An Expanded Feedback View of Decision Maker Mental Models

Alexander Y. Lubyansky, PhD Student
Rockefeller College of Public Affairs and Policy, University at Albany
135 Western Avenue, Albany, NY 12222
alubyansky@gmail.com

Abstract

It may be useful to simulate the feedback dynamics of individual and group decisionmaking to study certain problems, like the diffusion of insurgent tactics. A good place to begin is to expand on Richardson, Andersen, Maxwell, & Stewart's (1994) SDS conference paper on mental model research.

The main part of this paper elaborates on Richardson et al.'s causal map by incorporating theories necessary to make a more "complete" representation of the decision process. The theories include theories of cue perception and interpretation, mental models, decision-making, attention (salience), and social influence. The paper concludes with a small, initial simulation of part of the decision-making and social influence dynamics and shows how the model can accommodate external datasets.

Key Words: Diffusion, Mental Models, Perception, Judgment, Social Influence, Salience

Introduction

Generic Problem

It is difficult to study the dynamics of systems where the important behavior comes from heterogeneous decision makers communicating ideas with each other and making boundedly rational judgments based on those ideas. Several features characterize this generic kind of problem:

1. **Data** needed to understand decision maker mental models and social networks may be **qualitative, sparse, and imprecise**. Despite this, the amount of data may be quite **large** if it includes the issues, goals, actions, influence relationships, etc for all relevant decision makers.
2. There may be **no data about individual decision makers**, but rather **proxy data** about events in the world, with little or no idea about what particular individuals or groups caused these events.
3. The important dynamics of decision maker **social cognition** and **social influence** are **theoretically complex**.
4. The combination of complex theory and a set of problematic data make it very **difficult to analyze** the whole problem using **qualitative methods** such as mental simulation and role-playing.

Example Problem: Diffusion of Insurgent Tactics

A concrete example of this generic problem is the problem of predicting the diffusion of insurgent tactics. Insurgents pose a difficult threat to counterinsurgents such as the US in Iraq

and Afghanistan. Cells can rapidly change their tactics to respond to and even anticipate counterinsurgent actions (see Figure 1). It is too difficult to predict exactly which new tactics insurgents will use, but it may be useful to understand how tactics "diffuse" throughout an insurgent population.

Figure 1. Counterinsurgent and insurgent adaptation to each others' tactics.

The known data (START, 2009) about insurgent tactics is uneven:

1. We know **most** about what happened (group A attacked target B on date C using method D).
2. We know a **bit less** about the networks involved (group A's members, their interactions with each other and their interaction with other actors). However, we can estimate the composition and communication patterns of "typical" cells.
3. We know **even less** about mental models. How did the cell decide to use one tactic or another? Interviews are difficult (impossible?) and self-reporting on these matters is unreliable.

From the Global Terrorism Database (START, 2009), one of the most comprehensive open source databases on terrorism, we can find or derive the following information:

- **Who**
  - Insurgents – estimate their attributes and identities based on region, demographics, or randomly; some groups claim responsibility for attacks or are identified
- **What**
  - Actions (insurgent attacks)
  - Target type (government, military, etc)
  - Target (in cases where the specific target is important)
- **Where**
  - Countries, regions, cities, neighborhoods
- **Why**
  - Self-claims
  - By attacker identity
- **When**
  - Date
- **How**

    - Suicide or not
    - Number of attackers
    - Weapons used
    - Vehicles used
    - Method of attack
- **Outcomes**
    - Success or failure
    - Targets killed, wounded, captured
    - Perpetrators killed, wounded captured
    - Property damage

Approach

Given a problem, such as diffusion of insurgent tactics, with the above-mentioned theoretical and data problems, one potential approach is to develop an integrated **theory** dynamics of decision maker mental models, make that theory into a **simulation model**, and test the simulation model against the existing **data**. This approach allows quantified, theoretically-sound modeling of data otherwise unsuitable to model decision maker dynamics.

Theory

The proposed theory for the system dynamics model comes from an integrated and inherently boundedly rational view of decision maker social cognition and social influence. This view corresponds with the system dynamics assumption of bounded rationality and represents the main processes within the "system boundary" of social cognition and social influence.

The main inspiration for this integrated theory comes from the expanded dynamic hypothesis (Figure 7) of Richardson, Andersen, Maxwell, & Stewart's (1994) research into the feedback dynamics of mental models. The integrated theory in this paper builds out on this hypothesis such that the new hypothesis (Figures 3, 4, and 8) resemble Richardson, Andersen, Maxwell, & Stewart's (1994) hypotheses (Figures 5 and 7).

At a high level, the theories used in this section fall under the subsections of Cue Perception and Interpretation, Mental Models, Decisionmaking under Uncertainty, Salience, and Social Influence. These theories largely coincide with the viewpoints of other system dynamics models of integrated social cognition (Deegan, 2005; Martinez-Moyano, 2005; Martinez-Moyano, McCaffrey, & Oliva, 2005; Rahn, 2005; Rich et al., 2005; Weaver & Richardson, 2006).

Cue Perception and Interpretation

Boundedly rational models of cue perception and interpretation come originally from the Brunswik Lens Model (Brunswik, 1939, , 1952; Wolf, 2005). This model shows the perception of data about an uncertain environment by the (human) organism as indirect. Basically, a given phenomenon has various characteristics that can be perceived and interpreted by a person as **cues**. Only via these cues does the person get an understanding of their environment, even though this understanding is biased and uncertain.

