Emotional Cognition in Urban Planning

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Introduction

The design of cities requires cognition – mental processes that include planning, decision making, problem solving, and learning. There is substantial experimental evidence that all of these processes have a large emotional component, where emotions are conscious experiences resulting from a combination of physiological changes and evaluations of the relevance of situations to goals (Thagard, 2006; Thagard & Aubie, 2008; Thagard and Schröder, forthcoming). How does emotional cognition contribute to urban planning?

This chapter defends the following claims about the relevance of emotion to urban planning.

1. Urban planning requires values, which are emotional mental/neural representations of things and situations.
2. Decisions about how to design cities are based on emotional coherence.
3. The concepts used in urban planning are best understood as a new kind of neural representation called semantic pointers.
4. The social processes of planning cities and living in them can be modeled using multi-agent systems, where the agents are emotional.

5. The cognitive, emotional, and social mechanisms underlying urban development are complex: nonlinear, emergent, chaotic, synergistic, amplified by feedback loops, resulting in tipping points.

6. The goal of making cities sources of creativity can be accomplished in part by understanding the social and cognitive processes that help people to be creative. Understanding of these processes can be enhanced by computational models that provide social simulations of creativity.

Values in Urban Planning

Values are mental processes that are both cognitive and emotional. They combine cognitive representations such as concepts, goals, and beliefs with emotional attitudes that have positive or negative valence. For example, the values associated with life and death require the mental concepts of *life* and *death* and also the emotional attitudes that view life as positive and death as negative.

Advances in neuroscience are making it plausible that such mental states are neural processes that combine cognition and emotion. Concepts operate in the brain as patterns of firing in populations of neurons that can work to classify objects and also make general inferences about them. Such neural representations are continuously bound with emotional activity carried out by populations of neurons in brain areas such as the amygdala, ventral striatum, and ventromedial prefrontal cortex. From this perspective, values are neural processes resulting from binding cognitive representations of concepts, goals, and beliefs together with emotional attitudes.

The emotional component of values might seem to suggest that values are purely subjective, just a reflection of individual whims. In philosophical ethics, the positions called emotivism and expressivism demote value judgments to statements of personal preferences. Such views, however, reflect a naïve view of emotions, which are not just perceptions of physiological states. Emotions combine such perceptions with cognitive appraisals that reflect an estimate of the extent to which your current situation promotes or threatens your goals, based in part on affective meanings that are culturally acquired (Thagard and Schröder, forthcoming). Such appraisals can be evaluated based on how the situation actually does affect goals and on how well the goals taken into account fit with overall goals. Goals need not be arbitrary wants, but can derive from fundamental human needs, including biological needs such as food, water, shelter and healthcare, as well as psychological needs for relatedness, competence, and autonomy (Thagard, 2010a).

Hence even though values are most plausibly viewed as neural processes, they can be objectively correct or incorrect based on the extent to which they fit with human needs. Such values legitimately contribute to deliberation about how cities should operate and develop. When urban planners make decisions about housing, industry, and transportation routes, they consciously or implicitly apply values concerning how cities ought to operate and how people can benefit from living in them.

Cognitive-Affective Mapping

The role of values in urban planning can be illustrated using a new technique called cognitive-affective mapping, which supplements traditional kinds of concept mapping (e.g. Portugali, 1996) by including positive and negative emotional values. A cognitive-affective map (CAM) is a visual representation of the emotional values of a group of interconnected concepts. This technique has already proved useful for numerous applications, from conflict analysis to literary interpretation (Thagard, 2010b, 2011, 2012a, 2012b, forthcoming-a, forthcoming-b, forthcoming-c; Findlay and Thagard, forthcoming; Homer-Dixon et al. 2013; Homer-Dixon et al. 2014).

CAMs employ the following conventions:

1. Ovals represent emotionally positive (pleasurable) elements.
2. Hexagons represent emotionally negative (painful) elements.
3. Rectangles represent elements that are neutral or carry both positive and negative aspects.
4. The thickness of the lines in the shape represents the relative strength of the positive or negative value associated with it.
5. Solid lines represent the relations between elements that are mutually supportive.
6. Dashed lines represent the relations between elements that are incompatible with each other.
7. The thickness of the lines in the connection represents the strength of the positive or negative relation.

