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Information Diffusion and Attitude Change Among Cognitive Agents

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Cognitive Science Application1

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Introduction

- Graduated from the University of Illinois at Urbana-Champaign.
- Member of the Cognitive Science and Applications1 group.
- Primary project funded through the Early Career R&D process.

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Interests

- Ph.D. Thesis: “Agreement, information and time in Multiagent Systems”
- Motivation: the study of linguistic diffusion.
- General interest: The study of information diffusion.
  - What cognitive factors inhibit/excite the diffusion of information?
  - Language an instance of a more general problem.
  - Attitude change in populations.
- Important phenomena: Community resiliency, TTP diffusion, etc.

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Language Change 1/2

- Language changes at several levels:
  - Phonetically: Great English Vowel Shift (GEVS), Northern Cities Vowel Shift.
  - Lexically: New terms (“blog”, “to google”) come and old terms disappear.
  - Grammatically: Absolute constructions (see the 2nd amendment brief).

Language Change 2/2

- How does language change?
  - Individual variation;
  - Pressure to effectively communicate leads to uptake of the variation;
  - As individuals interact, the variation spreads.
- Competing forces: Individual variation vs. global homogeneity

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Why is language change interesting?

- Language is a *collective* phenomena – useful only if others use the same language.
  - How does a large population collectively agree without a central organizer?
- Language can provide insight into attitudes/beliefs of groups.
- Developing computational models of the diffusion of linguistic variants through a population.
  - What factors influence the rate of diffusion?

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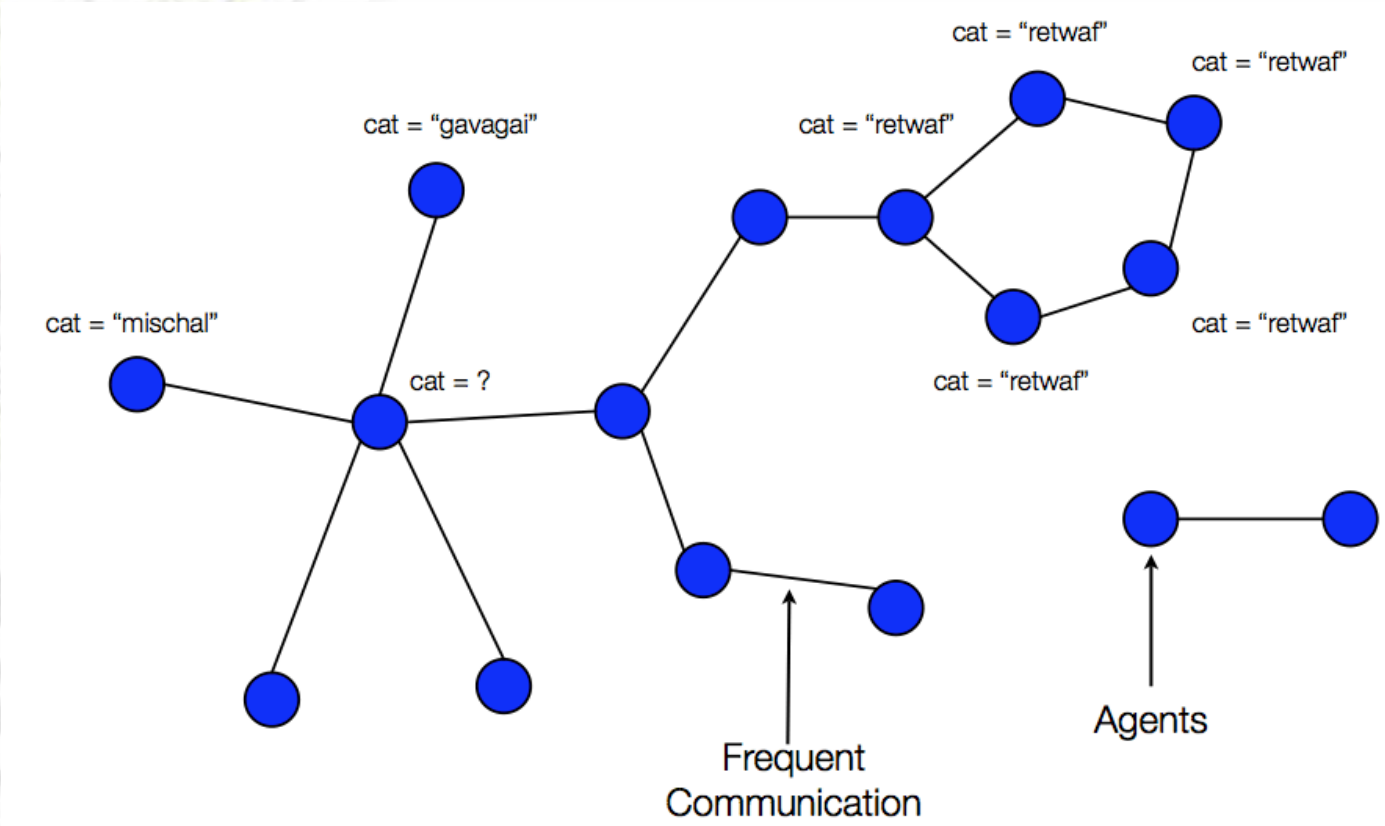
Example