In the policy process literature, there is a set of scholarly work (Baumgartner & Jones, 1993, , 2002; Birkland, 1997, , 1998, , 2001; Jones & Baumgartner, 2004, , 2005a, , 2005b; Kingdon, 1995; Lindblom, 1959; Sabatier, 1999) dedicated to understanding policymaking from a

boundedly rational perspective. In their theory, Jones & Baumgartner (2005b) use a cue-based model to describe individual and organizational policy maker perception and interpretation. In their model, the policymaker only sees the world through a set of biased cues. Furthermore, the policy maker can only perceive the cues by paying attention to them or making them salient (more on salience later). This process is shown in Figure 2.

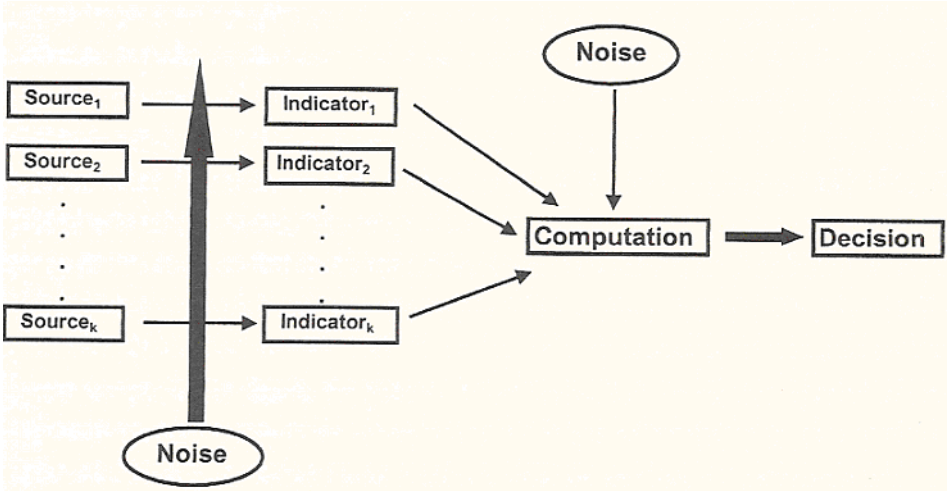

Figure 2. Baumgartner & Jones' (2005b) depiction of cue perception and interpretation.

For the proposed method, the implication of a cue-based model of perception is that there are four kinds of cue-related ideas and states:

1. A **state of the world.**
2. A **cue** about the state of the world.
3. A **perceived state of the world.** The speed with which states of the world are perceived depends on the **salience** of the cues informing the perceived state. A decision maker can only perceive a state of the world if he or she is paying attention to the relevant cues.
4. A **goal**. Both a perceived state of the world and a goal state of the world are necessary to form a gap. The gap allows perceptions to be understood as a mental model idea about a problem, a solution, or a causal explanation.

Figure 3 shows the part of the Dynamic hypothesis that relates to cues.

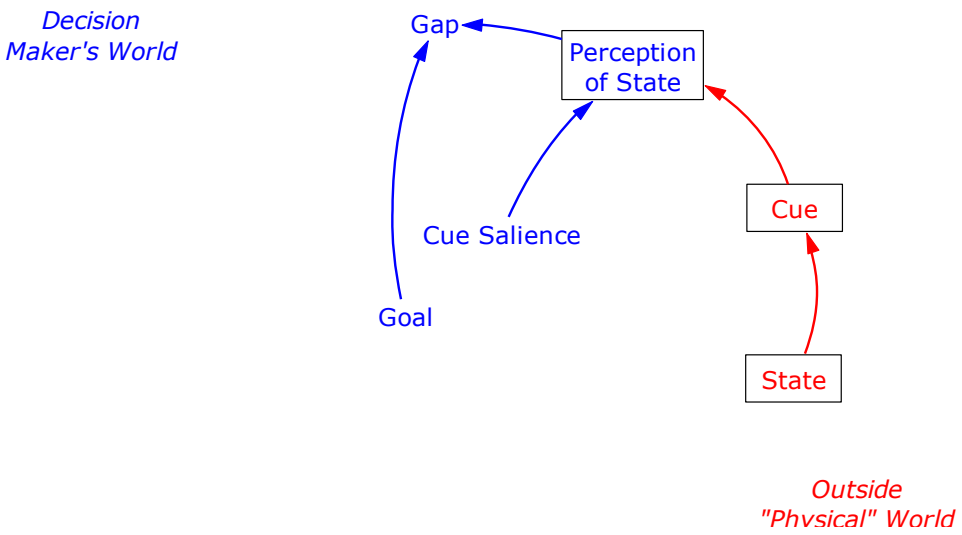

Figure 3. State of the world, cue perception, and cue interpretation.

Mental Models

Mental models are central to most models of boundedly rational cognition (Craik, 1943; Johnson-Laird, 1983), certainly so in the system dynamics community (Sterman, 2000). In the theory of mental models, a person has a representation of all their knowledge in the form of a set of interconnected symbols or ideas.

Mental models may be divided into several kinds of ideas. The most relevant to the decision maker decision view of mental models are ends, means, and means-ends ideas (Richardson, Andersen, Maxwell, & Stewart, 1994). These correspond to the **problems**, **solutions**, and **causal explanations** in the decision maker's mind. This representation is backed up by organizational and policy process theories of decisionmaking (particularly the Garbage Can Model of Organizational Choice), even though these models often implicitly represent causal explanations (Cohen, March, & Olsen, 1972; Jones & Baumgartner, 2005b; Kingdon, 1995).

There are three kinds of mental models ideas (aside from the aforementioned perceived states and goals). These ideas come from perceived states and goals and are used to make decisions.

