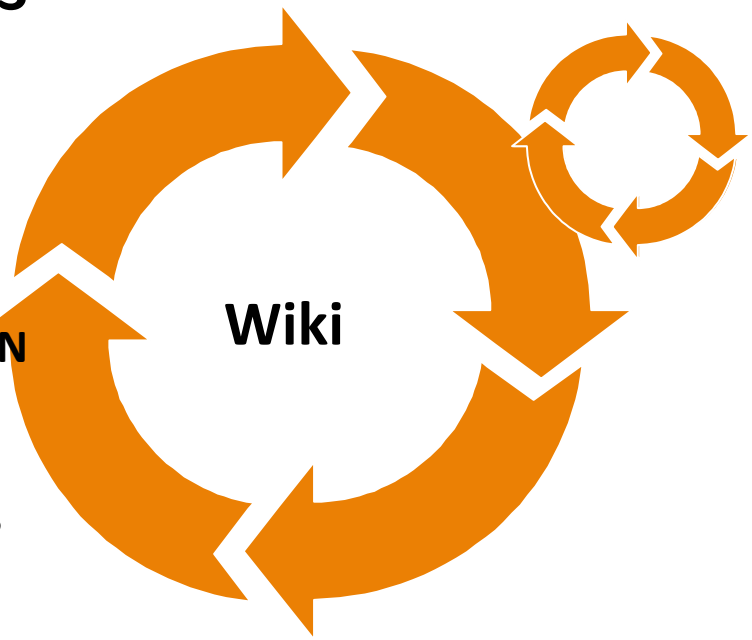
controversal topic

pro argument

con argument

STUDIES WITH WIKIs

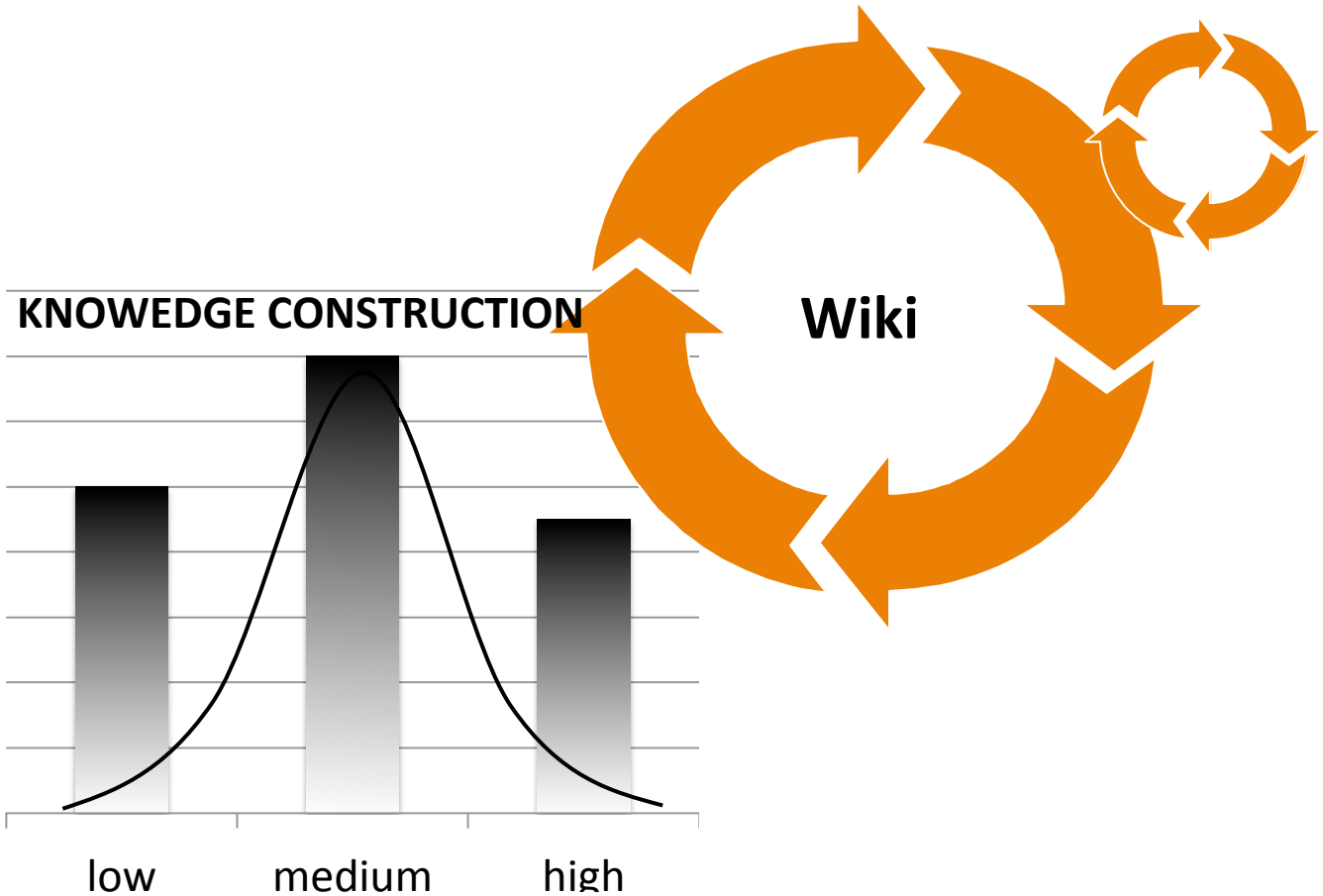
OUTCOME MEASURES

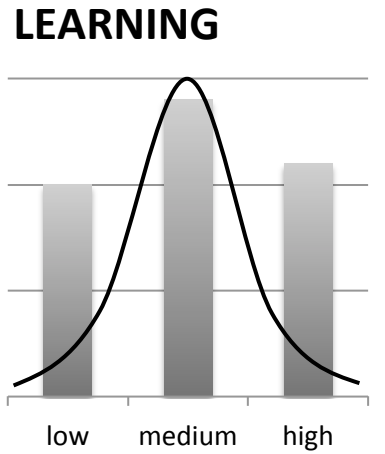


LEARNING
- knowledge
- attitudes

KNOWEDGE CONSTRUCTION
produced wiki-text
- arguments
- integration of arguments
- one-sidedness

FINDINGS


KNOWEDGE CONSTRUCTION
Wiki
low
medium
high
level of incongruity


LEARNING
low
medium
high
level of incongruity

FIRST APPROACH WITH FIELD (BIG) DATA

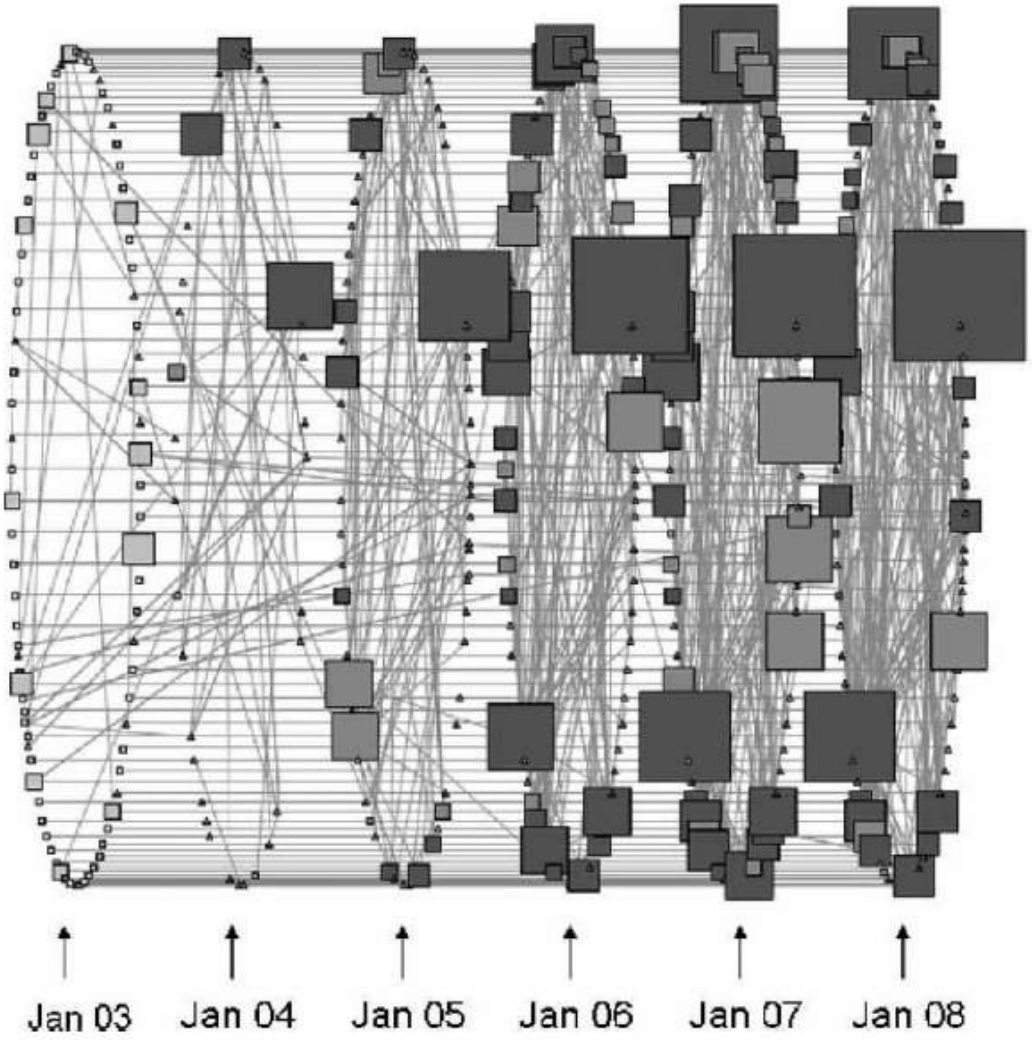
Goal: Analyze the **conceptual** development knowledge

Study in Wikipedia: CAUSES OF SCHIZOPHRENIA

Data: direct neighbours of the Wikipedia-page “causes of schizophrenia”

- development of the *linkage* of pages (knowledge construction)
- development of *individual*s (learning)
- years 2003-2008