cat = "retwaf"
cat = "retwaf"
cat = "gavagai"
cat = "retwaf"
cat = "mischal"
cat = ?
cat = "retwaf"
cat = "retwaf"
Frequent
Communication
Agents

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MAS model of language diffusion

- Agents represent individuals.
- Each agent has a language.
- Interaction between agents results in communication of linguistic variants.
  - "language game" concept (Wittgenstein).
- This type of framework used to study:
  - Lexical and grammatical agreement (Steels).
  - Self-organization in vowel systems (de Boer).

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Agreement Problems

- Linguistic diffusion and instance of the more general "information diffusion"
  - Information on language of speakers.
  - Information on other topics that can change attitudes.

- Innovation Diffusion (Rogers 2003)
- Emergence of norms and conventions (Shoham 1997)
- Distributed commit problem (Lynch 1997)
- Ising/Potts model (de Oliveira 1993)
- Voter Model (Sood 2005)

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- **Significant amount of analytical work**
  - **Focus on complex social networks, but not on complex cognitive models.**
  - **Just because some hears the word "gavagai" does not mean they are going to use it.**
- **What social and cognitive factors influence the diffusion of information?**

Develop computational models based on social science that can be used to explore information diffusion and are amenable to analysis.

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Research Goal

Social Science Theory

- Cognitive/Social psychology (attitude formation/change)
- Cognitive consistency theories.
- Sociology (social influence processes).
- Socio-linguistics.

Computational Models

- Multiagent system (MAS).
- Parallel Constraint Satisfaction
- Distributed Constraint Satisfaction.

DACCA: Diffusion among Cognitively Complex Agents.

Computational Models of Language Change and Diffusion.

Analysis

- Statistical Physics (Voter Model, Ising Model)
- Nonlinear Dynamic Systems (Feedback networks)
- Cellular Automata.
- Finite-state automata.

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Current Project: Diffusion Among Cognitively Complex Agents

- Funding through Lab Directed Research and Development (LDRD) program.
- Part of the Early Career Research and Development (ECR&D) element:
  - Fund PI to conduct: “high-risk, potentially high-value research”
- Project Manager: John Mitchiner (1430)
- Technical Mentor: Ann Speed (1434)

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Information Diffusion Scenarios

- Attitude change in populations.
- DHS:
  - Goal to promote community preparedness and resiliency.
- DoD:
  - Models the diffusion of tactics, techniques and procedures.
- DOE:
  - Diffusion of climate change information.

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Constraint Networks 1/2

- Constraint networks: A set of variables and links that define the valid values for the variables.
- Language:
  - Represents constraints between linguistic elements.
  - Phonetic example: vowel pronunciations should satisfy a phonetic differentiation constraint (Lakkaraju 2009).
- Cognitive consistency: attitudes, beliefs should be consistent with each other.

Constraint Networks 2/2

- Constraint satisfaction well studied in Artificial Intelligence (Yokoo 2001)
- Parallel Constraint Satisfaction:
  - Connectionist approach to solving constraint problems.
  - Similar to Hopfield networks. (Read 1994).