1. A "**problem**" idea is the "ends" part of a mental model. The statement behind a problem idea is, "Problem X is important and needs to be addressed now."
2. A "**solution**" idea is the "means" part of a mental model. The statement behind a solution idea is, "Solution Y is feasible and available for use now."
3. A "**causal explanation**" idea is the "means-ends" part of a mental model. The statement behind a causality idea is, "Solution Y is effective at addressing problem X."

Operationally, the attributes that measure problem, solution, and causality ideas in the model are **certainty**, and **salience**. Certainty is the degree to which the decision maker is convinced that the statements in the above list are true. For example, a problem idea held with great certainty means that the decision maker strongly believes that problem is important and urgent. Certainty changes based on the **gaps** in perceived states and goals relevant to the mental models idea. For example, if a principal's goal compliance is much higher than perceived compliance, they will eventually acquire the strong belief that compliance is a serious and urgent problem.

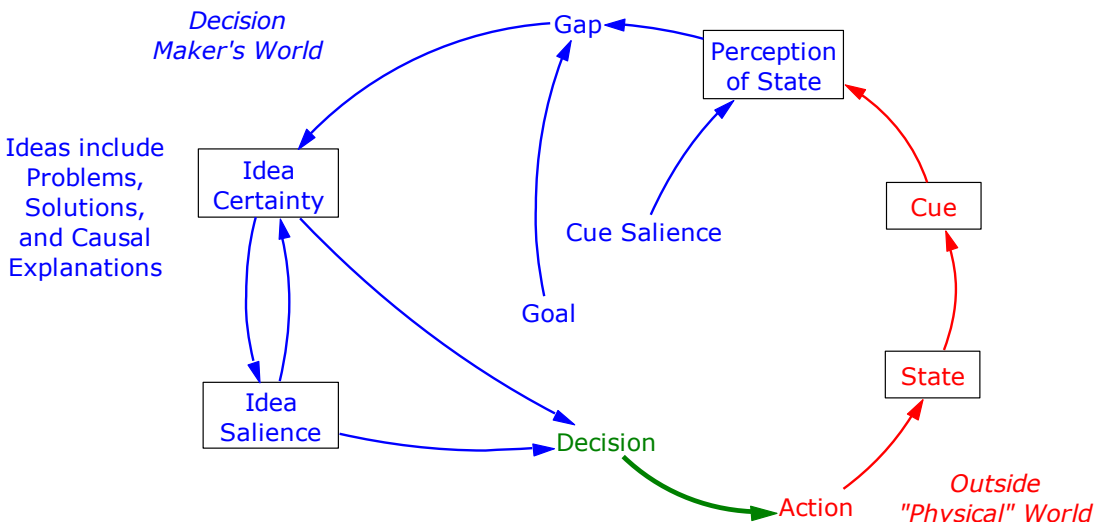

Figure 4. Mental model ideas, decisions, and actions to change the state of the world.

Salience is the degree to which the decision maker is paying attention to an idea. The dynamics of salience are explained later. **Decisions** are made based on the certainty and salience of mental model ideas about problems, solutions, and causal explanations. A combination of **certain** and **salient problem**, **solution**, and **causal explanation** creates **pressure** for a decision.

These decisions lead to **actions** which may be aimed at correcting the state of the world, forming a long feedback loop. Figure 4 shows the part of the Dynamic hypothesis that illustrates this process. This partial dynamic hypothesis highly resembles the system dynamics diagram of Richardson, Andersen, Maxwell, & Stewart's (1994) basic dynamic hypothesis in Figure 5.

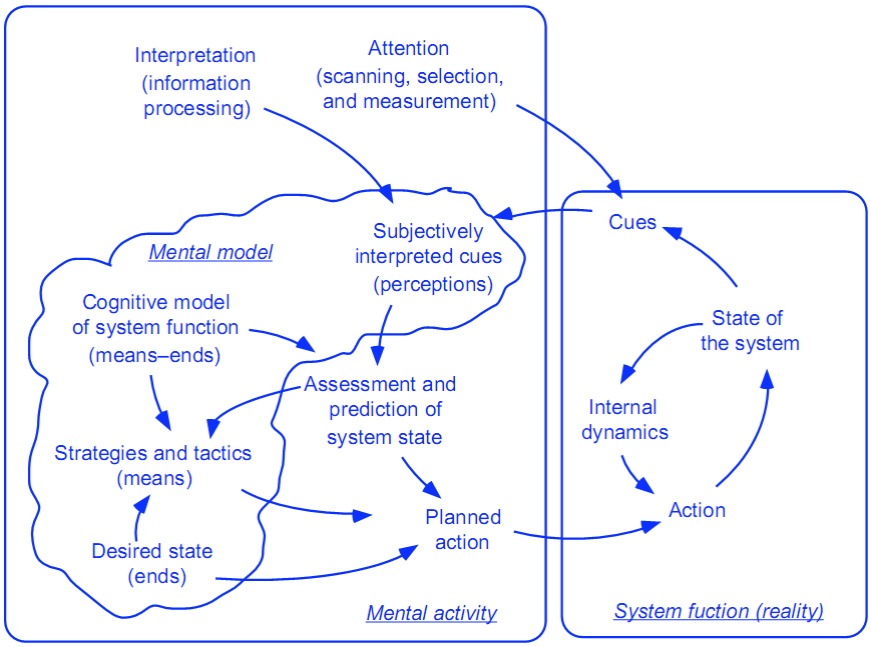

Figure 5. Richardson, Andersen, Maxwell, & Stewart's (1994) basic model of cognition.