DEVELOPMENT OF CORPUS



square size = nr. of in-links

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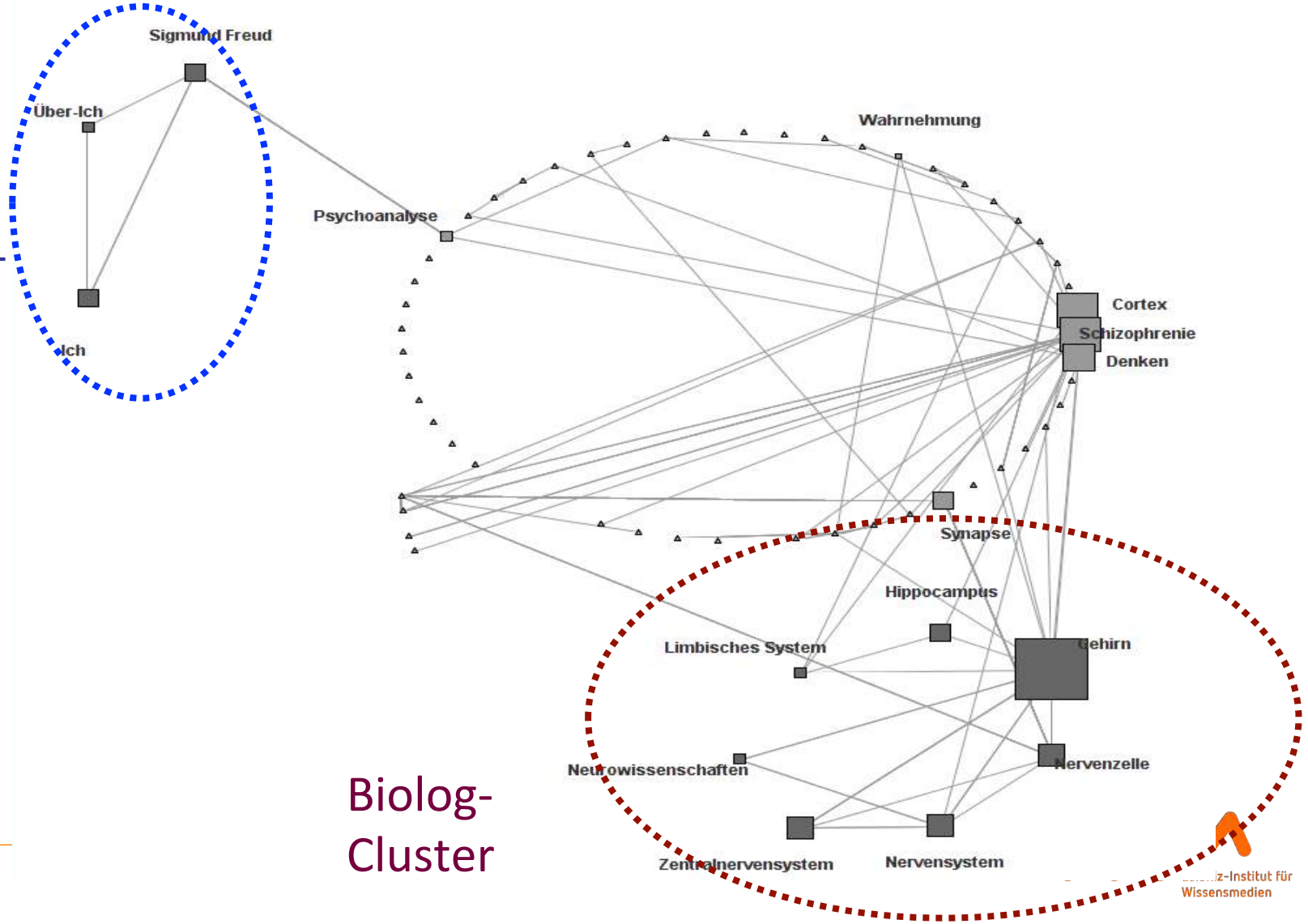
CORPUS 2003

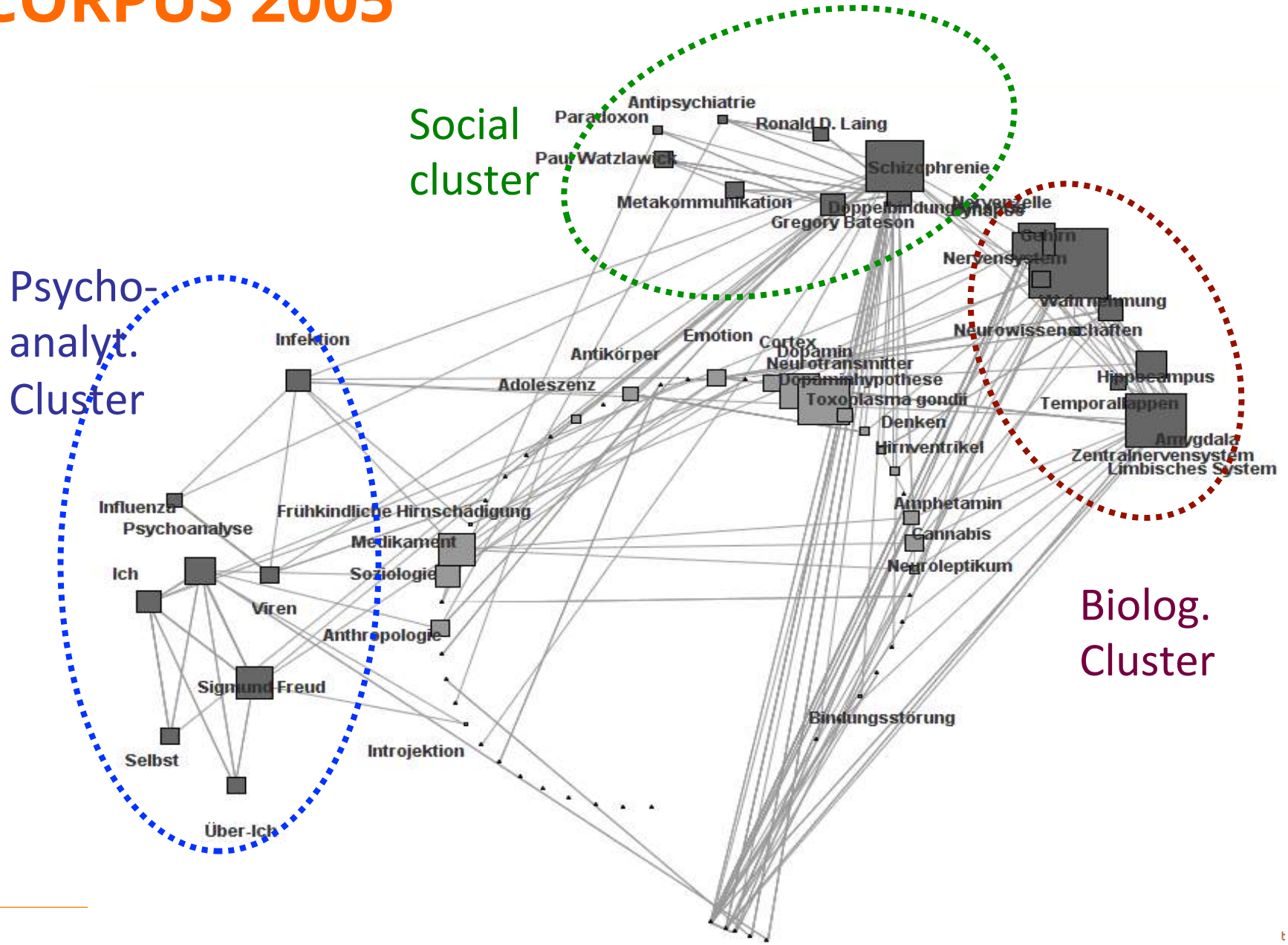
black squares: grouped pages (k-cycles length 3)
grey squares: boundary spanner
small triangle: not grouped

Psycho-analyt. Cluster

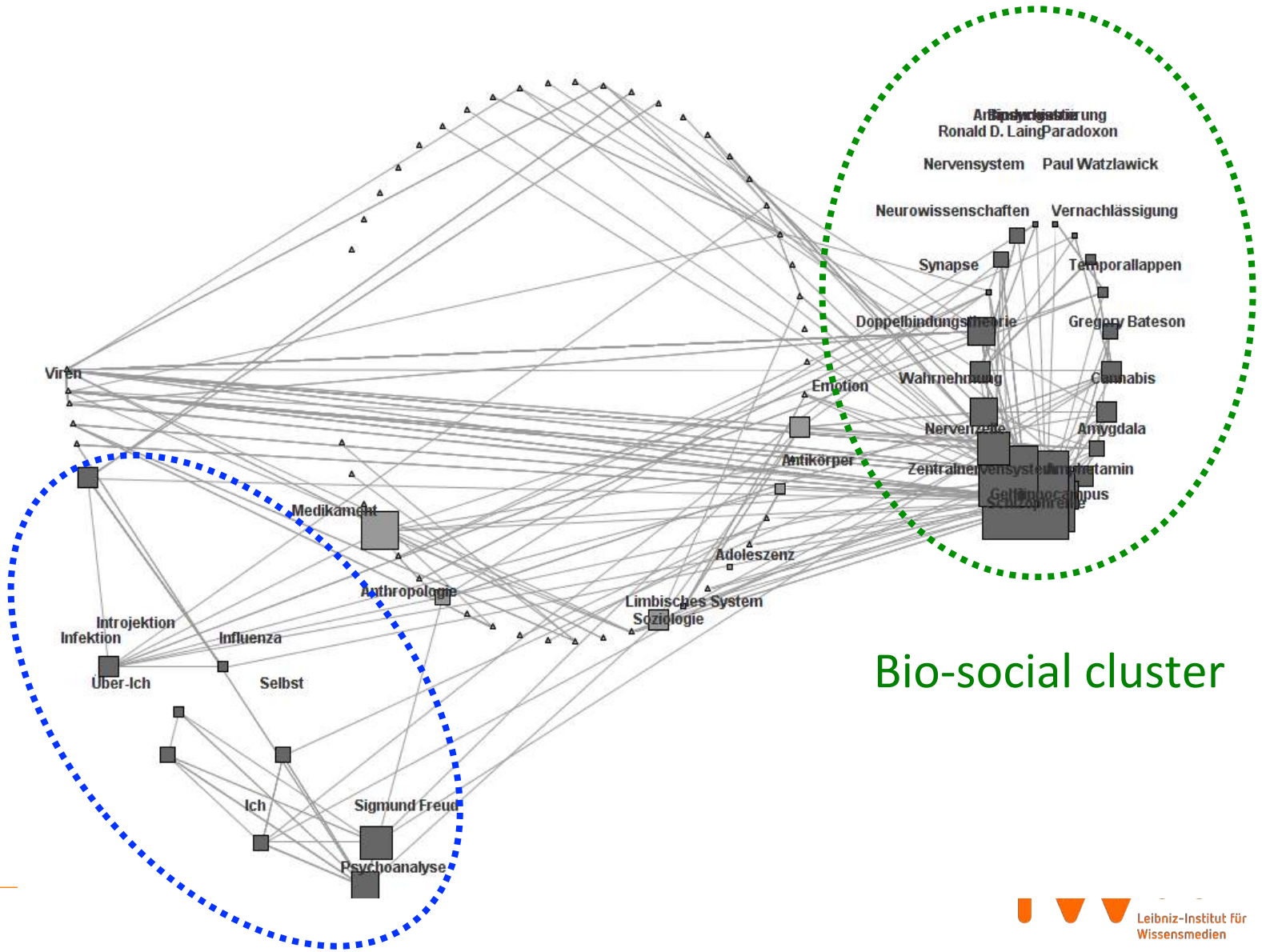


Biolog-Cluster

CORPUS 2005


Social cluster
Psycho-analyt. Cluster
Biolog. Cluster
Antipsychiatrie
Paradoxon
Ronald D. Laing
Paul Watzlawick
Schizophrenie
Metakommunikation
Doppelbindung
Gregory Bateson
Gehirn
Nervensystem
Wahrnehmung
Neurowissenschaften
Infektion
Antikörper
Emotion
Cortex
Dopamin
Neurotransmitter
Dopaminhypothese
Adoleszenz
Toxoplasma gondii
Denken
Hirnventrikel
Hippocampus
Temporallappen
Amygdala
Zentralnervensystem
Limbisches System
Influenza
Psychoanalyse
Frühkindliche Hirnschädigung
Medikament
Soziologie
Ich
Viren
Anthropologie
Amphetamin
Cannabis
Neuroleptikum
Sigmund Freud
Selbst
Introjektion
Über-Ich
Bindungsstörung

