Framing and Resource Activation: Bridging the Cognitive-Situative Divide Using a Dynamic Unit of Cognitive Analysis

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Abstract

Theory in cognitive science often splits into those who treat cognition as occurring in individual minds those who treat it as situated or distributed, as irreducibly a matter of an individual-in-a-setting or of multiple individuals and artifacts. Prominent accounts have treated this split as between incommensurable paradigms (Sfard, 1998), competing theories (Greeno, 1997), and as complementary perspectives (Cobb, 1994). In the present paper, however, we argue that the accounts can be seen as theoretically continuous, differing in the scale of dynamics, such that a "society of mind" (Minsky, 1988) model of individual cognition is theoretically continuous with a "mind of society" model of social cognition. We sketch our framework and show how it leads to this continuity. We also argue that the relevant scale in any instance should be guided by the evidence, rather than based on purely *a priori* commitments.

Keywords: Modeling cognition; situated cognition; distributed cognition; resources; framing, education, collaborative learning

Theoretical Backdrop

Cognitive science has undergone dramatic advances that have forced us to question our basic assumptions of the nature of mind and its relation to the world. This progress has followed a path analogous to the conceptual changes in astronomy over the centuries. As astronomers have extended their gaze outward into the cosmos, they have revolutionized our view of the world and our place in it. These revolutions have been patently decentralizing—the Copernican revolution displaced the Earth from the center of the universe, and Einstein's cosmology went so far as to remove the very concept of 'center' from the universe.

A similarly decentralizing pattern of revolutions has also been the fruit of our gaze inward, using the tools and trade of cognitive science. While ancient views of consciousness assumed a central role for the heart, neuroscience has followed Hippocrates in focusing on the brain as lexis of mental life (Finger, 2001). Descartes in particular placed the "center of consciousness" squarely between the ears by postulating that the connection between spirit and body occurs in the pineal gland near the center of the brain. Modern cognitive science has shown that Descartes was wrong not only about the function of the pineal gland, but that the very concept of a 'center' can apply to consciousness and cognition—there is apparently no single place or time in the brain where it all 'comes together' (Dennett & Weiner, 1993). Vision provides a case in point: we have moved away from the assumption that the visual cortex functions something like a neural correspondence of our visual field, finding instead that vision is hierarchically distributed over various parts of the brain (Felleman & Van Essen, 1991)[1].

This decentralized view of mind has been highlighted by researchers working within the traditions of situated and distributed cognition. Situativity theorists claim that cognition cannot be defined apart from the situation in which it takes place and so take the appropriate unit of analysis the individual-in-a-setting (Greeno, 1997; Greeno & Moore, 1993; Lave, Murtaugh, & de la Rocha, 1984). In a commonly cited example, Lave et al. (1984) argued that whether or not a person knows how to find 3/4 of 2/3 a cup of cottage cheese depends critically on how the person takes up the affordances of the situation at hand; whereas the person may be unable to solve the problem via manipulation of symbolic fractions, they may still get the correct result by manipulating the physical objects. Theorists of distributed cognition have decentralized the mind even further by considering how information processing can be distributed across multiple individuals as well as artifacts. Hutchins (1995) has detailed a paradigmatic example by arguing that it is the cockpit—not any individual pilot—that remembers the safe landing speed of an airplane.

[1] Even if one of the area of cortical 'projection' is damaged, so that a blindsight patient reports seeing nothing at all, their 'visual location' capabilities can be quite intact, as evidenced by their ability to 'guess' well above the level of chance where an object is in their field of 'vision'.

Meanwhile, researchers in the 'cognitivist' tradition have resisted extending the border of cognition past the most intuitively obvious one—the brain. Where we draw the line around cognition has important consequences for how educational research is carried out, the conclusions we can draw from such research, and the recommendations we can then provide to practitioners. Anderson, Reder, and Simon (1996), for example, argued that the educational implications of situated theories of learning are often misguided. They advocated for the importance of training by abstraction, in contrast to training purely through concrete examples as situated theories would seem to favor. In his counter, Greeno (1997) took issue with this characterization but did point out a specific instructional consequence of situated cognition: teaching algorithmic skills is insufficient for achieving one of the main goals of education, namely getting students to "reason successfully in their everyday activity outside of school" (p. 7).

The cognitivist, situated, and distributed perspectives appear to have drastically different ontologies of mind. After all, there seems to be a vast ontological divide between claiming that it is a person who is remembering, rather than a cockpit. Such conceptual differences have contributed to the miscommunication between these camps, as several researchers have noted (e.g., Greeno, 1997; Sfard, 1998).