Decisionmaking under Uncertainty

The model of decisionmaking in the proposed method comes from both boundedly rational models of analytical decisionmaking and from a boundedly rational model of intuitive decisionmaking. These models confirm the dynamic hypothesis in Figure 4 and suggest that the decision maker's actions include those shown in Figure 6.

The analytical models are the Garbage Can Model (Cohen, March, & Olsen, 1972) and its policy process descendents (Jones & Baumgartner, 2005b; Kingdon, 1995). These models specify that when there is an urgent **problem**, a feasible **solution**, and a believable **causal explanation** that the solution addresses the problem, and then a decision is make to apply the solution to the problem. Jones & Baumgartner (2005b) make the important amendment that these mental models ideas must be salient for the decision to occur.

In Kingdon's and Jones & Baumgartner's models, there is also mention of actions other than the enactment of policy to change the state of the world. Before, during, and after proper "decisions", the decision makers in policymaking change their goals, the attention that they pay to cues and mental model ideas, and the mental model ideas themselves.

The intuitive model is the Recognition-Primed Model of Decisionmaking (Flin, 1996; Klein, 1998). This model, developed from empirical research into decisions taken under great stress and time pressure in uncertain environments, suggests three types of intuitive decisions.

In a **simple match** decision, the decision maker perceives a situation through a set of indicators and automatically matches the situation they indicate with an action. In a **diagnosing the situation** decision, the decision maker has cues that don't perfectly match potential actions. In this case, the decision maker must think harder about the indicators, matching them up feature by feature to possible actions. In the final type of decision, called **evaluate course of action**, the decision maker cannot match the indicators to the action without a suspicion that something important does not fit. The decision maker mentally simulates the situation to double-check the decision and try to customize it to fit the environment.

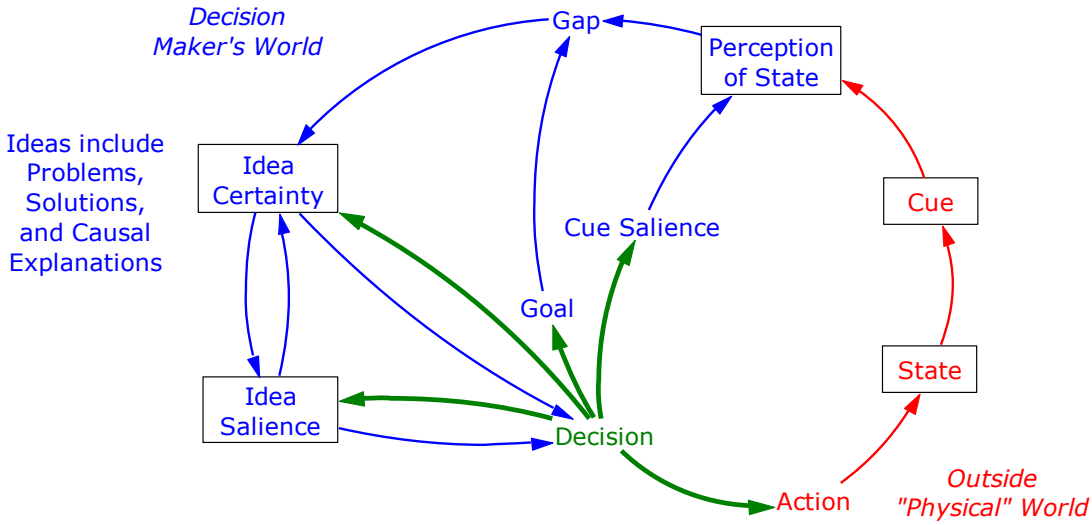

Figure 6. Different kinds of actions.

Like the analytical models, this model suggests that the decision maker's **decisions include changes to cue salience, goals, idea certainties, and idea saliences**. The dynamic hypothesis in Figure 6 shows these additional decisions and largely overlaps with the representation of these decisions in Richardson, Andersen, Maxwell, & Stewart's (1994) expanded dynamic hypothesis shown in Figure 7.