CORPUS 2008



Bio-social cluster

Psycho-analyt. cluster

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AUTHORS' EDITS

Individual edits on Wikipedia-pages

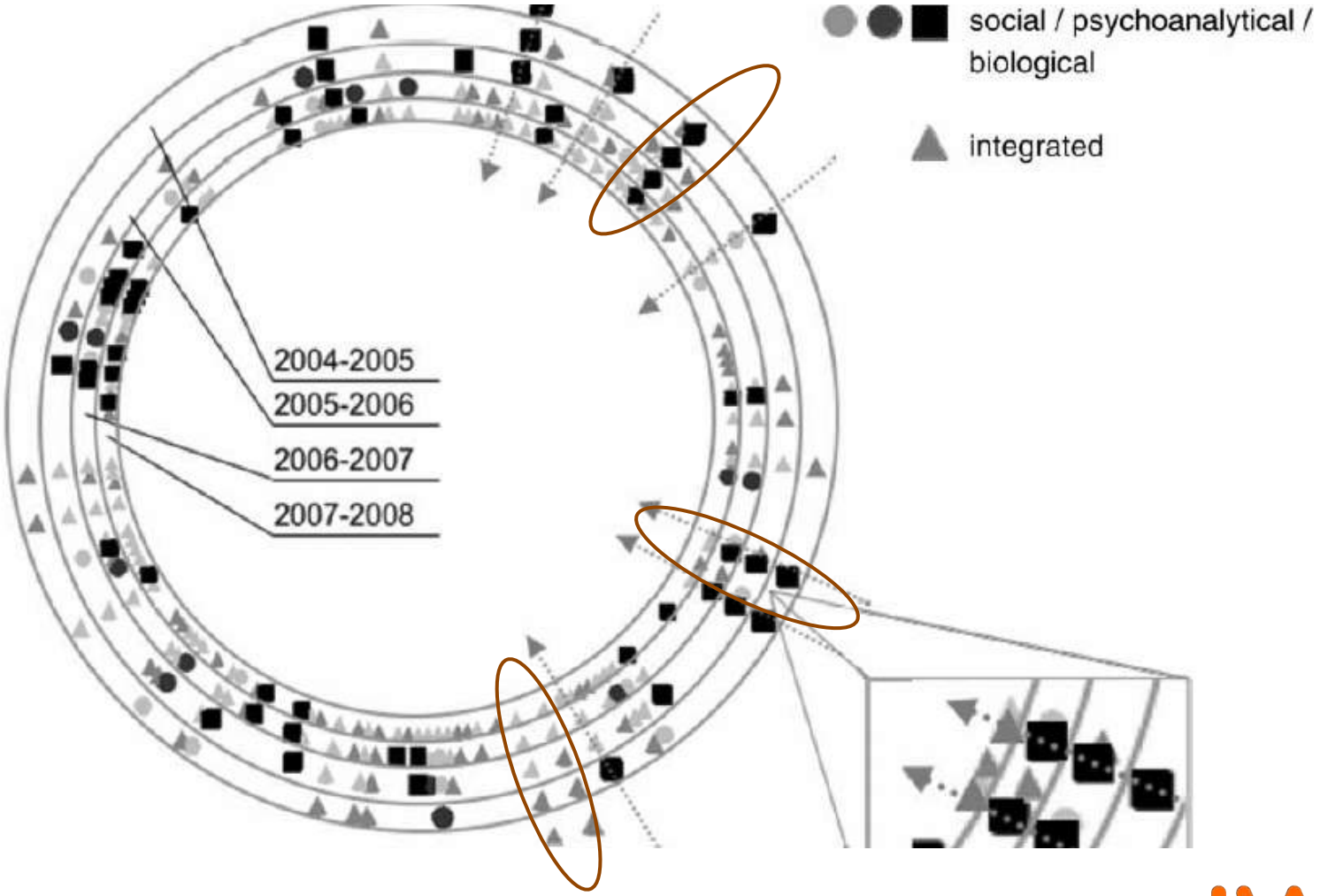
Expert classification of *pages*

- Psychoanalytic: Freud; ÜBER-ICH
- Biological: HIPPOCAMPUS
- Social: DOUBLE COMMUNICATION
- integrated socio-biological (diathese-stress model) (VULNERABILITY)

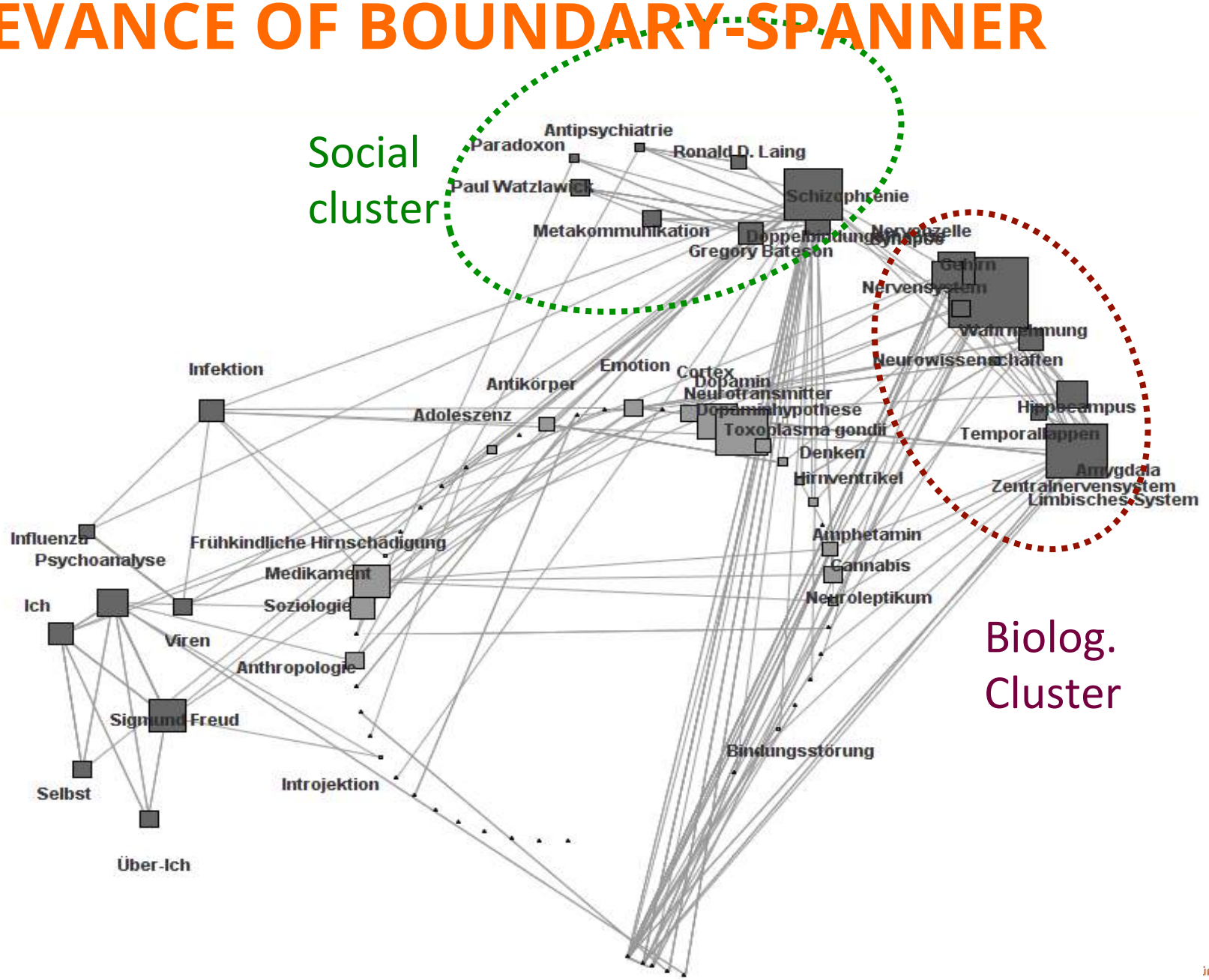
Classification of authors according their contributions