When color is available, CAMs conventionally represent positive elements by green ovals (go), negative ones by red hexagons (stop) , and neutral ones by yellow rectangles. Figure 1 schematizes this kind of representation. A software program called Empathica is available that makes drawing CAMs efficient and fun: http://cogsci.uwaterloo.ca/empathica.html. The name of this program reflects the aim of increasing mutual empathy between conflicting parties through depiction of the value maps of the people involved.

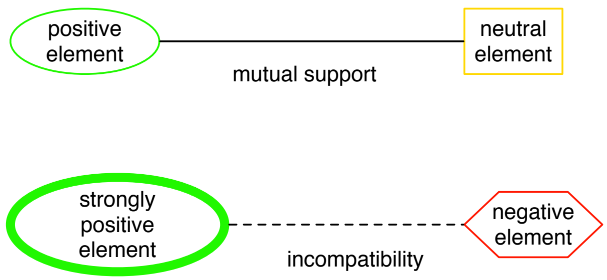

Figure 1. Schema for a cognitive-affective map. Use of color is optional depending on the medium used.

To illustrate the usefulness of CAMs in mapping values relevant to urban planning, I have used the Empathica program to produce value maps of two opposing theorists about how cities should work: Le Corbusier and Jane Jacobs. Figure 2 maps the values adopted by Le Corbusier (1967) in his influential book *The Radiant City,* first published in 1935. He encouraged the kinds of urban renewal that dominated much urban planning in the 1950s and 1960s, with replacement of traditional housing with high rises and freeways. Figure 3 shows the very different set of values defended by Jane Jacobs (2011) in her scathing critique of modernist urban planning first published in 1961. The two value maps serve to highlight the contrasting positive and negative values that drove modernist plans and the New Urbanist backlash. They differ on numerous values, including that of planning itself. The two figures show how values do not occur in isolation, but rather form connected systems that work together to influence decisions.

At the Delft conference that generated this book, I was told that there had been a plan in the 1960s to disrupt the lovely town by bringing major roads into the centre, in line with the modernist values shown in figure 2. Fortunately, the traditional values shown in figure 3 prevailed, and Delft retains its seventeenth-century organization and charm.

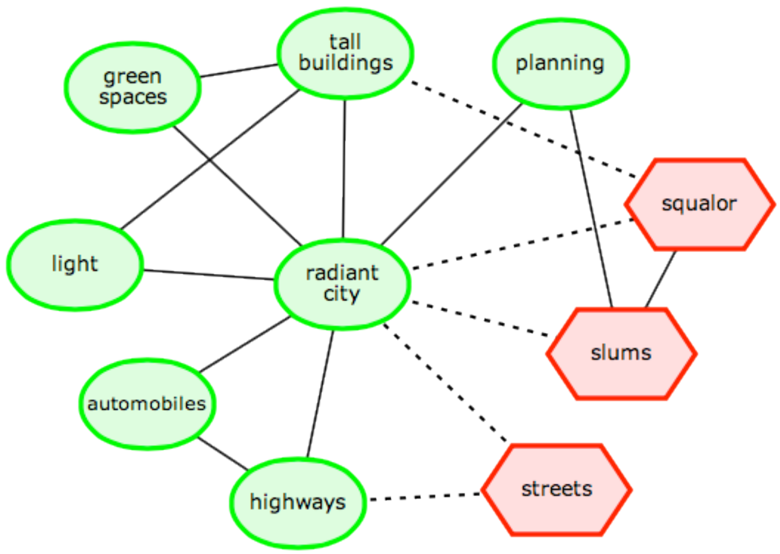

Figure 2. Cognitive-affective map of modernist values of urban planning, based on Le Corbusier (1967). Ovals show emotionally positive concepts, and hexagons show negative ones. Solid lines indicate support, and dotted lines indicate incompatibility. This map was produced by the program Empathica, available free at http://cogsci.uwaterloo.ca/empathica.html.