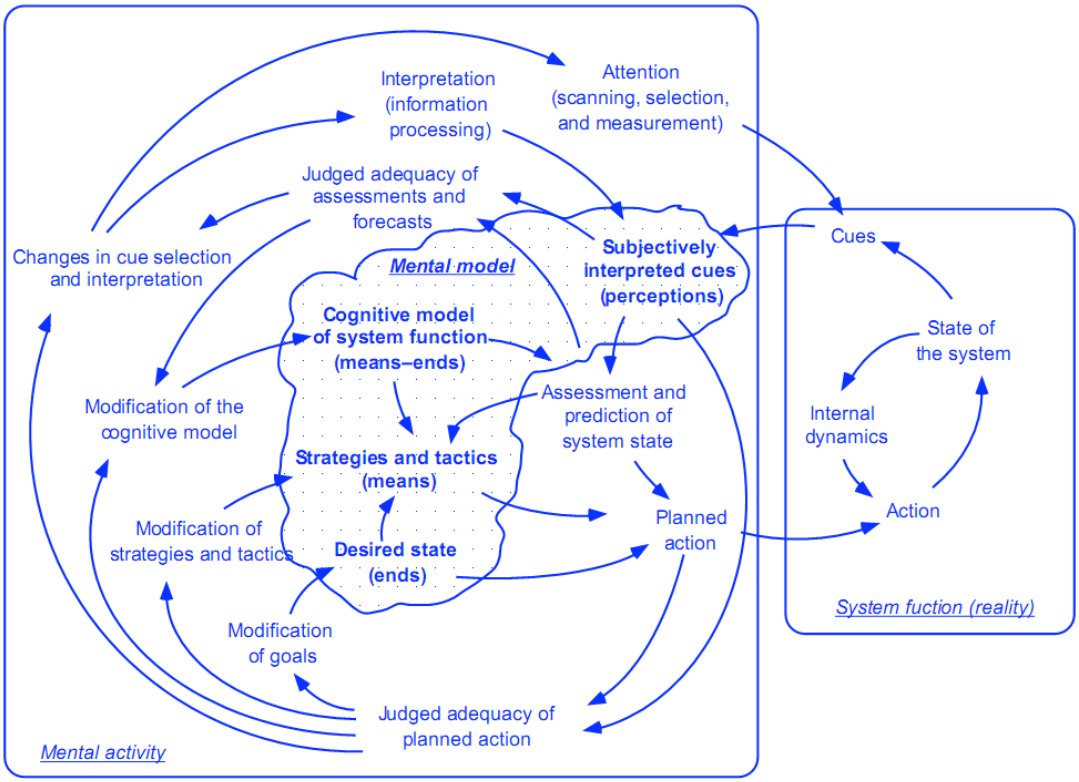

Figure 7. Richardson, Andersen, Maxwell, & Stewart's (1994) expanded model of cognition.

Salience

Salience means prominence and is used in theories of social cognition and social influence to describe the degree to which a person pays attention to an idea or cue (Wikipedia, 2009). There are several basic determinants of salience.

The first determinant of salience is **direct experience**. The more exposure a decision maker has to cues and communications from other people (social influence is discussed later), the higher the salience of the perception of the relevant cues and mental model ideas. This can be extrapolated into the idea that changes in cues and mental model ideas also create salience. If something changes rapidly, the more one can be said to "experience" it.

The second and third determinants of salience are the degree to which ideas relate to **consequences** for- and **aspirations** of- the decision maker. This means that important problems, feasible solutions, and convincing causal explanations have more salience. In summary, high idea certainty leads to high idea salience and low idea certainty leads to low idea salience.

Jones & Baumgartner's (2005b) understanding of salience in a policy process context also adds the following properties of salience:

1. **Attention inertia**: Attention, once focused on a given cue or mental model idea, tends to stay there by default. This suggests that the salience allocated to a given cue or mental model idea is a system dynamics stock.
2. **Attention shifting**: Powerful government decision makers tend to stop paying attention to a policy once it has been dealt with, as new and different issues demand attention. This goes along with the positive effect of idea certainty on idea salience.
3. **Threshold effects**: Policy makers will not perceive information to be serious enough to act upon, until it passes some threshold of importance. This threshold is variable, and shifts over time for various reasons. This goes along with the conclusions of the Decision Making under Uncertainty section, where a combination of problem, solution, and causal explanation needs to be certain and salient for a decision to occur.
4. **Agenda crowding**: An organization can only pay attention to so many issues at once. Agenda crowding makes it harder for new issues to get attention. This suggests that total salience is limited, a bottleneck on the amount of attention that can be focused on any one cue or mental model idea.
5. **Friction/overreaction**: If policy makers have been ignoring or not adequately dealing with pressures for change, the acknowledgement of these pent up pressures often leads policy makers to overreact in their response to a policy issue. This rule is not immediately applicable to the proposed model.
6. **Cascades/herd mentality**: The more a given issue, problem, or solution gains attention with policy makers, the more others mimic this attention. This suggests that salience positively affects idea certainty, which therefore positively affects idea salience, creating a positive feedback loop.
7. **Sieves/sequential selection**: Policy makers go sequentially through alternative sets of policy issues, problems, and solutions, rather than paying attention to all of them at once. This conforms to the "agenda crowding" idea.

Social Influence

Social influence models have two roots. The theoretical root is in organizational behavior and social psychology studies, including pioneering work by Asch (1956), Festinger (1954), and French (1956). The methodological root is in dynamic network models of contagion and diffusion, including research by Schelling (1971), Friedkin & Johnson (Friedkin, 1993, , 1999; Friedkin & Johnson, 1990, , 1999), Axelrod (1997), Sznajd-Weron & Sznajd (2000), Hegselmann & Krause (2002), Deffuant, Amblard, Weisbuch, & Faure (2002), Lorenz (2007), and Stauffer (2007).

While differing in their focus and algorithms, these models share the same heritage and many of the same features. Broadly, social influence models are subsets of contagion/infection/diffusion models (Monge & Contractor, 2003, pp. 173-182) such as the SIR and Bass Diffusion models with which system dynamics scholars are familiar (Sterman, 2000, pp. 295-347).

In a generic social influence model, the "disease" being spread is an opinion. At the beginning, a group of people have a set of different opinions; as they communicate with each other, changes in opinions spread from person to person. The basic dynamic is a negative feedback loop where the receiver's opinion seeks to match the sender's opinion, given several factors. Possible

outcomes of such a model include convergence to a single equilibrium opinion, a "fracturing" of the group into two or more equilibrium opinions, oscillations in opinions, and various other behaviors.

In social influence models, the following factors may affect the process of spreading an idea from a message sender to a message receiver:

1. The **inherent persuasiveness** of the sender to the receiver. This is a catch-all constant that encompasses charisma, power relationships, social similarity, institutional reporting structures, etc. This factor is not immediately applicable to the proposed model.
2. The **frequency, length, and intensity of communication** by the sender to the receiver. The more the amount of communication, the more salient the sender's message is to the receiver and the more chances the sender has to sway the receiver's opinion.
3. The **difference between sender and receiver opinions**. This is known as "bounded confidence", where the more of a gap there is between sender and receiver opinions (certainties of mental model ideas), the less the sender's opinion will change. However, since the difference between opinions is what drives social influence, if there is little gap then the receiver's opinion does not change much. Therefore, the largest change in receiver opinion comes from a "medium size" gap.
4. The **certainty** of the receiver's opinion. The more certain the receiver is of a mental model idea, the harder it is to sway them. For example, if a principal becomes convinced that there is a compliance problem, it becomes more difficult for social influencers to convince the principal otherwise.