- Psychoanalytic
- Biological
- Social
- Socio-biological

DEVELOPMENT OF AUTHORS: LEARNING



RELEVANCE OF BOUNDARY-SPANNER



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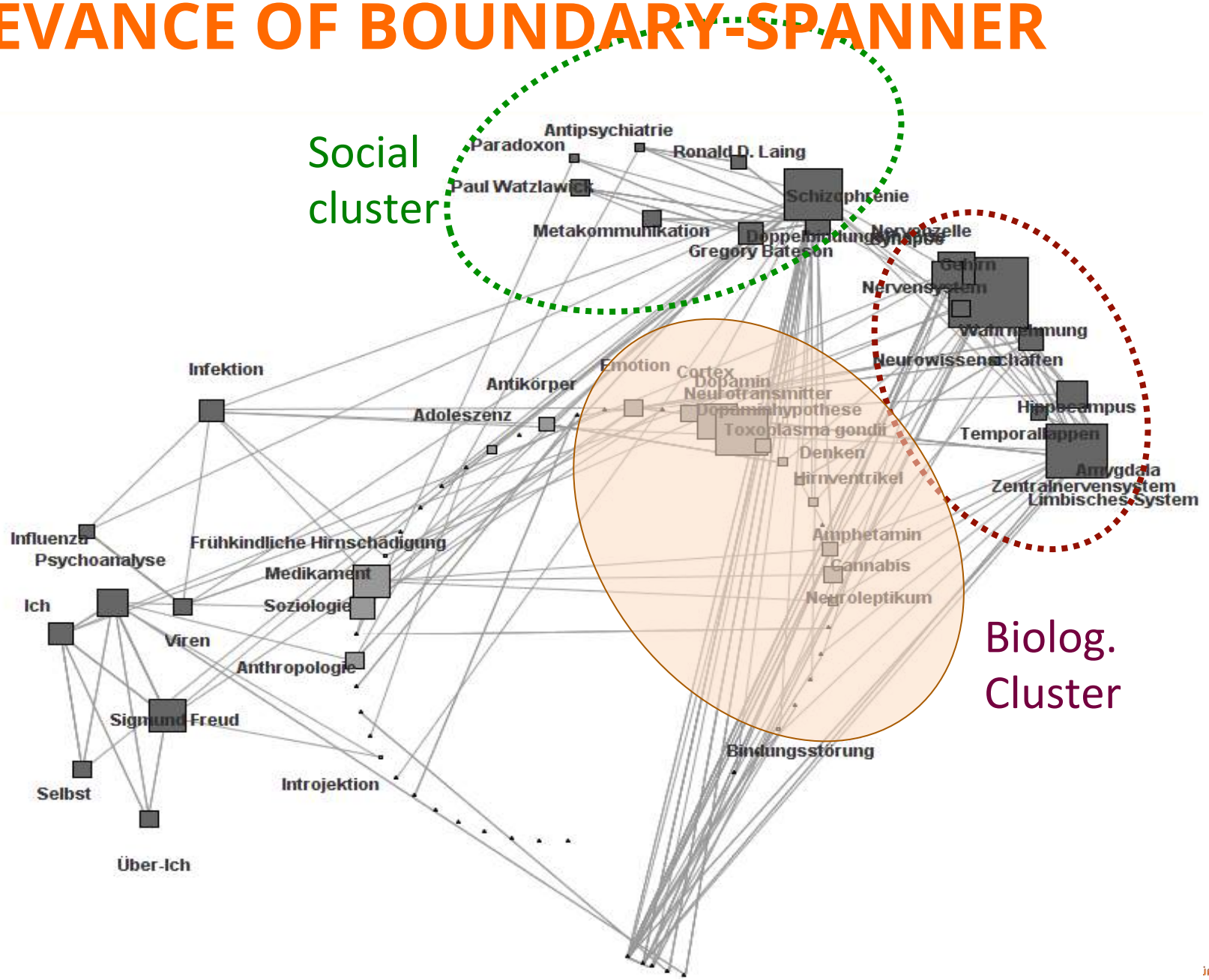
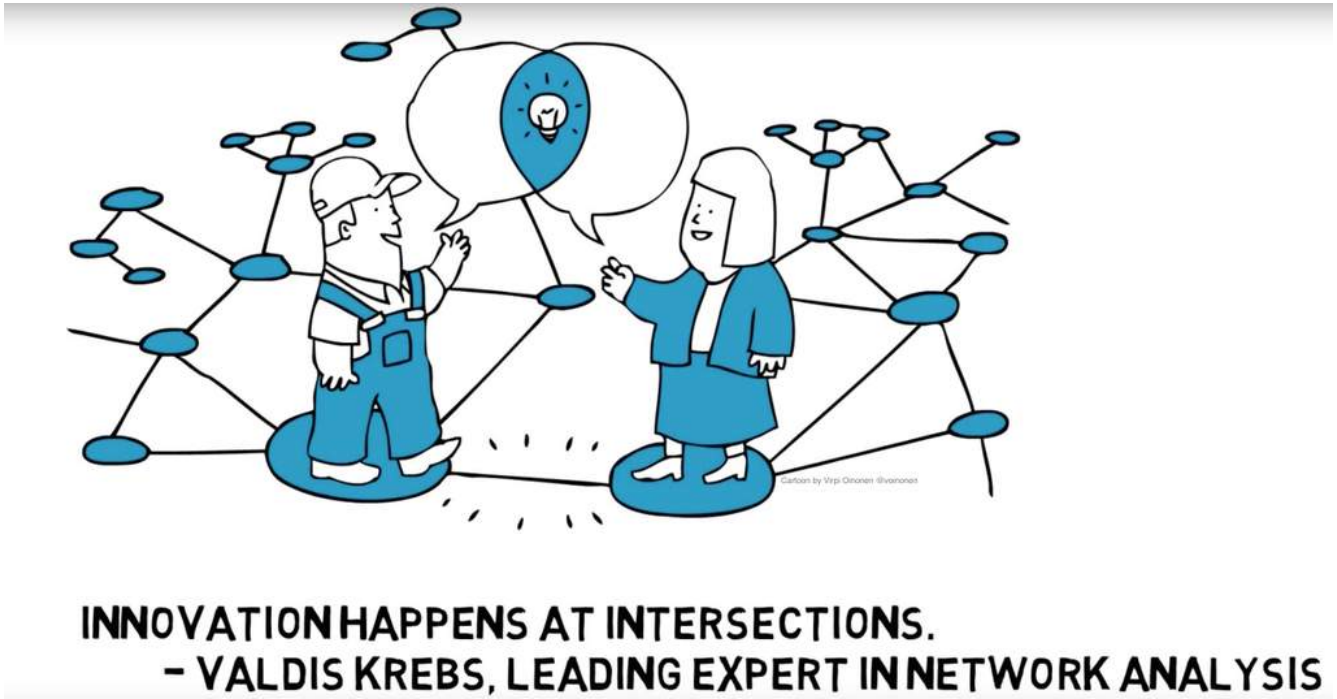


RELEVANCE OF BOUNDARY-SPANNER

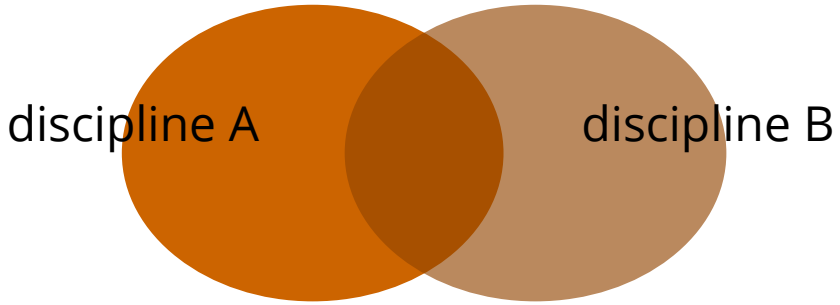
Hypothesis: knowledge progress happens in the intersection of different domains/communities



RELEVANCE OF BOUNDARY-SPANNER

The role of boundary-spanning articles for knowledge creation.

Who creates boundary-spanning (interdisciplinary) articles?



Study with two different but overlapping topics: pedagogy, psychology

DOMAIN CLASSIFICATION

Category:Psychology

From Wikipedia, the free encyclopedia

Pages in this category should be moved to subcategories where applicable.
This category may require frequent maintenance to avoid becoming too large. It should dire

The main article for th
See also: Category:C

Psychology is a collectio
industrial disciplines conc
and prediction of behavio
pathologies.

Subcategories

This category has the foll

A
- Psychology awards (3

B
- Branches of psycholog

C
- Psychological concept
- Cyberpsychology (6 P

E
- Psychology experimer

H
- History of psychology (1 C, 59 P)

Category:Pedagogy

From Wikipedia, the free encyclopedia

Pedagogy is the art or science of teaching.

Wikime
media
Pedag

Subcategories

This category has the following 13 subcategories, out of 13 total.

A
- Applied learning (2 C, 33 P)

C
- Critical pedagogy (51 P)
- Curricula (5 C, 67 P)

D
- Didactics (1 C, 12 P)

E
- Educational psychology (18 C, 269 P)
- Educationists (5 C, 42 P)
- Personality (6 C, 59 P)
- Philosophy of psychology (9 C, 20 P)
- Pedagogic integrated development environments (24 P)
- Internships (3 C, 29 P)

L
- Language-teaching methodology (3 C, 33 P)
- Learning programs (21 C, 29 P)

M
- Montessori education (2 C, 11 P)

O
- Online edutainment (1 C, 17 P)

P
- Women and

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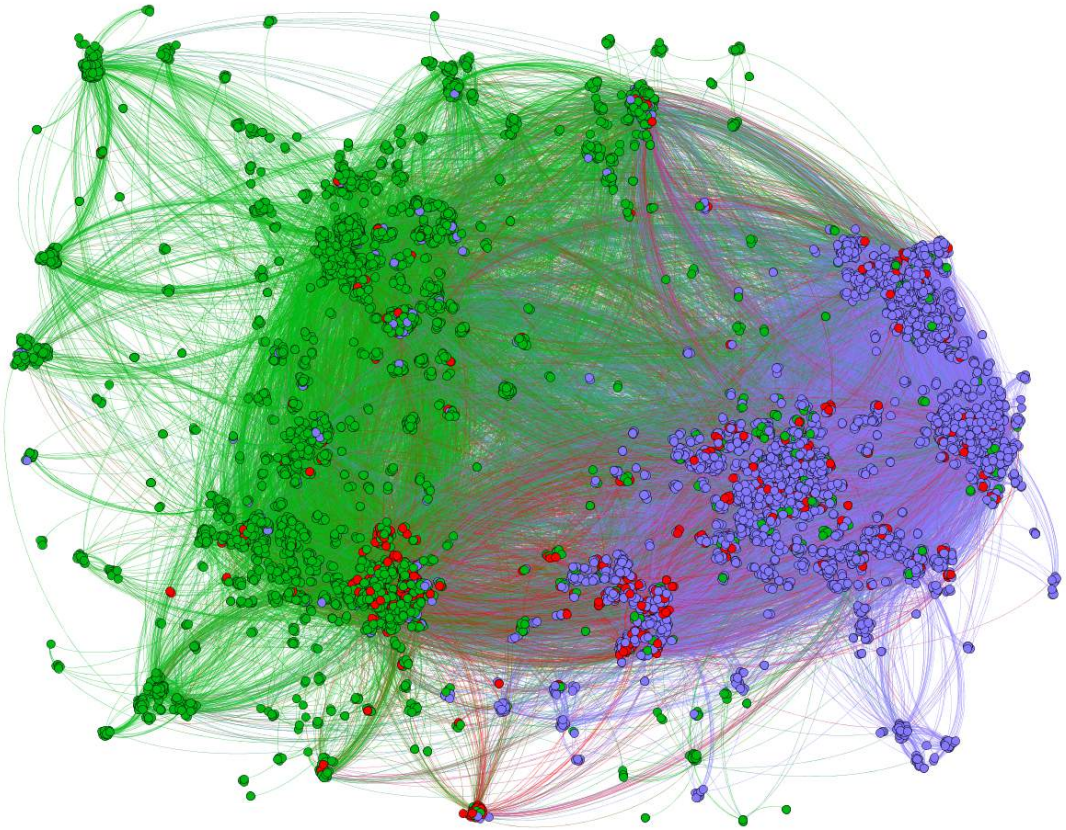
ARTICLE CORPUS