In this paper, we sketch a framework for cognitive analysis that has the potential to bridge these major ontological rifts in cognitive science. This is afforded, in part, by the dynamic unit of cognitive analysis we adopt in our model. We suggest heuristics for basing the unit of analysis on the data, rather than prescribing the cognitive unit based purely on theoretical commitments. Our account thus has the potential to unify or coordinate these perspectives.

Our Theoretical Framework

We work from a view of mind as a complex, dynamic system involving manifold cognitive resources, a generalization in line with schema theory (Bartlett, 1932, Rumelhart, 1980), Minsky's (1988) "society of mind" in which cognition is distributed within the mind across manifold "agents," and diSessa's "knowledge in pieces" (1993). "Resources" is a generic term for cognitive elements at various grain sizes that may be in different states of activation at any given moment (Hammer, et. al. 2005). For example, a student might explain the motion of a ball tossed into the air by saying it slows down as the force from your hand 'dies away,' but a moment later claim that it stops at the top of the trajectory because gravity has exactly balanced by the force from your toss[2]. Rather than assume the student is utterly confused, we find it productive to explain the dynamics of reasoning in terms of activation of fine-grained cognitive elements – "dying away" in one instance and "balancing" in the other (diSessa, 1993) – and the contextual features that cue these different resources. On this view, the phenomenology of reasoning is understood in terms of the activations of resources, of which there must be many kinds, including conceptual resources such as for understanding causal mechanisms (diSessa, 1993) or mathematical expressions (Sherin, 2001), as well as epistemological resources (Hammer & Elby, 2002), which will be of more central concern here. Resources often activate in stable patterns, and in what follows we will be concerned with the dynamics and patterns of resource activations, in particular with what the evidence suggests is involved in their formation and stabilities.

We refer to these patterns as "frames," (Hammer, et. al. 2005), building from accounts in the literature of frames as structures of expectation (Bateson, 1955; Minsky, 1988; Tannen, 1993) that undergird our sense of "what is it that is going on here" (Goffman & Berger, 1974). In the analyses below, we focus on the dynamics of how students, as individuals or as groups, frame what they are doing primarily with respect to knowledge, which we refer to as *epistemological framing* (Redish, 2004).

Phenomenological and ontological views of framing Describing a frame as a sense of 'what is going on' may be called a phenomenological view of framing. Most accounts in the literature on framing are phenomenological, focused on evidence of how individuals or groups understand what is taking place, as well as how individuals send "metamessages" (Bateson, 1955; Redish, 2004) to signal how they are framing the situation, in order to help each other interpret the accompanying message. For instance, a student who uses a rising intonation while offering an idea may convey more uncertainty than if they had delivered the idea with a falling intonation (Ward & Hirschberg, 1985).

Our account also incorporates an ontological view of framing by describing frames in terms of coherent activation patterns of resources. For instance, Rosenberg, Hammer, & Phelan (2006) found that when students framed their discussion of the rock cycle as "storytelling" they stably activated a set of epistemological resources including 'knowledge as fabricated stuff', 'knowledge as mental imagery', and 'knowledge as connectable through causal relations.'

Dynamics of framing. The phenomenological accounts in the literature cited above emphasize the dynamic nature of framing—Tannen (1993) prefers the gerund to emphasize the dynamic process, citing Bartlett's account of schemas as "active organized settings." The ontological view suggests models of framings as emergent patterns in a complex system. We may ask, then, what contributes to the dynamics of the system?

We suggest that the stability of a framing, as a pattern of activations, may just as easily involve manifold resources within an individual mind as across minds or across minds

[2] Phenomenological primitives (DiSessa, 1993) are examples of resources, but this by no means exhausts the set nor scale of resources.

and materials. That is, given an ontology of mind as comprised of manifold resources—a society of agents or a complex system of conceptual primitives—it is natural to expect dynamics that involve particular resources of one mind interacting with particular resources of others. To put this succinctly, a "society of mind" view of individuals (Minsky, 1988) should be consistent and continuous with a "mind of society" view of social cognition. It is a question of the scale of the relevant system (or subsystem) that is involved in the particular phenomena under study.

Thus we look for evidence of what contributes to the dynamics, and we expect that the relevant unit of analysis may vary from the individual (or perhaps even smaller) to much larger groups. Here, we limit ourselves to groups of four. We look for evidence, as we elaborate below, in the data for the scale of the dynamics involved for any particular instance.