Figure 8 shows the basic "macro" factors of social influence in the dynamic hypothesis.

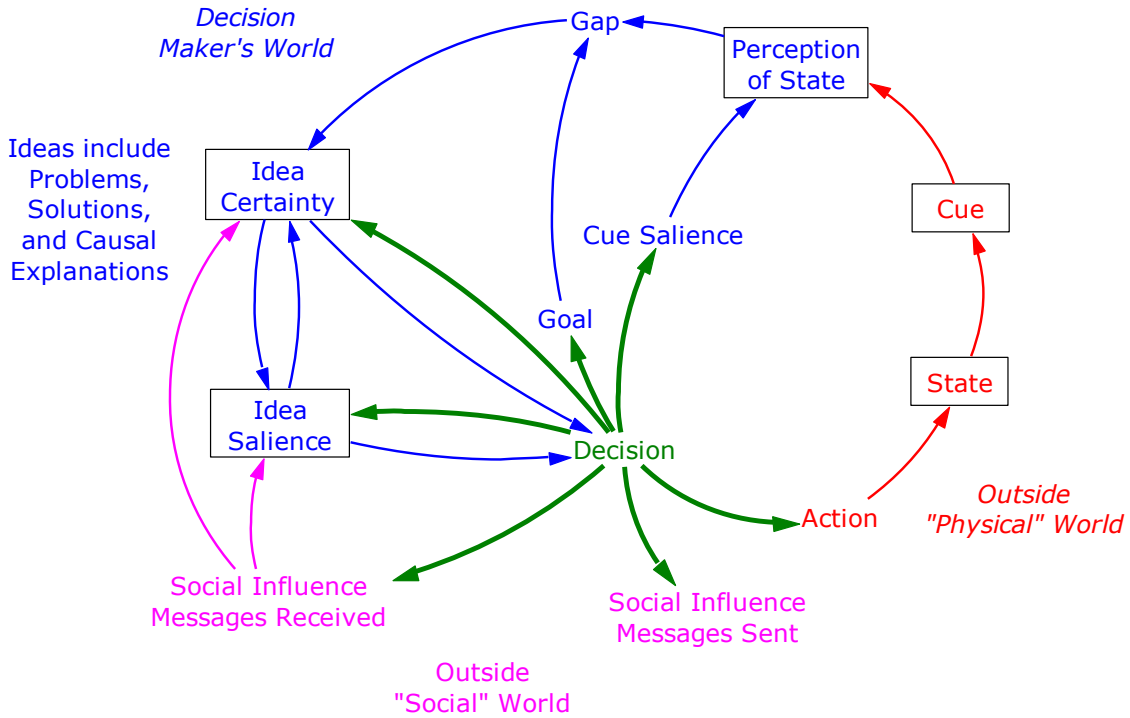

Figure 8. The final dynamic hypothesis, showing social influence inputs and outputs.

Simulations

Inspirational Simulation Models of Diffusion

The simulation models that are most relevant to diffusion (Monge & Contractor, 2003, pp. 173-182) come from the marketing, epidemiology, sociology, and econophysics communities. The main examples of these models are the Bass Diffusion model, the SIR model, the Friedkin & Johnson model, and the Hegselmann & Krause model. The basic stock and flow dynamics of these models are shown in Figure 9.