Network of 11.000 articles
undirected hyperlinks as edges



Pedagogy

Psychology

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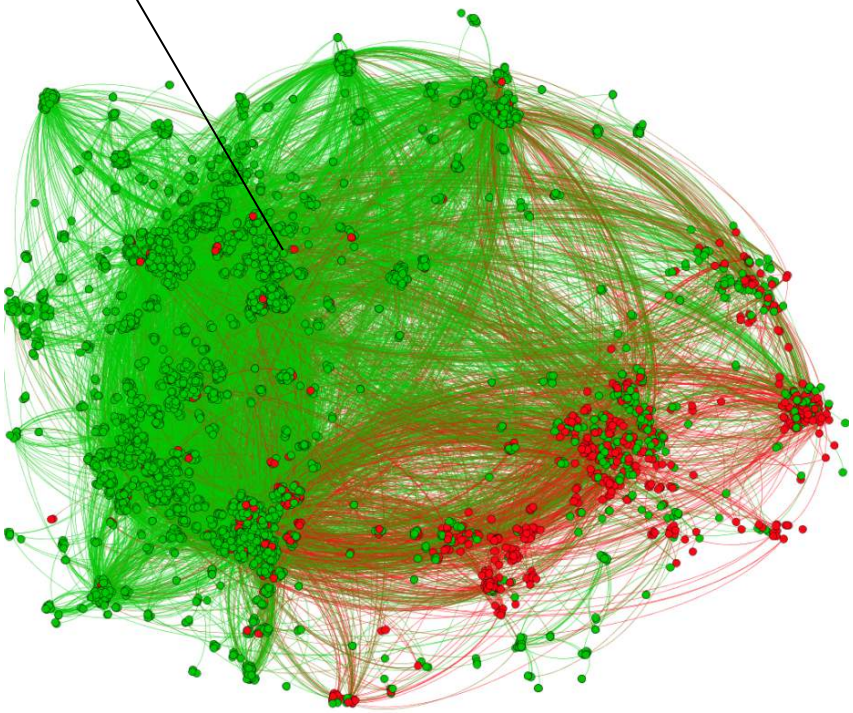
RELEVANCE OF ARTICLE

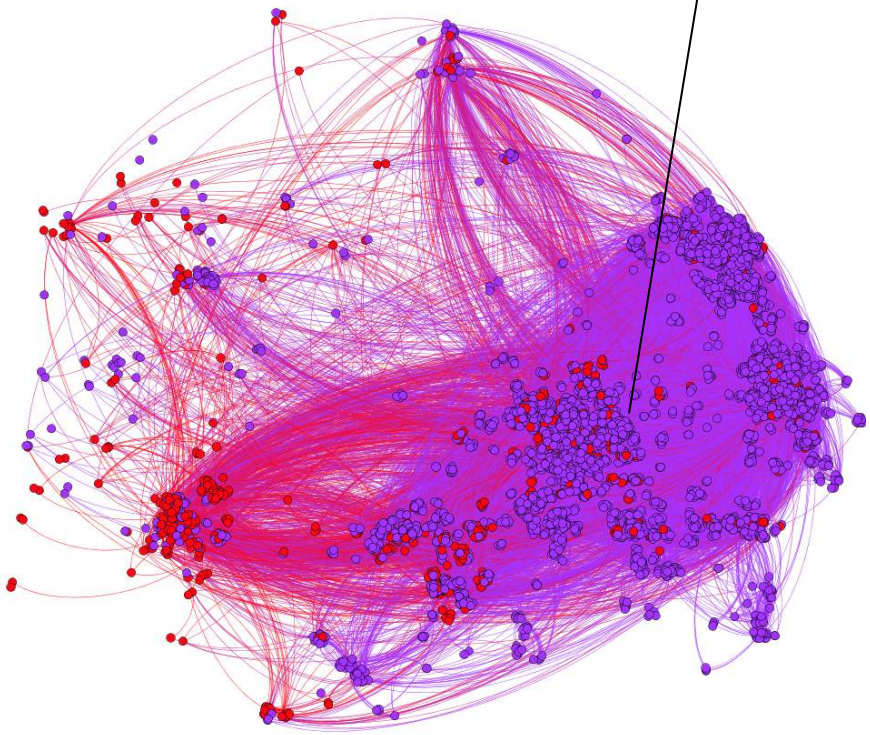
Pedagogy

Psychology

eigenvector



eigenvector



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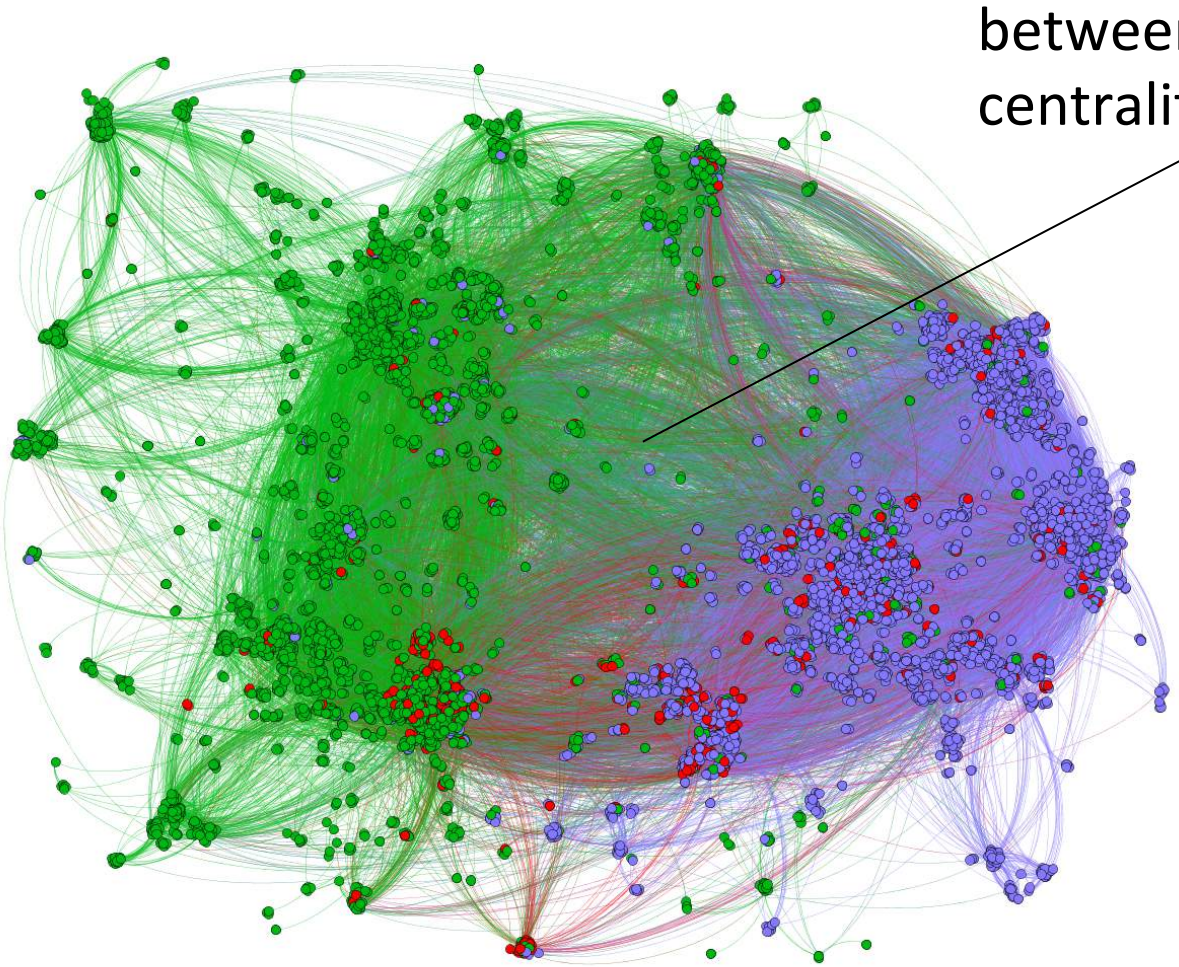
RELEVANCE OF ARTICLE

Combined network



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CATEGORIZATION OF AUTHORS

identification of all edits from an author (> 150 characters)

Categorization as

- specialist (either Psych. or Ped.)
- generalist (Psych. and Ped.)

- Wikipedia expertise (no. of edits)

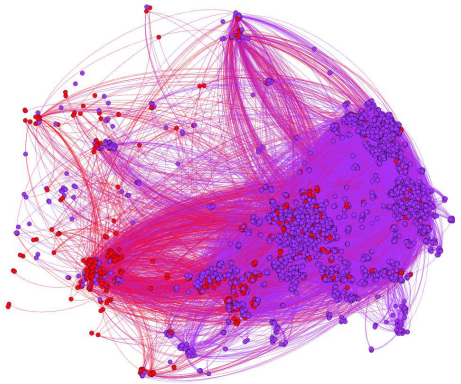
Do these features predict if an author‘s contributions are central?

REGRESSION MODEL

What predicts the centrality of an author's contribution in the Psychology corpus

$Y_i = \alpha + \beta X_i + \delta Z_i + \varepsilon_i$

- Y_i = log eigenvector of author i
- X_i = 1 if author i ein generalist
  i= 0 if author i ein specialist in Psychology
- Z_i = log number of articles of author i
- ε_i = Residuum



Domain	Centrality Measures	β generalist /specialist	δ general expertise author
psychology	Eigenvector	-0.36***	0.30***

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REGRESSION MODEL

What predicts the centrality of an author's contribution? in the Pedagogy Corpus?

$$Y_i = \alpha + \beta X_i + \delta Z_i + \varepsilon_i$$

- Y_i = log eigenvector of author i
- X_i = 1 if author i ein generalist
  = 0 if author i ein specialist in Pedagogy
- Z_i = log number of articles of author i
- ε_i = Residuum

Domain	Centrality Measures	β generalist /specialist	δ general expertise author
psychology	Eigenvector	-0.36***	0.30***
pedagogy	Eigenvector	-0.15	0.38***

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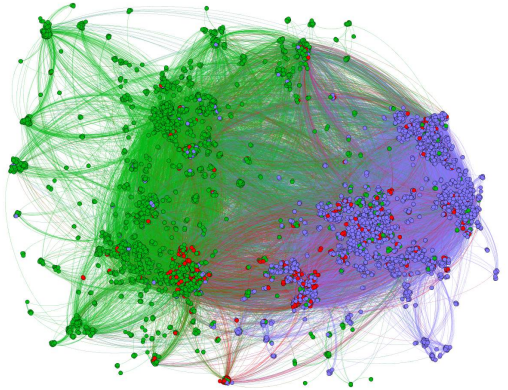
REGRESSION MODEL

What predicts the centrality of an author's contribution for the combined network?

$$Y_i = \alpha + \beta X_i + \delta Z_i + \varepsilon_i$$

- Y_i = log Betweenness of author i
- X_i = 1, if author i ein generalist
  = 0 if author i ein specialist
- Z_i = log number of articles of author i
- ε_i = Residuum



Domain	Centrality Measures	β generalist /specialist	δ general expertise author
psychology	Eigenvector	-0.36***	0.30***
pedagogy	Eigenvector	-0.15	0.38***
combined network	Betweenness	0.54***	0.60***

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TEMPORAL DEVELOPMENT OF NEW KNOWLEDGE

period	Psychology		Pedagogy		Intersection	whole network	
	articles	links	articles	links		articles	links
2006	2176	12834	1357	5007	325	3858	18592
2007	2911	20311	1980	7861	450	5341	29264
2008	3472	26615	2556	10925	526	6554	39033
2009	3908	31955	3108	13564	581	7597	47388
2010	4262	36028	3595	16074	626	8483	54430
2011	4660	40983	4166	18793	686	9512	62547
2012	5085	44939	4696	22518	731	10512	70666