Socio-Cognitive Model

- Two parts:
  - Social network: Defines the interaction between individuals.
  - Cognitive network: Defines the interaction between attitudes/beliefs within individuals.
    - Cognitive consistency
    - Information distortion
    - Social network
    - Cognitive load

Constraint Networks

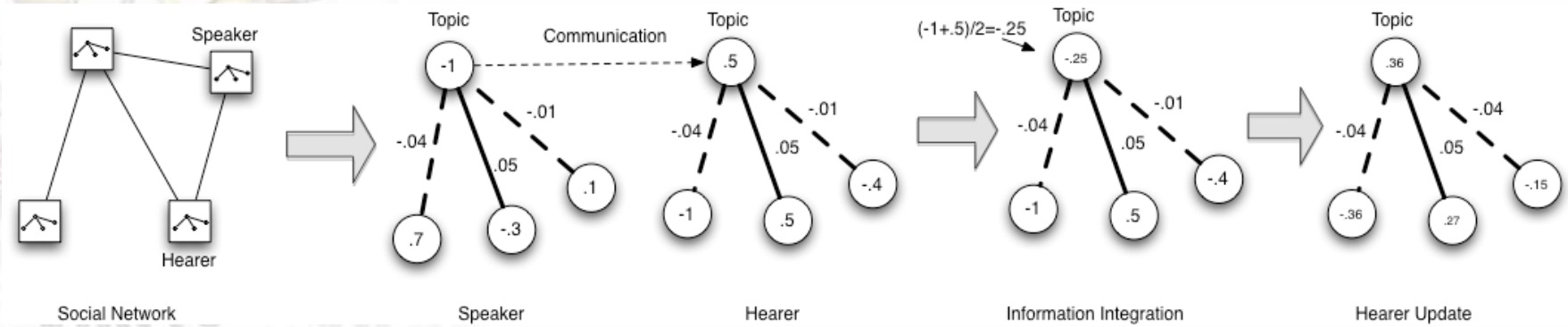
- Nodes represent *concepts*: propositions, beliefs, information, traits, actions, goals.
- Links represent positive/negative influences between concepts: entailment, explanation, deduction, similarity, association.
- Nodes have a value (i.e. -1 … +1) and a valence (+/-)
- Attitude towards a concept is determined by the value and the valence of the concept:
  - Positive value = positive feeling.
  - Negative value = negative feeling.

Example from Spellman 1993

Some Social and Cognitive Factors

- **Cognitive consistency:**
  - **Modify node values based on interacting with other nodes.**
- **Cognitive load:**
  - **Modulate the change in node values.**
- **Information distortion:**
  - **Manipulate the effect of another agents node value.**
- **Social context:**
  - **Social network neighborhood affects change in node value.**

Socio-Cognitive Model



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Current status

- In early stages of funding.
- Preliminary work with a simple cognitive network
  - How social network topology can influence the collective agreement.
  - Polarization occurs for small-world and lattice networks.

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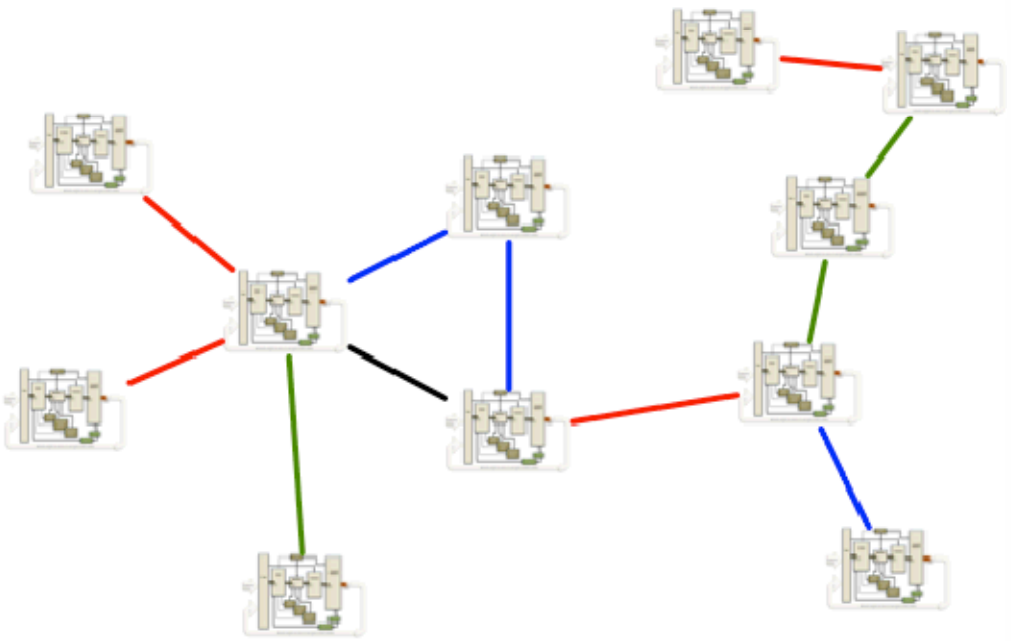
Future Work