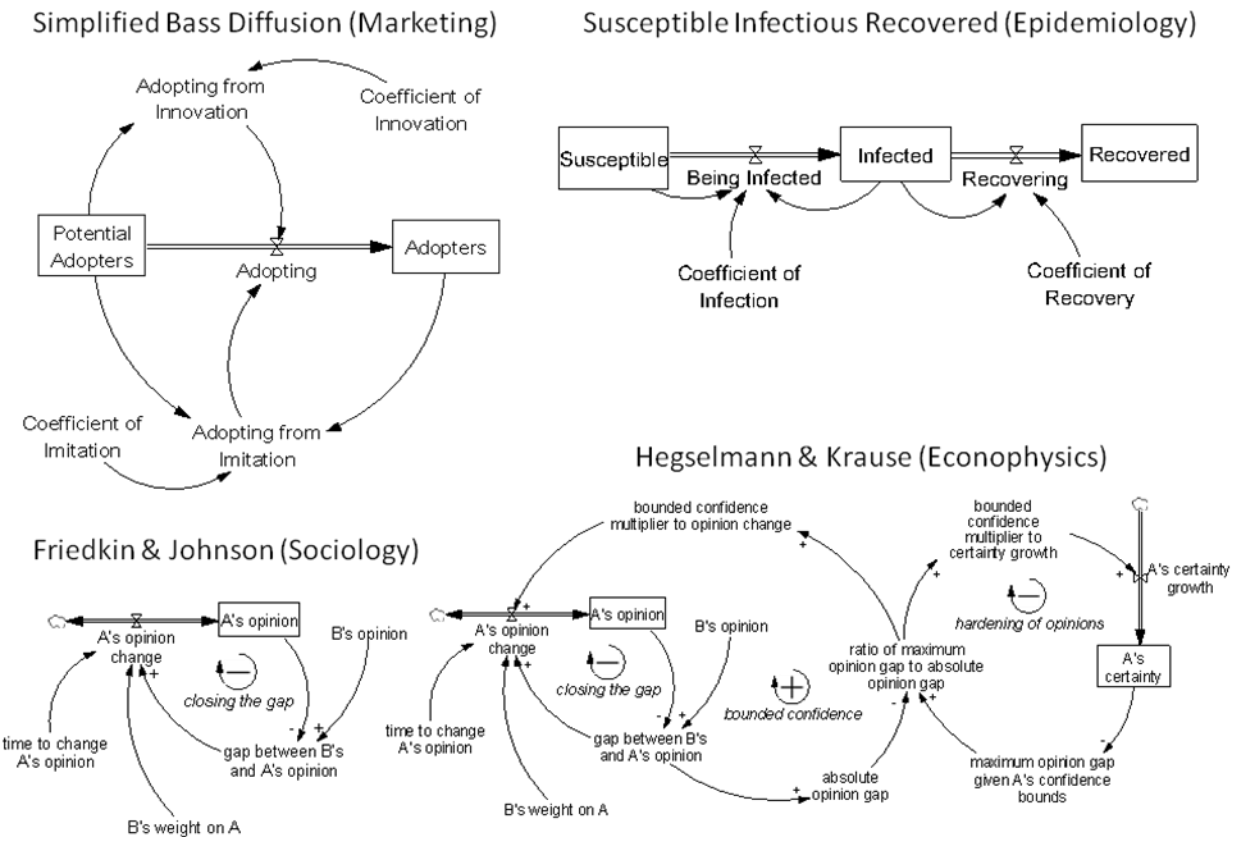

Figure 9. Various diffusion models.

The prototype model of decision maker idea diffusion developed comes from all these models. The next few figures show how this new model is related to the more common diffusion models, using the Bass Diffusion and SIR models as an example. Figure 10 shows the loop common to both these models from Figure 9, but with different names for the relevant variables.

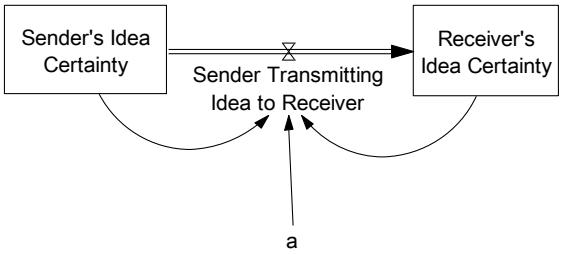

Figure 10. Basic diffusion model.

Notably, in Figure 10, the "susceptible" population is actually a stock of a sender decision maker's certainty of some idea (see theory in the previous section) and the "infected" population is a similar stock of a receiver decision maker's certainty of that idea.

The unit of analysis has moved from a population to an individual and the scale of the idea has moved from present/absent to a range of certainty/uncertainty. People are not "converted" by an idea. Rather, the ideas are in various individuals' heads to some degree and change due to communication.

Unfortunately, Figure 10 violates the laws of physics. Information does not obey the law of material conservation and thus the flow structure needs to be changed, as shown in Figure 11.

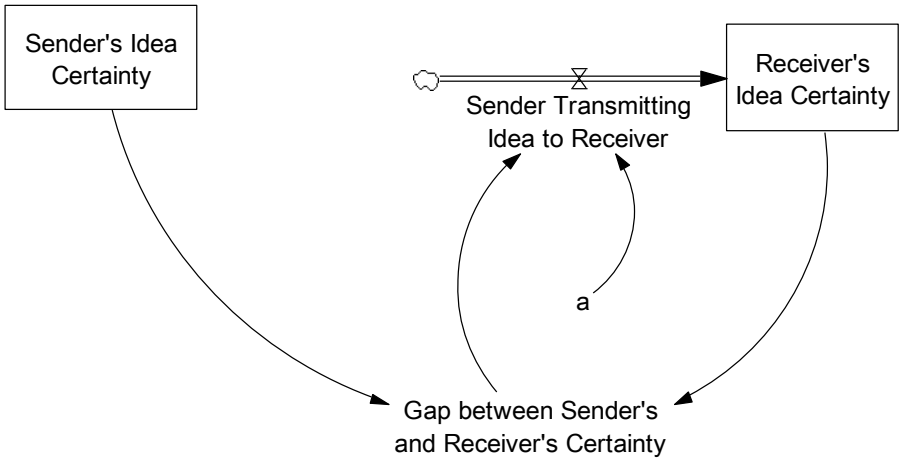

Figure 11. Revised diffusion model.

Figure 11 shows the proper information structure. The remaining changes needed to get the model in Figure 11 to the mostly complete model in Figure 12 are the additions of the "bounded confidence" loop and exogenous placeholders for more theory on social influence, salience, and network effects.

The Prototype Model of Decision Maker Idea Diffusion

The simulation model in Figure 12 shows the basic dynamics of social influence, with italics text indicating constants than can become feedback structure in order to simulate the rest of the theory. This prototype model can simulate social influence and the explicit change of ideas from a sender decision maker to a receiver decision maker.

The model in Figure 12 needs elaboration and testing to accurately describe the theory of perception, interpretation, mental models, judgment, decision making, salience, and social influence written about in this paper. This may be the subject of future work.

In addition, the model in Figure 12 is not suited to represent more than 2 decisionmaking "agents". It is also unsuited to run on subscripted data from spreadsheets and databases. Figure 13 shows a subscripted version of the Figure 12 model.