MULTILEVEL LOGISTIC MODEL (periods nested in articles)

new edits

	level	est. value	z	p
combined network				
(Intercept)		0.63	7.11	1.2e-12***
creation year	Article	-0.39	-34.40	<2e-16***
article age	Periode	-0.31	-32.86	<2e-16***
t-1 log betweenness	Periode	0.09	12.10	<2e-16***
t-1 log no. of edits	Periode	0.65	33.02	<2e-16***
excellent articles	Article	0.18	0.94	0.35
log controversiality	Article	0.20	16.34	<2e-16***

MULTILEVEL LOGISTIC MODEL (periods nested in articles)

newly created articles as neighbors

	level	est. value	z	p
combined network				
(Intercept)		2.56	23.19	1.2e-12***
creation year	Article	-0.33	-25.27	<2e-16***
article age	Periode	-0.22	-21.57	<2e-16***
t-1 log betweenness	Periode	0.31	12.10	<2e-16***
t-1 log no. of edits	Periode	0.26	11.40	<2e-16***
excellent articles	Article	0.04	0.20	0.83
log controversiality	Article	0.05	4.26	<2e-05***

MULTILEVEL LOGISTIC MODEL (periods nested in articles)

edit count of the neighboring articles

	level	est. value	z	p
combined network				
(Intercept)		131.95	32.29	<2e-12***
creation year	Article	-7.73	-15.97	<2e-16***
article age	Periode	-8.13	-23.32	<2e-16***
Δ neighbors since t-1	Periode	20.42	180.30	<2e-16***
t-1 log betweeness	Periode	5.86	17.82	<2e-16***
t-1 log no. of edits	Period	9.98	11.82	<2e-16***
excellent articles	Article	53.85	6.30	0.83
log controversiality	Article	6.28	12.68	<2e-05***

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MULTILEVEL LOGISTIC MODEL (periods nested in articles)

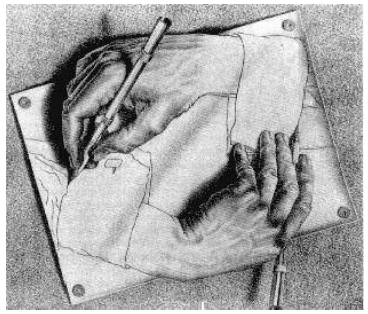
similar results for

- pedagogy network
- psychology network
- combined network

RESULTS

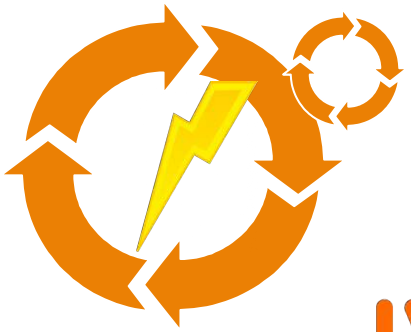
Preferential attachment

- central articles attract more edits, neighbours, edits in neighbours



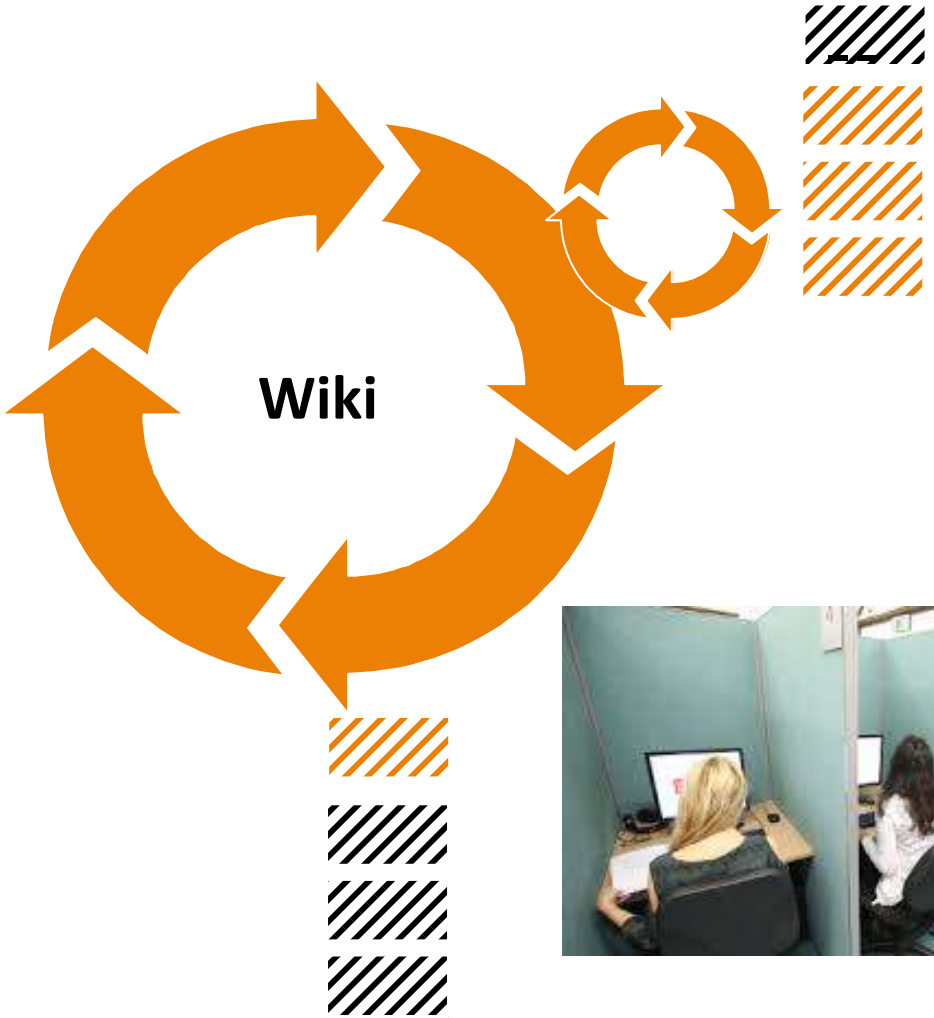
- Boundary-spanning articles attract more edits, neighbours, edits in neighbours

  → Role of conflict, discourse



CONTROVERSIES IN WIKIPEDIA

STUDIES WITH WIKIs



controversal topic

pro argument

con argument

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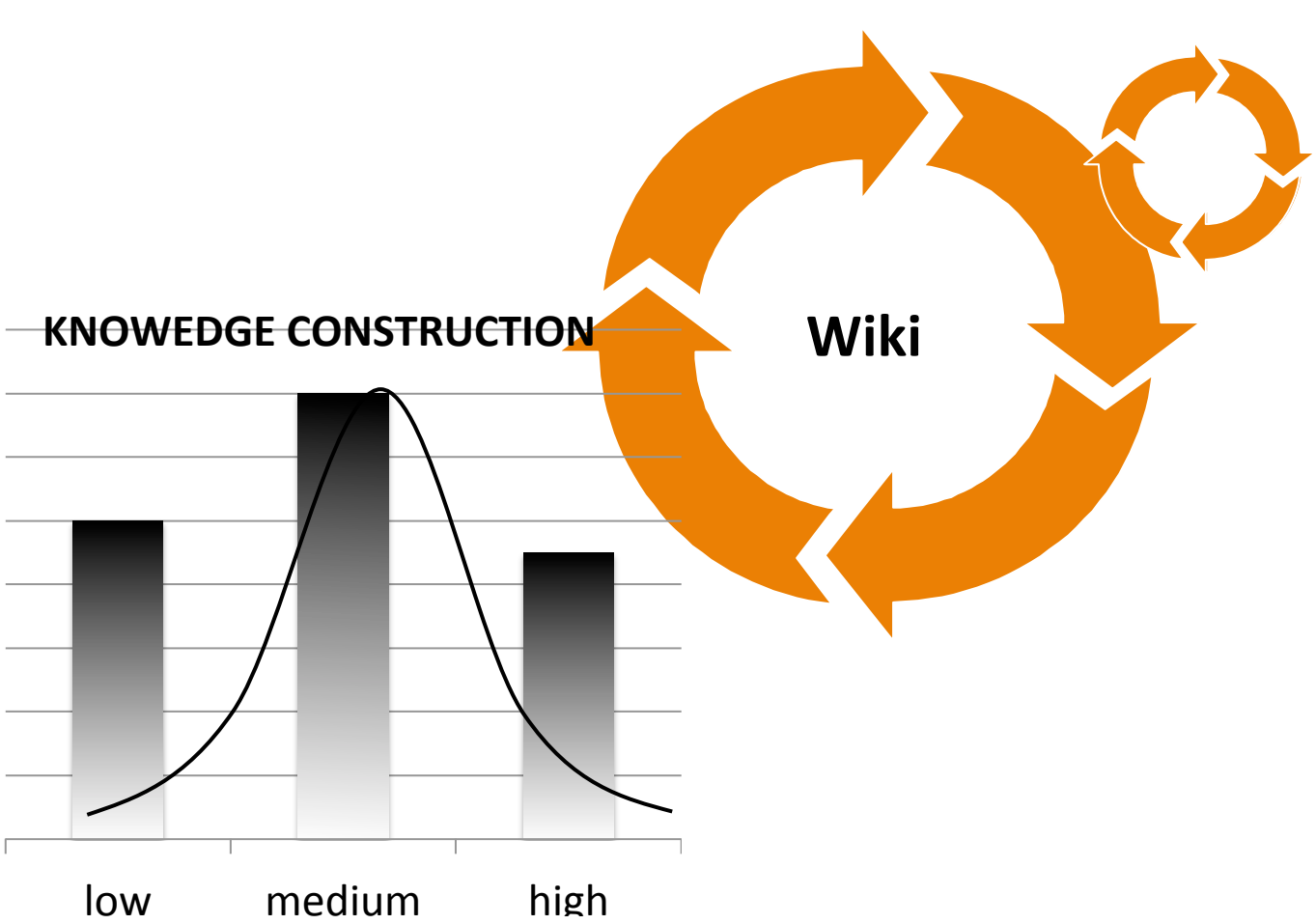
STUDIES WITH WIKIs