- **M. Bernards Influence Operations project provides a High-Definition Cognitive Model (HDCM)**



HDCM diagram courtesy of
Michael Bernard

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Summary

- **Motivation:**
  - **Understand the factors the influence information diffusion.**
- **Plan:**
  - **Develop a socio-cognitive model using a constraint network representation.**
- **Potential impact:**
  - **A “what if” tool.**

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Research Goal

Develop computational models based on social science that can be used to explore knowledge diffusion and are amenable to analysis.

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Informational Influence

- Dissemination of information through interaction.
- Learn about reality from others (a trait found primarily in humans).
- Examples:
  - Neighbors discussing new innovations in farming.
  - Music trends via discussion with friends.
  - Linguistic trends through discussion with others.

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Computational Models of Informational Influence

- Innovation Diffusion
- Opinion Dynamics
- Linguistic change
- Network topology and impact on diffusion:
  - Voter model
  - Distributed function calculation
- Primarily focused on extremely simple models of individuals.
  - Two states.

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What about the *cognitive* aspect?

- Exposure to information does not mean acceptance of information.
  - Just because your friend says “gavagai” does not mean you say it as well.
- Influences:
  - Cognitive consistency.
  - Cognitive Load.
  - Information distortion.
  - Social context.

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Constraint Satisfaction

- How do we bring together the body of work on social factors along with the cognitive factors into a model that allows:
  - Manipulation of the variables.
  - Analysis.
- Our perspective: Many of the cognitive influences can be captured through *constraint networks:*
  - Representation of the interaction between attitudes/beliefs as constraints.