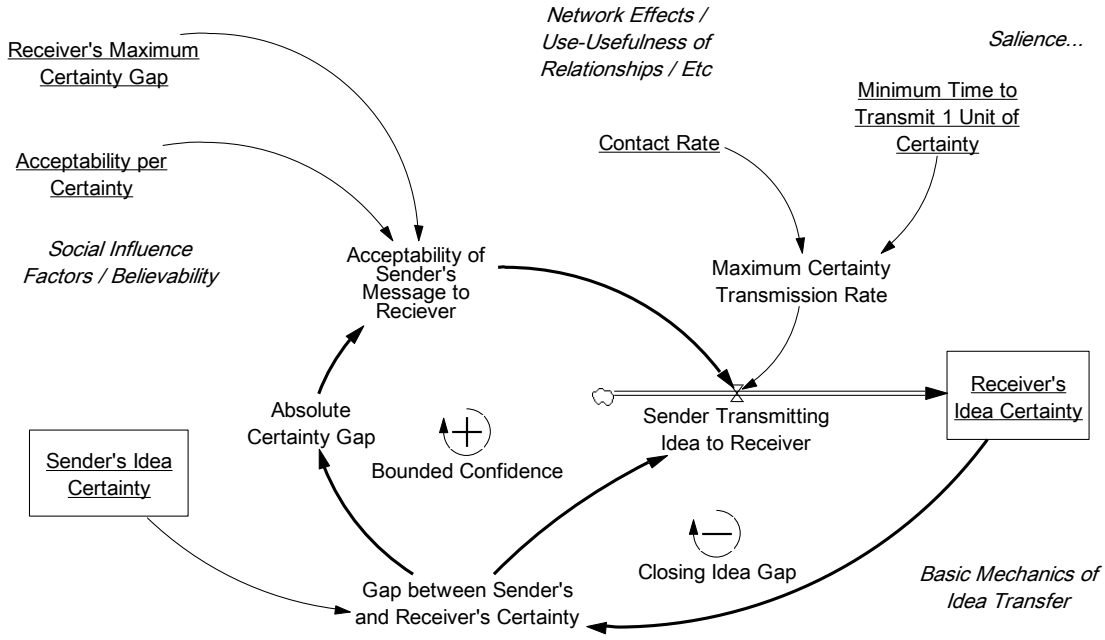

Figure 12. Full diffusion model.

The model in Figure 13 has removed the twin decision maker roles of "sender" and "receiver" and replaced them with a set of subscripted matrices. The model in Figure 13 can simulate a potentially large number of agents representing individual decision makers or groups of decision makers. This subscripted model is also configured to take data from spreadsheets, with some mock data shown in Figure 13. Work is ongoing to take actual data series from sources like the Global Terrorism Database (START, 2009), transform them into spreadsheet variables representing decision makers, communication networks, ideas, and events, and use them to populate the model shown in Figure 13.

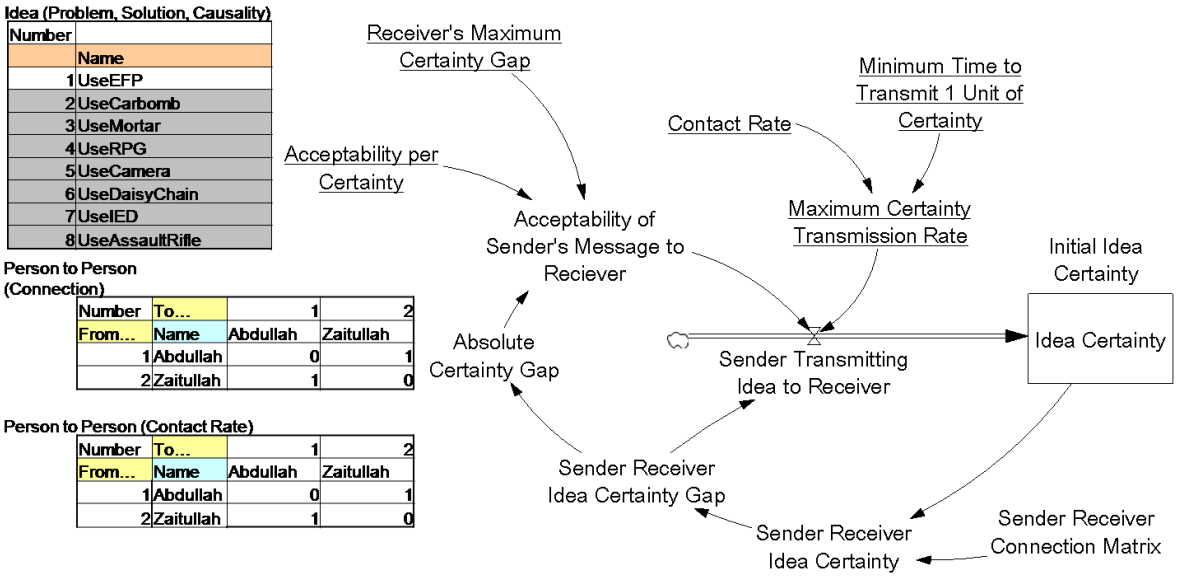

Figure 13. Subscripted diffusion model.

Discussion

This paper has described a possible feedback simulation approach to study the dynamics of individual and group decisionmaking. The paper theoretically elaborates on Richardson, Andersen, Maxwell, & Stewart's (1994) work to build an expanded theoretical model of decision maker to study certain problems, like the diffusion of insurgent tactics. The elaborated theory includes various components of decisionmaking in the social world, including perception, mental models, judgment, salience, and social influence. In addition to the theory, there is the description of a small prototype model that is based on social influence models, can be expanded to include the other theoretical dynamics, and can link with an external data set for subscripted simulation.

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