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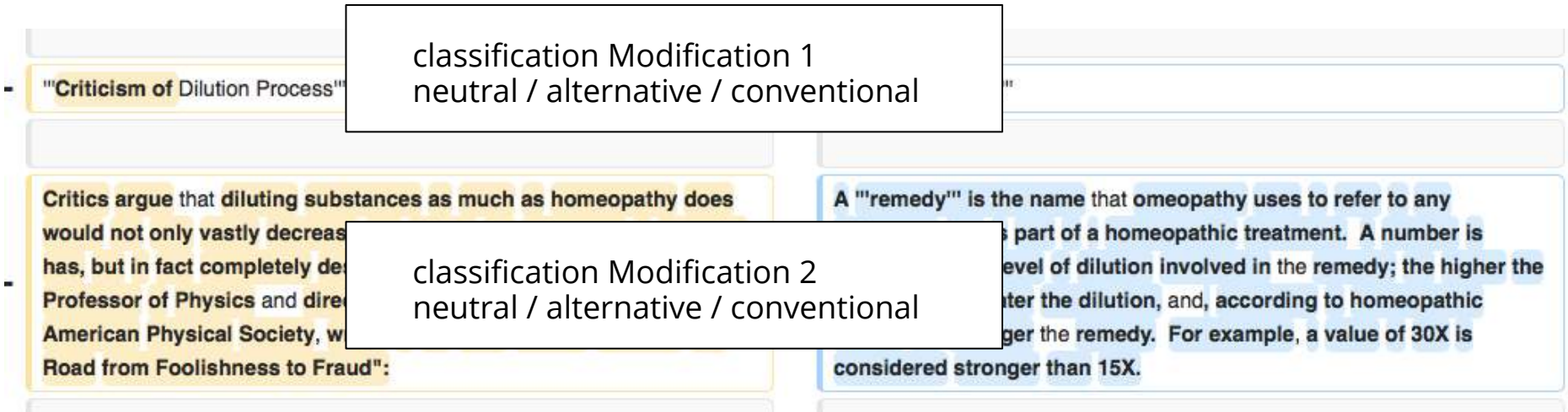
USE OF SEMANTICS

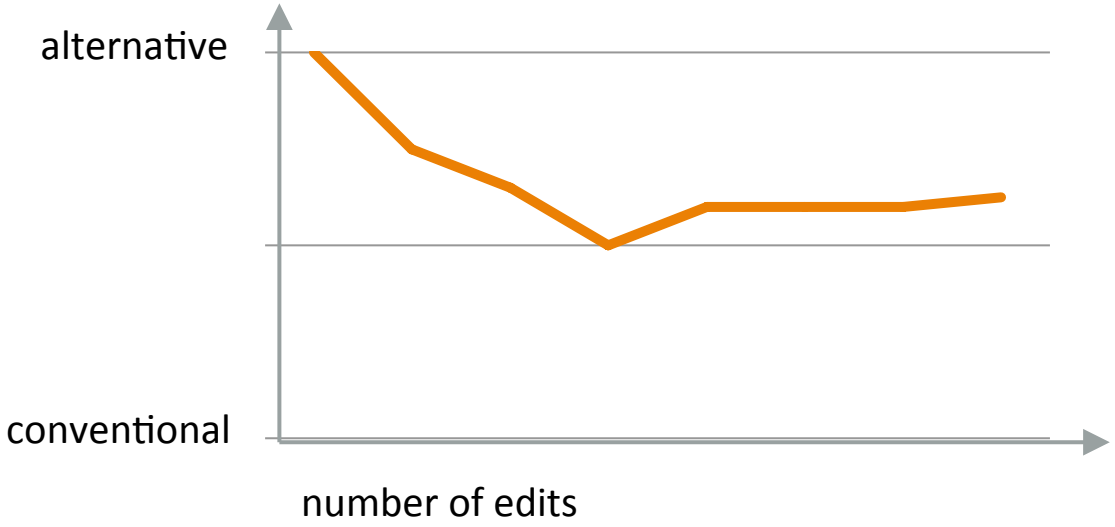
Wikipedia: All articles about alternative medicine (400 articles)

- classification of the 500.000 modifications (via machine learning)



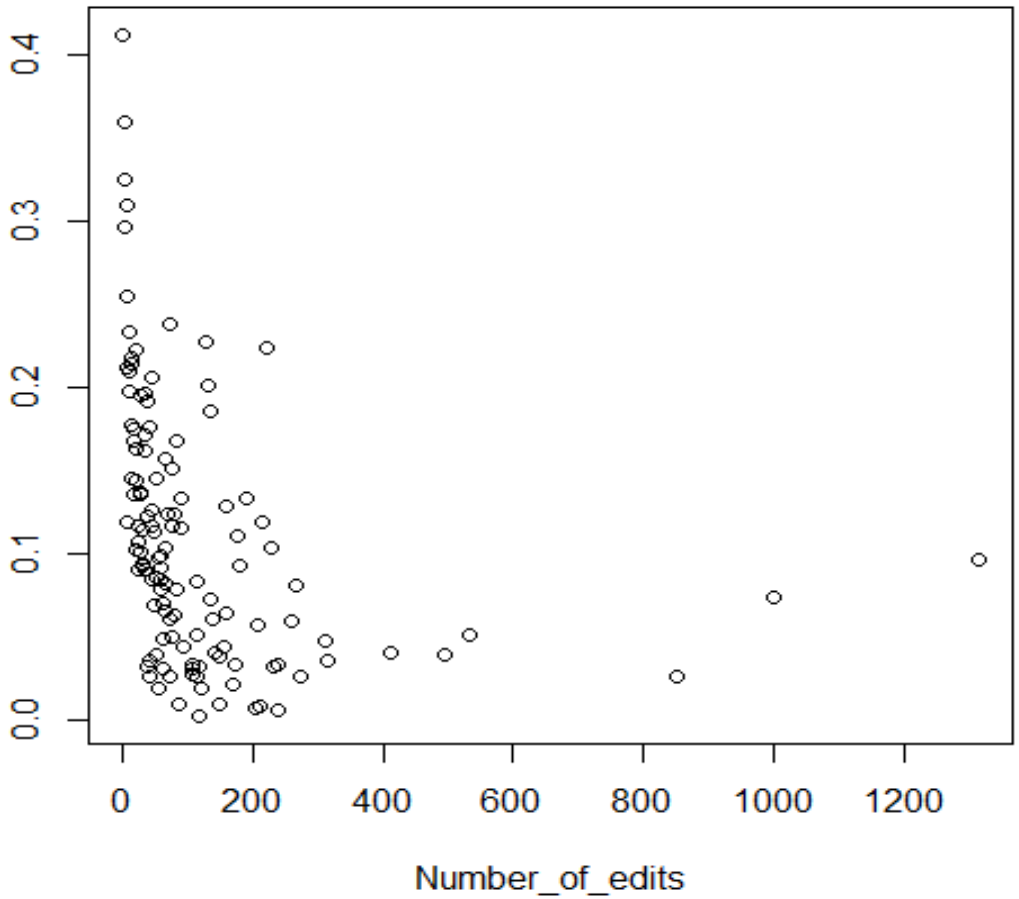
ARTICLE PROFILS

Dynamic development of an *article: aggregation of all edits*



ARTICLE PROFILES

Extremity



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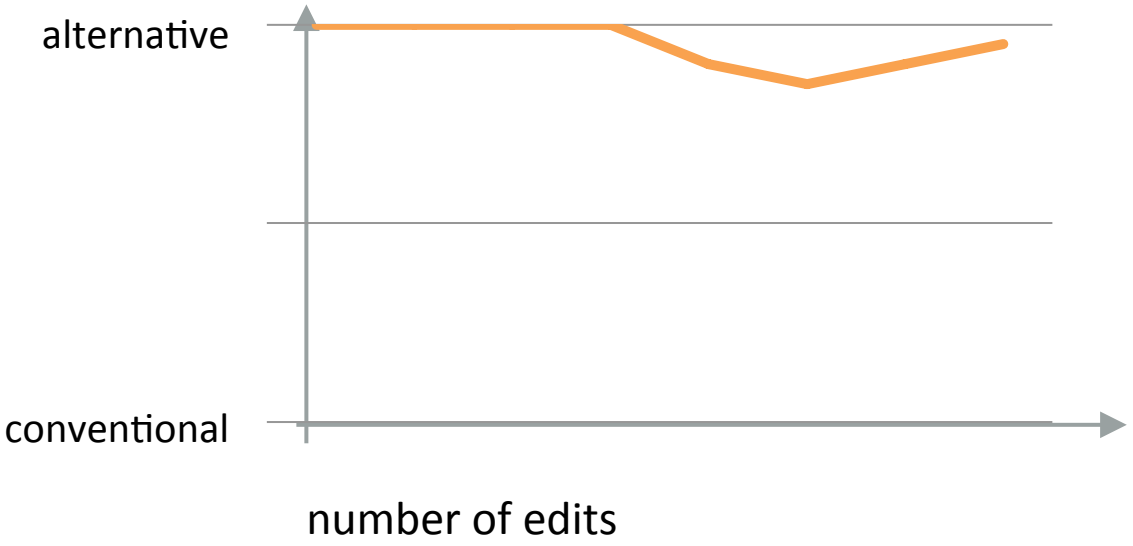
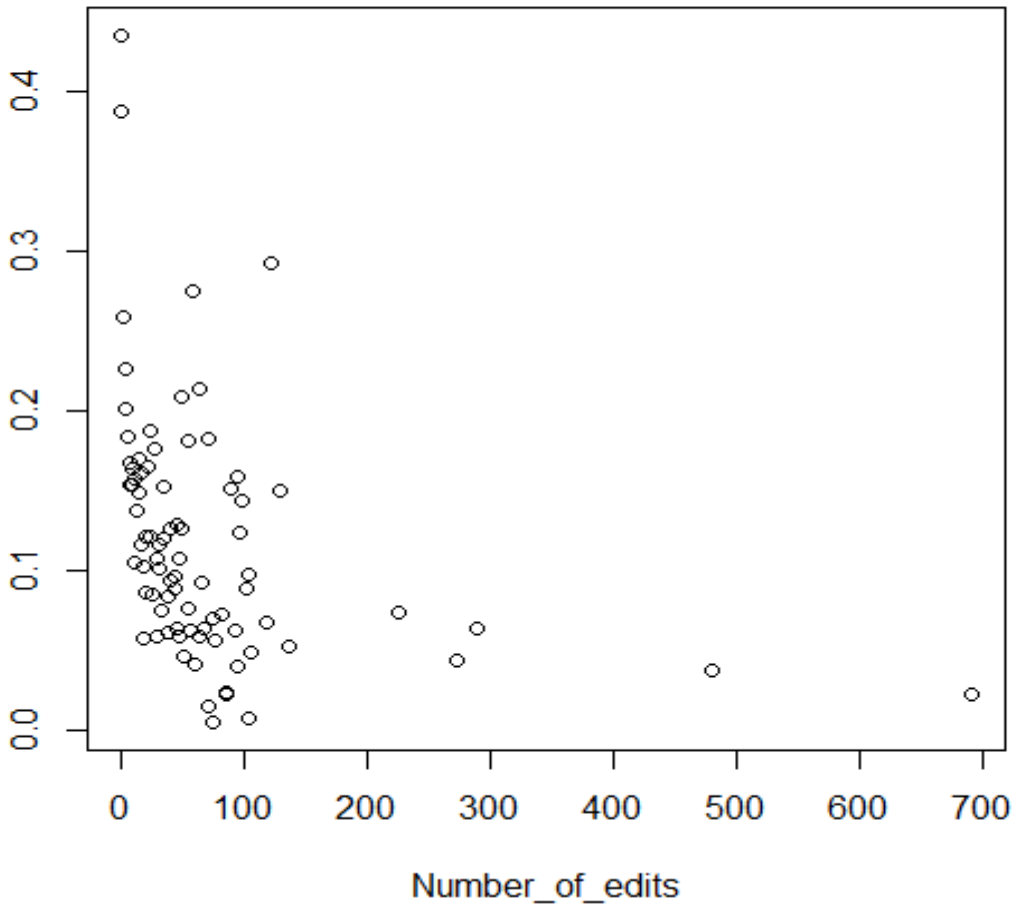
AUTHOR PROFILS