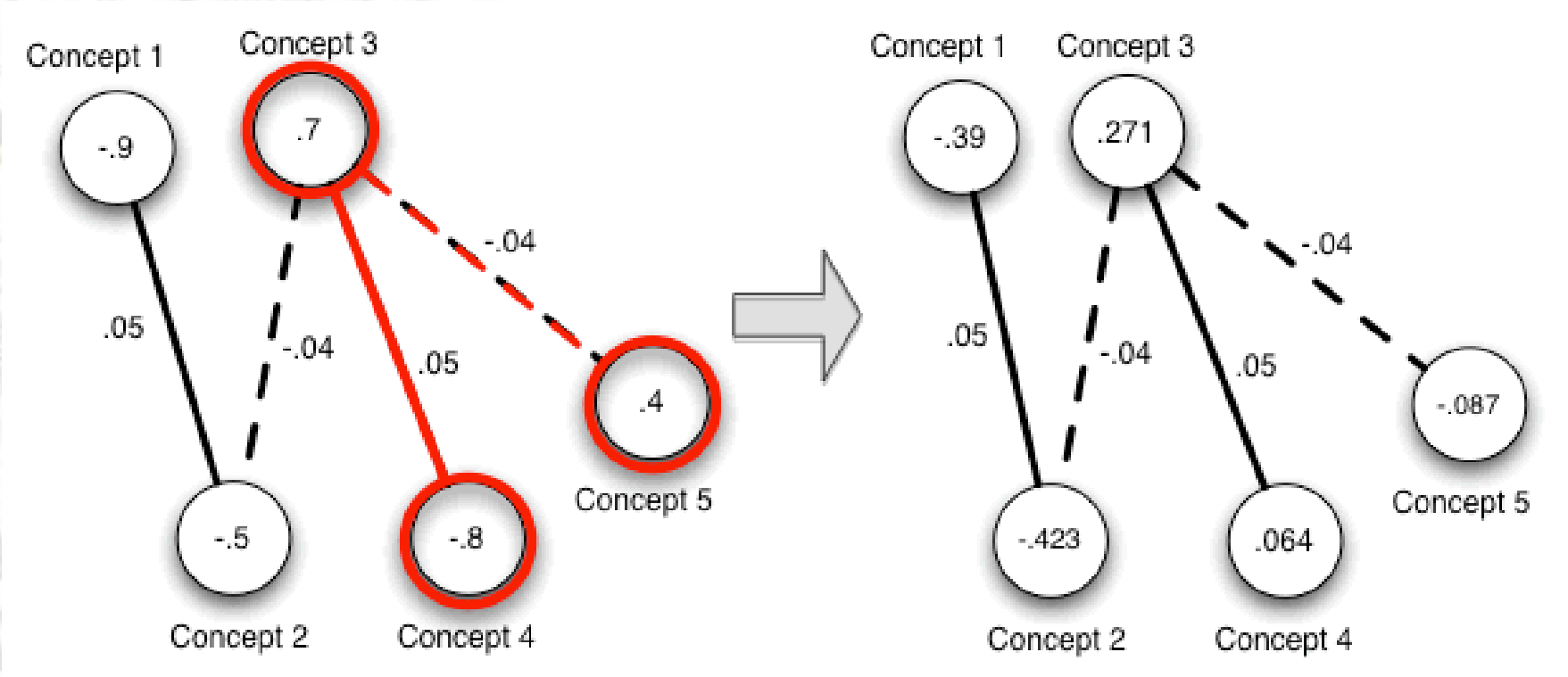
Impression Formation (IMP) model

$$a_j(t+1) = a_j(t)(1-d) + \begin{cases} net_j(\max - a_j(t)) & \text{if } net_j > 0 \\ net_j(a_j(t) - \min) & \text{if } net_j \leq 0 \end{cases} \quad (1)$$

where:

$$net_j = \sum_i w_{ij} a_i(t) \quad (2)$$

Example Dynamics



Related Scenarios

- **Language change:**
  - **Phonetic: Pronunciation shifts based on vowel discernibility.**
  - **Lexical: Competition between words that represent the same concept.**
  - **Grammatical:**

Mission Relevance

- **Community Resiliency**
  - **DHS goal to promote community preparedness and resiliency.**
- **DOD:**
  - **Models the diffusion of tactics, techniques and procedures.**
- **DoE:**
  - **Diffusion of climate change information.**

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Types of social networks.