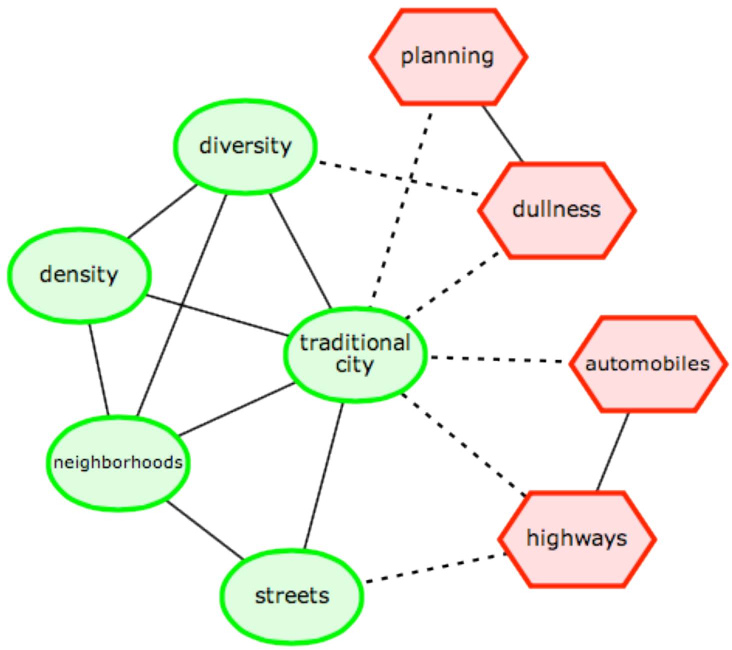

Figure 3. Cognitive-affective map of New Urbanist values of urban planning, based on Jacobs (2011).

The Waterloo Region Controversy on Light Rail Transit

Cognitive-affective mapping can also be used to display the differences in emotional values in specific contemporary disputes, such as my hometown controversy concerning whether to implement light rail transit. Waterloo Region is a prosperous area in southwestern Ontario, about 100 kilometers west of Toronto. The region has a population of 540,000, mostly concentrated in three contiguous cities: Waterloo, Kitchener, and Cambridge. The region is moving rapidly on a plan to implement a light rail line from the north of Waterloo to the south of Kitchener, with connecting rapid bus service to Cambridge. The dispute partly concerns matters of future fact, such as how much the light rail project will actually cost and how many riders it will attract. But the dispute also reflects very different and highly emotional values held by supporters and critics of the project. Cognitive-affective maps provide a concise and perspicuous way of displaying these value differences.

Figure 4 is a CAM of the values supporting light rail transit, derived from information on the website of the Region of Waterloo. Light rail is held to be desirable because it promotes goals such as moving people efficiently in order to avoid traffic congestion and building new roads. The light rail project is also intended to concentrate growth in established areas near light rail stations in order prevent urban sprawl into the countryside.