Dynamic development of an *author: aggregation of all edits done by that author*



AUTHOR PROFILS

Extremity



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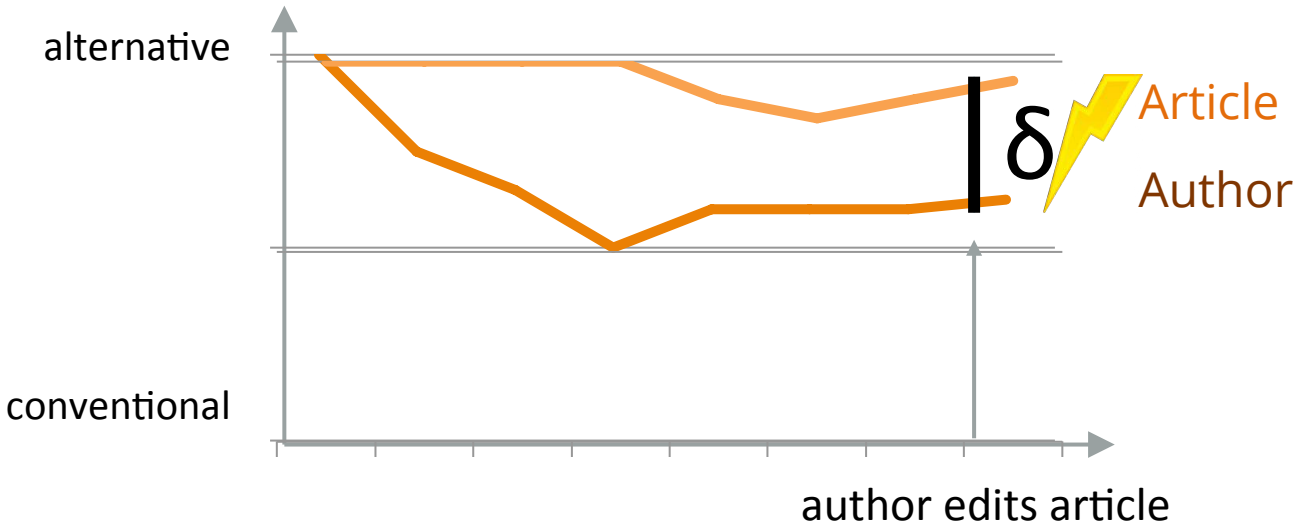
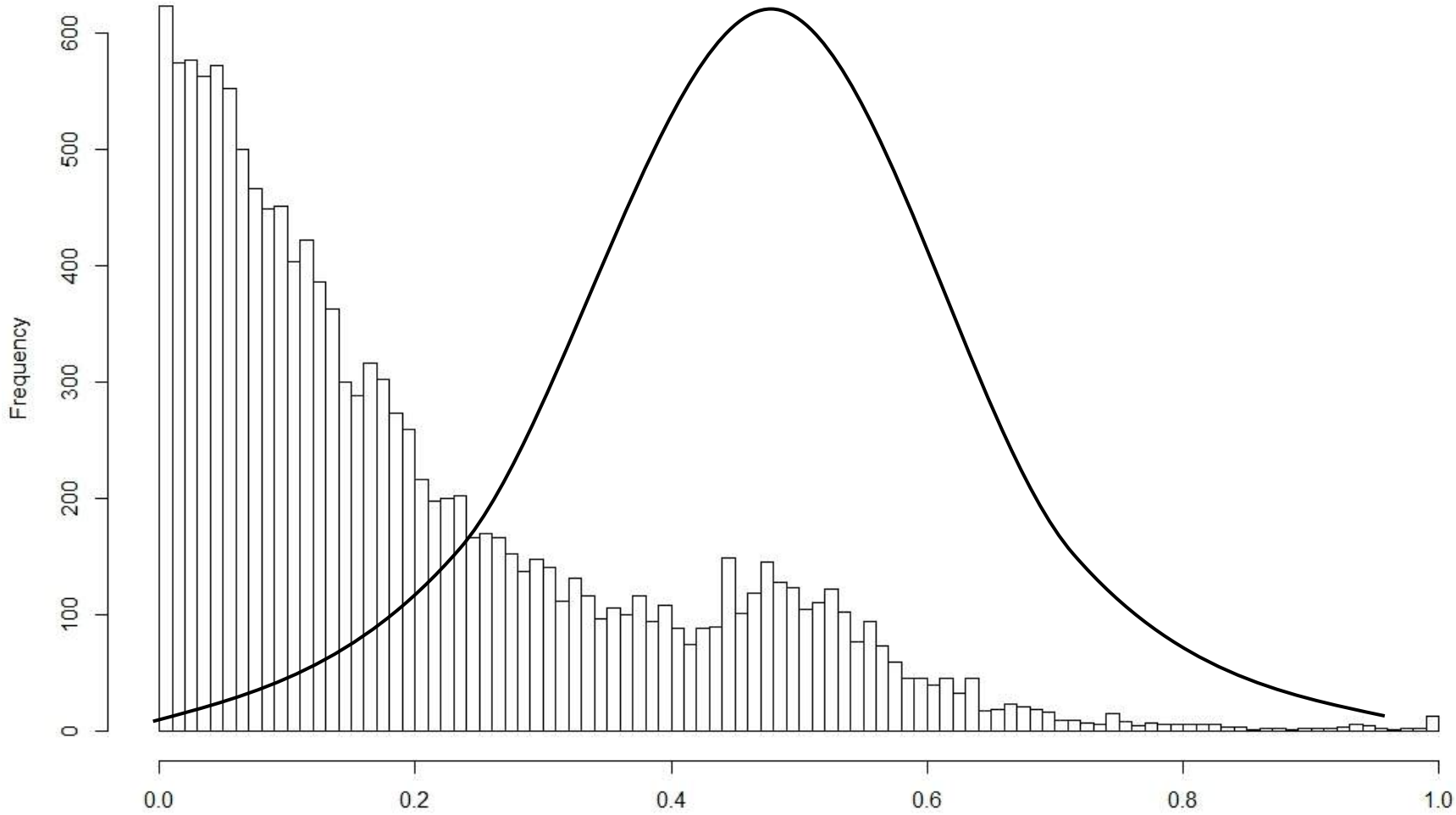
INCONGRUITY AUTHOR/ARTICLE



INCONGRUITY: DELTAS AUTHOR-ARTICLE



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PREDICTION OF EDITS

significant predictors

- article profile ***
- author profile ***
- interaction ***

conventional .....alternative

author / article	0 - 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	0.8 - 1
0 - 0.2	*	=	*	=	=
0.2 - 0.4	*	*	*	=	=
0.4 - 0.6	=	*	*	=	=
0.6 - 0.8	=	=	=	*	*
0.8 - 1	=	=	=	*	*

$\chi^2 = 339.2$, df = 16, $p < 0.0001$

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INTERPRETATION

- Controversy does not always lead to knowledge production
- authors contribute to article they agree on
- articles become less extreme over time
- authors become less extreme over time

https://upload.wikimedia.org/wikipedia/commons/f/fa/Wikipedia_scale_of_justice.png

CONCLUSION

What can network theory and methods provide for the analysis of knowledge construction?

Fits to the autopoietic framework

- preferential attachment
- structure shapes dynamics
- no external criteria for relevance, quality etc.
- features of an element are determined through the whole network

Deals with the bimodal person-artefact network

- allows to analyse dynamics of individuals
- allows to analyse dynamics of the artefact

CONCLUSION

What can network theory and methods provide for the analysis of knowledge construction?

Fits to the concept of knowledge and collaboration

- knowledge as network
- communication as network
- learning, knowledge construction as development of conceptual / communicational networks

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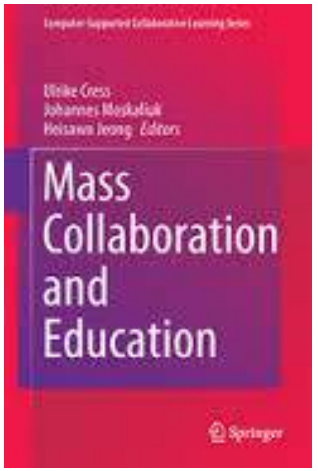

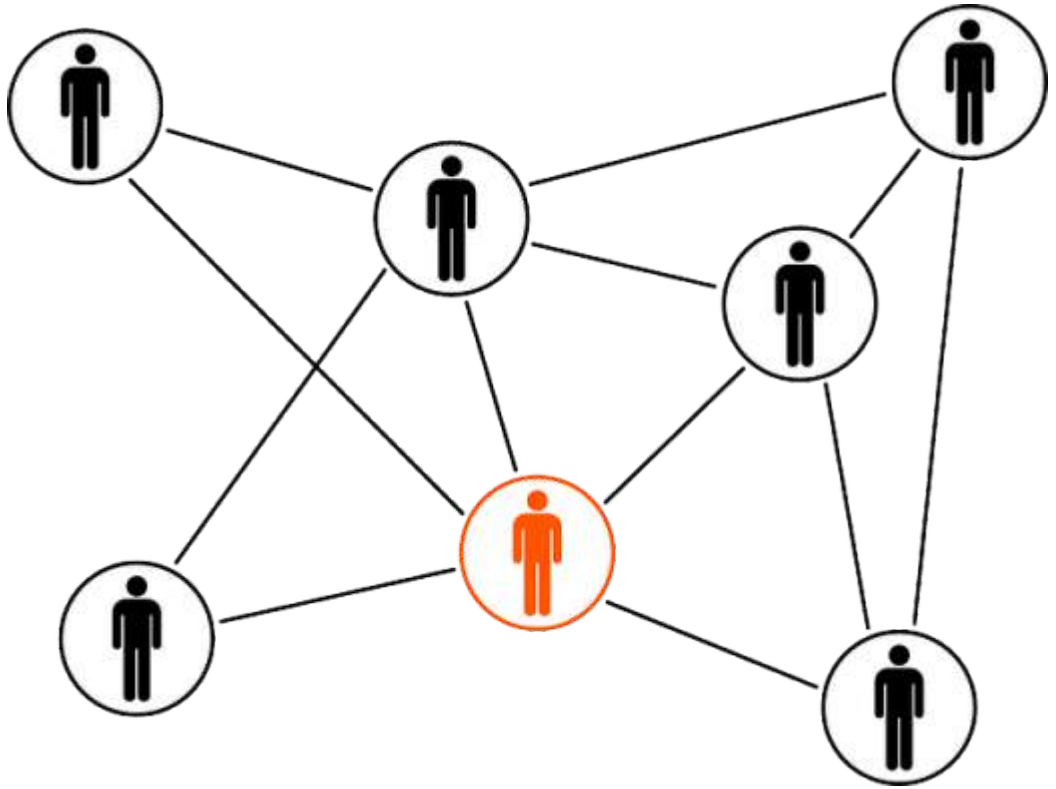

Thank you for your attention