- Complete
- Lattice
- Scale Free
- Small World
- Random

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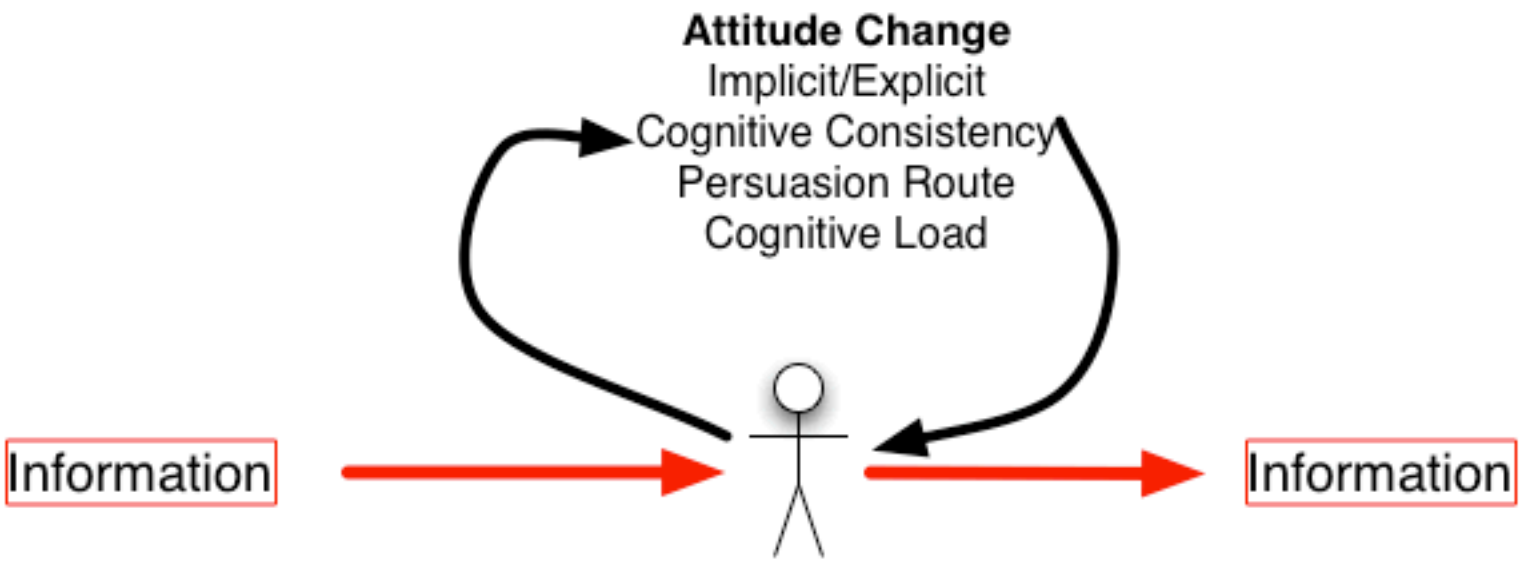
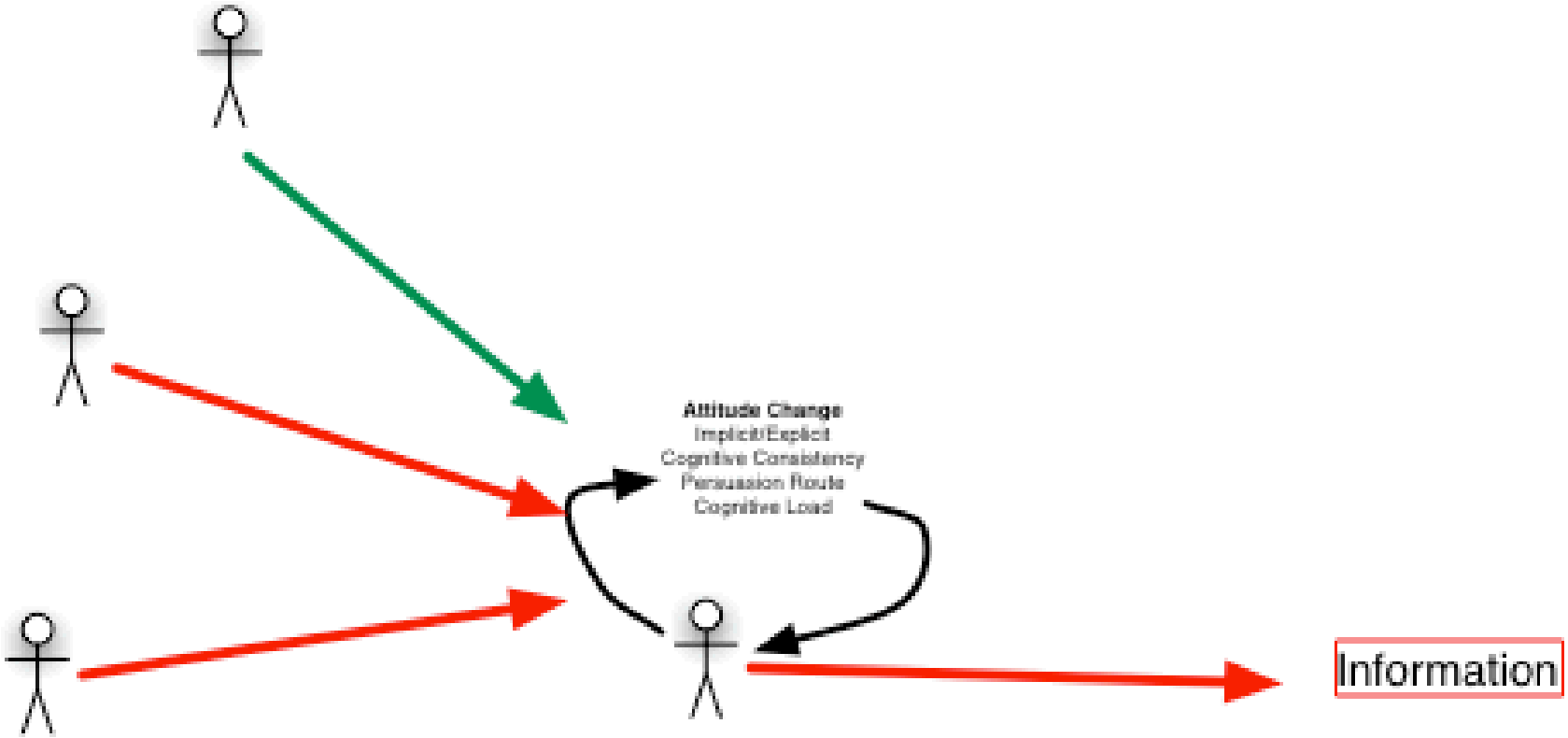