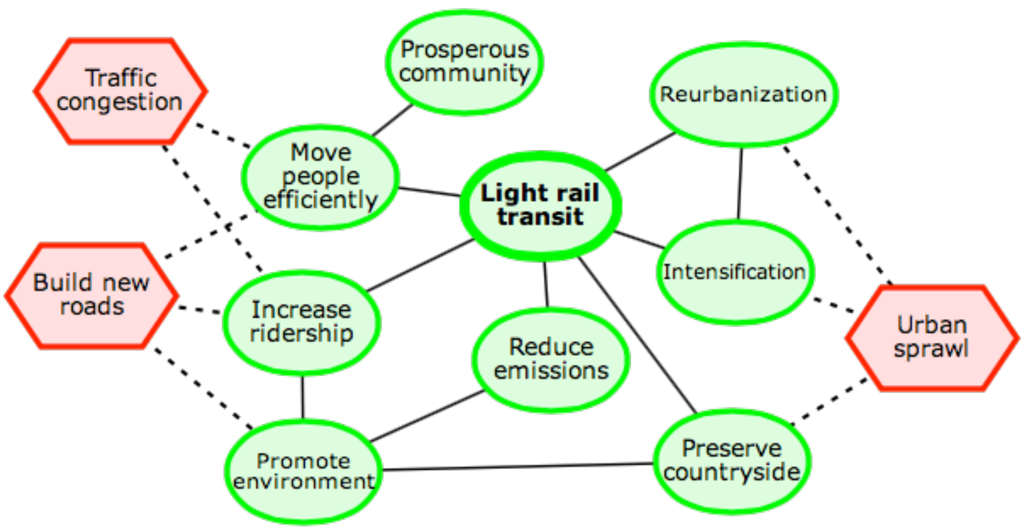

Figure 4: Cognitive-affective map of the values supporting light rail transit in Waterloo Region, based on http://rapidtransit.regionofwaterloo.ca/en/. The ovals indicate strong support for light rail transit.

Opponents of the light rail project have a very different set of values, shown in figure 5. They emphasize how unpredictably high costs of the project will lead to higher taxes and reduce prosperity. They like fostering convenient car use rather than urbanization concentration, and think that buses provide a cheaper and more flexible means of public transit. Residents of the city of Cambridge are annoyed that they will contributed to the cost of light rail but will reap few benefits until it is extended to Cambridge at an unspecified time.

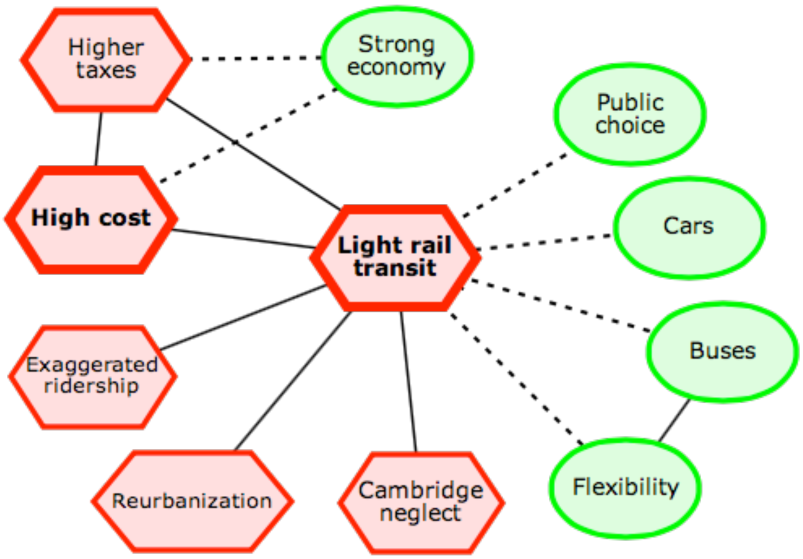

Figure 5. CAM of the values used to oppose light rail transit in Waterloo Region, based on the websites http://www.stoplightrail.ca and http://www.t4st.com. The hexagons indicate strong rejection of light rail transit.

How can urban planning disputes such as the Waterloo light rail issue be resolved? Figures 4 and 5 make it clear that the issue goes beyond factual questions such as cost and ridership. The two sides emphasize very different values, such as urban intensification for supporters and low taxes for opponents. Recognizing such differences may lead to the conclusion that the conflict is irresolvable, but it also may encourage people to seek resolution by emphasizing common values, such as having a prosperous community.

Decisions by Emotional Coherence

Cognitive-affective maps are based on the theory of emotional coherence developed by Thagard (2000, 2006). This theory is an extension of the view that inference is not the kind of serial process assumed by formal logic, but rather a parallel process of maximizing coherence by satisfying conflicting constraints. I proposed that elements in coherence systems have, in addition to acceptability, an emotional valence, which can be positive or negative. Depending on what the element represents, the valence of an element can indicate likability, desirability, or other positive or negative attitude. Elements are related to each other by positive and negative valence constraints. The calculated valence of an element is like the expected utility of an action, with degrees of acceptability analogous to probabilities and valences analogous to utilities.

The basic theory of emotional coherence can be summarized in three principles:

1. Elements have positive or negative valences.
2. Elements can have positive or negative emotional connections to other elements.
3. The valence of an element is determined by the valences and acceptability of all the elements to which it is connected.

This theory is implemented in a computational model called "HOTCO" for "hot coherence," in which units (artificial neurons) have valences as well as activations. Positive emotional connections are implemented by mutual excitatory links between units, and negative emotional connections are implemented by mutual inhibitory links between units. The valence of a unit u_j is the sum of the results of multiplying, for all units u_i to which it is linked, the activation of u_i times the valence of u_i, times the weight of the link between u_i and u_j.

Every CAM can be converted into a HOTCO simulation of emotional coherence by the following method - the program Empathica for drawing CAMs actually generates the required computer code:

1. Every CAM element becomes a HOTCO unit, capable of acquiring positive or negative valence.

2. Every CAM solid line (coherent link) between elements becomes an excitatory link between the corresponding units.

3. Every CAM dotted line (incoherent link) between elements becomes an inhibitory link between the corresponding units.

The major difference between the HOTCO simulations and the CAM method is that the latter only displays the results of a calculation of emotional coherence, whereas HOTCO actually carries out the computation. CAMs display the static result of the dynamic process of computing emotional coherence as performed by HOTCO.

Emotional coherence explains the differences in decisions made by different planners. Suppose the issue is whether to build a new freeway through an established neighborhood, an issue that Jane Jacobs worked on in New York City in the 1950s and later when she moved to Toronto in the 1960s. It is obvious that building a freeway is coherent with the values in figure 2, but not with the values in figure 3. Similarly, the decision not to bring major roads into the city centre of Delft is based on coherence with the values shown in figure 3 rather than those in figure 2. The values in figure 4 support the judgment that building light rail is the emotionally coherent choice for Waterloo Region, but the values in figure 5 support the opposite conclusion.

Cognition, Emotion, and Semantic Pointers

Brains are obviously a lot more complicated than the small networks of neurons representing whole ideas used in the HOTCO model. My colleague Chris Eliasmith (2013) has published an amazing book, *How to Build a Brain* that provides a new way of thinking about how brains make minds and synthesizes the major approaches to cognitive science. To simplify, we can sketch this history as follows:

Thesis (1950s): Thinking results from the manipulation of physical symbols like those that operate in digital computers.

Antithesis (1980s): Thinking results from sub-symbolic processes through the interaction of large numbers of neurons.

Synthesis (2013): Thinking results from neural process that can function as symbols.

Cognitive science got rolling in the 1950s with the insightful idea that new ideas about computing could suggest how thinking works as a mechanical processes. This idea was a major advance over previous analogies such as clockwork, vibrating strings, and telephone switchboards, and it generated many important psychological insights. But there remained many unsolved problems in the field of artificial intelligence, such as how purely computational symbols could have meaningful relations to the world.

In the 1980s, an alternative approach called connectionism arose with the claim that ideas about neural networks provide a better way of understanding how the mind works. Representations in neural networks do not look like symbols in natural language or computer programs because they are distributed across many simple neuron-like entities that interact with many others. Processing is highly parallel, requiring the simultaneous firing of many neurons, not serial like the step-by-step inferences that occur in linguistic arguments and most computer programs. Connectionism generated many insights about psychological processes such as concept application, but had difficulty explaining the high-level symbolic reasoning that is also part of intelligence.

Eliasmith's new book provides the first plausible synthesis of symbolic and connectionist approaches to cognition. He proposes (2013, p. 78) the new idea of semantic pointers, which are "neural representations that carry partial semantic content and are composable into the representational structures necessary to support complex cognition." As in connectionism, semantic pointers are patterns of firing in large neural populations, but Eliasmith has figured out how to make them also work like symbols in high-level reasoning. His book describes the Semantic Pointer Architecture, SPA, which is a general account of how neural structures and processes can generate many kinds of psychological functions, from low-level perception and action generation to high-level inference such as what people do in intelligence tests. In my own work, I have found the semantic pointer idea to be wonderfully suggestive for developing new theories of intention, emotion, and consciousness (Schröder, Stewart, and Thagard, forthcoming; Thagard and Schröder, forthcoming; Thagard and Stewart, forthcoming).