Attitude Change
Implicit/Explicit
Cognitive Consistency
Persuasion Route
Cognitive Load
Information
Information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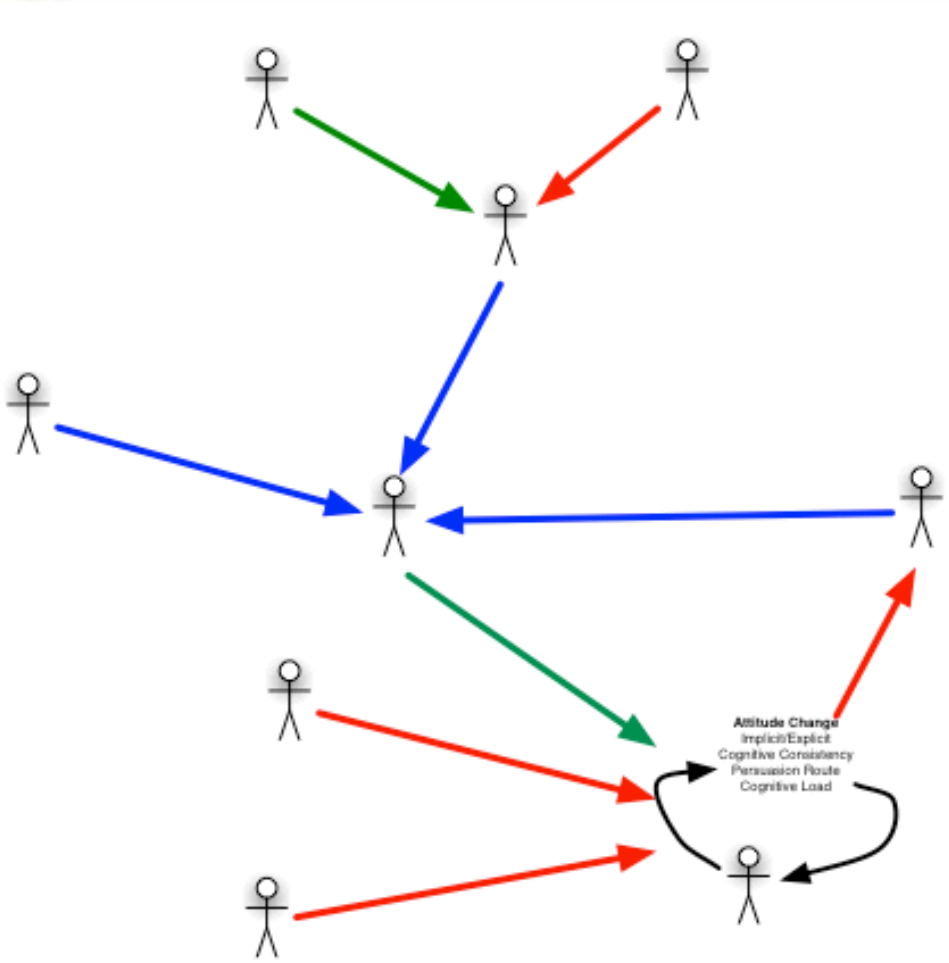
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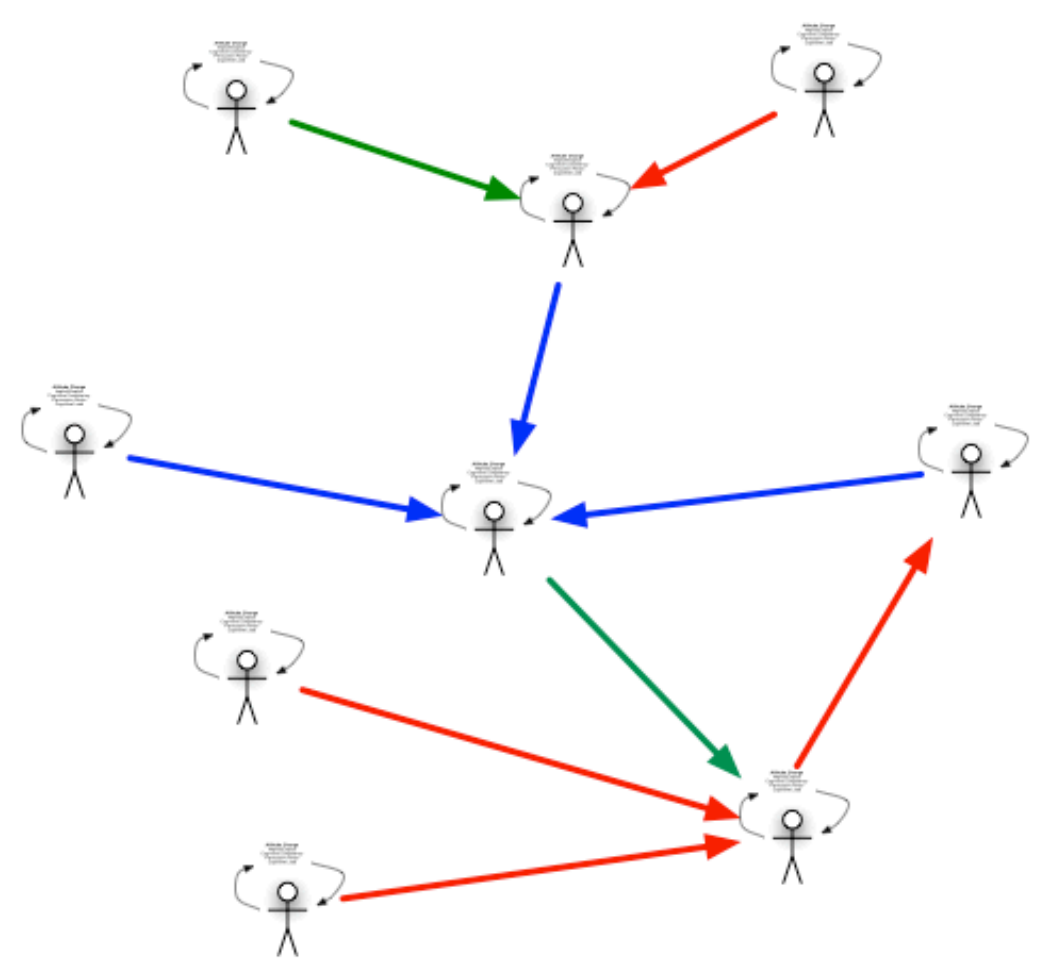

Cognitive Consistency Theories

- Gestaltian notion.
- Individual elements of thought linked to others.
- Applications:
  - Theory of Cognitive Dissonance (Festinger).
  - Balance Theory (Heider).
- Consistency is a driver for information distortion (Russo et. al 2008).

How do attitudes change?

- New information.
  - Experiential.
  - Social – learning from others (a unique human capability).
    - Shared communication system, erroneous statements, interpretation errors, etc.
-

Three questions

- **Three questions:**
  - **Does linguistic diffusion occur?**
  - **How long does diffusion take?**
  - **What language is agreed upon?**