Eliasmith's semantic pointer representations are very useful for understanding cognitive processes in urban planning because:

1. They can handle non-verbal representations that are visual, auditory, tactile, and kinesthetic. These are all important in representing urban environments, for example in the look of buildings, the sound of cars, the touch of fabrics, and the feel of opening a door.

2. Semantic pointers allow representations that are both symbolic and embodied.

3. Semantic pointers can include emotional bindings, so they show how values such as those in figures 2 and 3 can enter into emotional decisions.

For example, the concept of a city can be viewed as operating in the brain as a semantic pointer that results from binding together verbal information (e.g. a city is a kind of social organization), visual information (e.g. tall buildings), auditory information (e.g. traffic noise), and emotional information (e.g. cities are exciting, and/or dangerous). Such complex representations can contribute to verbal inferences and more complex decisions involving emotional coherence.

Social Processes and Mechanisms of Emotional Transmission

Urban planning is usually carried out by groups of people, and the interactions of people in cities affected by urban planning are also social processes. Hence emotional cognition requires attention to social processes as well as individual, psychological ones. The social processes of emotional transmission among persons include: molecular communication, e.g. the smell of fear; mirror neurons that fire in response to other people's behavior; emotional contagion by mimicry of facial expressions; attachment-based learning from parents and other mentors; altruism, sympathy, and empathy; social cuing where the emotions of others prompt different emotions; power manipulations; and propaganda (for explanations of these, see Thagard, forthcoming-a).

The best way to model the interactions of psychological and social systems is to use agent-based modeling where the agents engage in emotional cognition and the processes of interaction include transmission of emotions. HOTCO has been extended to include simple kinds of emotional transmission among agents who make their decisions by emotional coherence (Thagard, 2006, 2012). It would be useful to simulate the group decisions and negotiations that go into urban planning using an agent-based model of emotional communication and decision making. Berlin researchers have produced an adaptation of HOTCO that provides a very illuminating account of processes of changing minds about electric vehicles in Germany (Wolf, Schröder, Neumann, and de Haan, forthcoming. Here, however, I would like to address the issue of creativity in cities.

Social Simulation of Creativity

An important current interest among urban designers is how to foster the important role that cities play in creativity. I count a product, such as an idea, to be creative if it is new (novel, original), valuable (important, useful, appropriate, correct, accurate) and surprising (unexpected, non-obvious). (See e.g. Boden, 2004; Simonton, 2012). Theorists such as Richard Florida (2005) have described how vibrant cities can bring people together in ways that increase their individual and collective creativity. One might suppose that creativity is a purely cognitive phenomenon independent of emotion, but creative people ranging from artists to scientists are fueled by positive emotions such as enthusiasm as well as by negative emotions such as fear of failure. For a discussion of the role of emotions in individual scientists, see Thagard (2006, ch. 10).

Much less well understood is the role that emotions and cognition play in the social processes that help to generate creativity in urban environments. A computational model of social creativity should help to suggest what urban designers can look for in planning for creative cities. The resulting model has all the properties of complex systems described in the next section, plus the additional one that it operates at multiple levels. Individual creators are complex systems at the psychological and neural levels, but creative groups are also complex systems at a higher level – a system of systems. Many complexity theorists have noticed the importance of multilevel operations in complex systems (e.g. Findlay and Thagard, 2012; Thagard 2012a, etc.).

I have not yet produced a social simulation of creativity, but can outline a design for one by pointing to previous computational models. My first multilevel simulation was the CCC (consensus = communication + coherence) model of scientific consensus (Thagard, 2000, ch. 7). In this model, individual scientists are simulated as evaluating hypotheses with respect to evidence by assessing explanatory coherence, in accord with my ECHO neural network model of inference to explanatory hypotheses (Thagard, 1989, 1992). Each scientist can make its own evaluation of what hypotheses to accept given the available evidence, but CCC adds a social dimension by allowing scientists to exchange evidence and hypotheses. When two scientists meet randomly, they exchange evidence and hypotheses, just as happens at conferences. After exchanges, each scientist re-evaluates the acceptability of different hypotheses based on the enlarged set of hypotheses and evidence. Simulated scientists "change their minds" when hypotheses that were previously accepted become rejected and when hypotheses that were previously rejected become accepted. When all scientists in a community accept the same hypotheses, consensus has been reached. Thagard (2000) describes simulation of reaching consensus in two scientific cases, concerning the causes of ulcers and the origin of the moon. This kind of social simulation involves agents that are much more complicated than the simplistic ones in many agent-based models, in that the agents in CCC are capable of reasoning about hypotheses and evidence.

Nevertheless, CCC falls well short of being capable of social creativity. First, individual scientists in it are only able to evaluate and communicate hypotheses, with no capacity to generate new hypotheses or the concepts that are used to construct them. To introduce creativity, the agents would need algorithms for forming new concepts and hypotheses such as those found in my earlier PI model (Thagard, 1988). Second, CCC ignores the role of emotions in scientific thinking.

I introduced emotions into computer simulations in my HOTCO models (Thagard, 2006). Initially, HOTCO (for Hot Coherence) applied only to individuals, with representations such as actions and goals, as well as hypotheses and evidence, capable of possessing emotional valences as well as acceptability. However, in HOTCO 3, I added the capacity of simulated agents to exchange valences, goals, and actions just as the scientists in CCC could exchange hypotheses and evidence. Simulations with HOTCO 3 showed that groups of decision makers can achieve emotional consensus when all agents arrive through the exchange of information at similar valences resulting in agreement about their individual decisions.

Now let me sketch what it will take to expand HOTCO 3 into HOTCO 5, a model of social creativity. (HOTCO 4 enhanced HOTCO 3 by taking into account the role of special subgroups in group consensus and polarization – Thagard, 2012b). Here are the crucial ingredients. First, the representation of creative products needs to go beyond the symbolic representations used in HOTCO, because creativity can involve non-verbal representations such as visual, auditory, and tactile images (Thagard, forthcoming-a). Because vectors (lists of numbers) can be used as stand-ins for all sensory inputs, and images, HOTCO 5 should be able to store and manipulate vectors. I am not proposing that human brains use vectors, but rather exploiting the fact that Chris Eliasmith (2013) has developed methods for translating any vector into patterns of neural activity.

Second, each agent should be capable of generating new vectors by combining two previously existing ones. The idea that creativity results for combining representations has frequently been proposed, originating as far as I have found with Dugald Stewart (1792; see also Boden, 2004). Combination of vectors should not be simple addition and subtraction, but rather a more mathematically complicated operation such as circular convolution (Plate, 2003). Eliasmith and Thagard (2001) describe how convolution into vectors can represent many kinds of information. The translation of vector combination into neural activity has been used to simulate the combination of representations in creative processes, as well as the emotional response (Aha!) that results from such combination (Thagard and Stewart, 2011; reprinted in Thagard, 2012a). For evidence that all creativity involves the combination of previously unconnected ideas (what I call the combinatorial conjecture), see Thagard (2012a, forthcoming-a, forthcoming-c).

Third, in order to introduce emotions into the vector-combining version of HOTCO, we can use vectors as stand-ins for emotional responses that in reality would be more complicated combinations of cognitive appraisals and physiological perceptions, in line with the theories of emotions proposed by Thagard and Aubie (2008) and Thagard and Schröder (forthcoming). It is easy to do such binding by convolving vectors for cognitive representations such as hypotheses and actions with vectors for emotions.

Fourth, we can make HOTCO 5 social by allowing agents to exchange vectors! The vectors exchanged would encompass the full range of cognitive representations, including sensory images (visual, auditory, etc.), as well as the full range of emotional representations. The emotion vectors could include information about positive and negative valences, as in HOTCO 3, but they could also encode specific emotional reactions such as happiness, fear, and anger, so long as they were composed by binding (convolving) the full range of components of emotion.

Fifth, in order to make the social process of communication more efficient, we could use emotions to constrain the exchange of representations. Stochastically, a vector would be more likely to be transferred from one agent to another if it included an emotional representation corresponding to enthusiasm or other positive reaction. In words, one agent would be more likely to pass an idea on to another if the donor agent is enthusiastic about the idea. Like its predecessors, HOTCO 5 would be a highly complex multilevel system, a system of systems each of which is complex. But what does complexity mean in this context?

Complexity and Emotional Cognition

Cities and urban environments are obviously complex systems, but little work has been done to integrate complexity ideas (sometimes elevated to the status of a theory or science) with cognitive and affective ideas. Here is a sketch of how to do the integration.

Why Complexity Theory Needs Cognitive Science

Suggestive ideas about complexity include state space, attractors, chaos, feedback loops, tipping points (critical transitions), self-organization, and emergence. But these ideas are only vague metaphors unless they are specified in terms of variables and equations. For explaining human systems, many of the relevant variables and equations concern mental states and processes, which cognitive science explains using rigorous models that are mathematically precise enough to be implemented in computer simulations.

Why Cognitive Science Needs Complexity Theory

All computational cognitive models implicitly have state spaces and attractors, but many ignore chaos, feedback, tipping points, and emergence. The major exceptions are neural networks, which display all of these features, although they are rarely mentioned. More explicit use of this terminology can facilitate communication with people in other fields who routinely describe systems using complexity terminology. Cognitive science also needs to get better at dealing with interactions among multilevel systems, including social, neural, and molecular systems as well as psychological ones.

Translations

1. State space. In psychological cognitive models, the key variables are properties (such as acceptability) of mental representations (such as concepts and beliefs). The equations specified in computer programs describe how these variable change values as the result of changes in inputs and internal interactions. In neural models, the key variables are properties of artificial neurons such as firing rates, whose changes are defined by equations that indicate how the firing of one neuron changes because of inputs from other neurons.

2. Attractors and self-organization. If a psychological or neural model has multiple stable states that it can move among, depending on sensory inputs and stored information, then these states can be described as attractors. All neural models have such states, and

all can be considered as self-organizing in the sense that global order and coordination arise out of local interactions.

3. Chaos. All neural network models can show dramatic changes in response to small inputs, and a few psychological cognitive models (e.g. for spreading activation) are also chaotic.

4. Feedback loops. All neural network models have amplifying (positive) feedback loops resulting from excitatory connections, and dampening (negative) feedback loops resulting from inhibitory connects. The usual terms for such loops are "reentry" and "recurrent". ADD NONLINEAR.

5. Tipping points. All neural network models display tipping points when they move from one stable state (attractor) to another. The most important tipping points in individual humans are shifts in systems of beliefs and attitudes, which are easily modeled (e.g. by my HOTCO). The most important tipping points in societies are shifts in beliefs and attitudes that are shared among groups.

6. Emergence. An emergent property is one that belongs to a whole, does not belong to its parts, and is not just the aggregate of properties of the parts because it results from the interactions of the parts (Findlay and Thagard, 2012). Neural systems have such properties: Representation (standing for something) is an emergent property of a population of neurons. I think that consciousness is an emergent property of interacting neural populations (Thagard and Stewart, forthcoming). I conjecture that creative groups have emergent properties in the form of new, valuable, and surprising ideas that would not develop without social interactions.

Conclusion

I have tried to show some of the ways that new ideas about cognition, emotion, and group processes are relevant to urban planning. I have described the role that values play in decisions about cities, and shown the relevance of cognitive-affective maps and emotional coherence to understanding such decisions. Cognition and emotion also contribute to social processes such as group planning and collective creativity. Ideas about complexity can be fleshed out by indicating how neural and social networks display behaviors such as chaos, attractors, and tipping points. I hope that better cities can result from a deeper understanding of the cognitive, affective, and social processes that contribute to urban planning.

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FIX THAGARD FORTHCOMINGS