Dynamic Unit of Analysis

Since both resources and frames exist at many different grain sizes, and may be activated on many levels at once, it makes little sense to limit our empirical studies to one level of analysis. Roth (2001) has also argued for the need to dynamically focus on multiple 'zoom' levels while analyzing cognition, and has provided some of the epistemological justification for doing so. Mandelblit & Zachar (1998) have laid out ontological considerations that allow for a dynamic unit of analysis, and have discussed how such a tack may be useful in bridging disparate traditions in cognitive science.

Epistemological considerations One good reason to seek out a dynamic unit of analysis is to avoid the temptation of doing *a priori* science. By rigidly adhering to only one cognitive unit, we may be effectively telling the world how it ought to be. If the individual is the unit of cognition, this is something that should be empirically supported, not just theoretically presumed.

Perhaps the gravest risk of such myopia is that of missing salient data. We all know that our perceptions are contingent on our attention. So if we focus our attention merely on the individual as the cognitive unit, we risk missing critical data relevant not only to the behavior of that individual, but also the group or situation of which she is a part (e.g. a jury in deliberation, a romantic couple in an argument, or a group of students working on a problem). As Roth (2001) puts it, "[b]y changing focus and by zooming, phenomena pertaining to different fields of attention become visible and are of different grain sizes and time scales" (p. 55).

Ontological considerations In motivating the concept of a dynamic unit of analysis, Mandelblit & Zachar (1998) describe several varieties of fundamental unity. Each of these various forms of unity "is formed under *different environmental restrictions* and is characterized by *different patterns of correlation*" (p. 234, emphasis in original). Physics provides many illustrative examples: The electron, for instance, is considered a spatially integrated unit in some circumstances (e.g. a point charge, or a small sphere of charge), but becomes an inseparable part of a dynamically integrated unit called a "Cooper pair" within a superconductor. Although such an ontological commitment violates some of our intuitions about what an "object" is, it is underwritten by the explanatory and predictive success of the BCS theory of superconductivity.

A dynamic unit of analysis also has explanatory and predictive power in the social sciences. It is often noted that people can form groups that are more (or less) than the sum of their parts, and although this may sound like mere rhetoric, it becomes a matter of practical significance when considering the differences between how individuals and groups act and make decisions. That crowds behave coherently as a unit and in ways that differ substantially from how the individuals that comprise them might otherwise act has long been noted (see McPhail & Wohlstein, 1983 for a review), and has important consequences in many areas including, for example, fire safety (Cocking & Drury, 2008). Research on small groups has found important differences between how individuals and groups make decisions, something that has important consequences for some of our most influential decision makers, such as juries. Studies of simulated juries suggest that juries are, as Moscovici & Doise (1994) have put it, "something other than a dozen jurors" (p. 110) since they polarize towards the majority opinion regardless of what that opinion is (e.g., Myers & Kaplan, 1976). Although such research is far removed from our own work, it does highlight the need for a way of incorporating multiple units of analysis into a theoretical framework of decision-making, behaviors, and cognition.

Empirical considerations Our empirical work has led us to posit a set of heuristics for identifying the cognitive unit, which is to say the scale at which the evidence suggests the dynamics of framing occur: *clustering*, *persistence*, *resistance*, and *transitions*. Each of these guides us in making a reliable identification of the unit of cognitive analysis at various grain sizes and time scales. We describe these heuristics in greater detail elsewhere (Conlin, Gupta, & Hammer, forthcoming).

Scherr & Hammer (2009) provides an illustrative example of the work that motivated these heuristics. They found that in small student groups working on physics tutorials, various behaviors tended to cluster together both within and across the students. They identified four distinct clusters, which were sufficient to account for most of the time spent in tutorial. These clusters can be stable for several minutes on the level of the student group. Scherr & Hammer also provided instances in which a cluster was resilient to bids from students to change clusters. The groups, when they did transition, tended to do so abruptly and synchronously. These clusters and the timing of the transitions were coded with over 90% inter rater reliability, within 5 seconds accuracy.

These four behavioral clusters indicated four distinct epistemological frames (Scherr & Hammer, 2009). One frame corresponded with disproportionate quality of evidence for a measure of scientific reasoning (Conlin, Gupta, Scherr, & Hammer, 2009,). We will now offer two brief analyses of video data from these tutorials in order to illustrate the utility of having a dynamic unit of cognitive analysis.

Data & Discussion

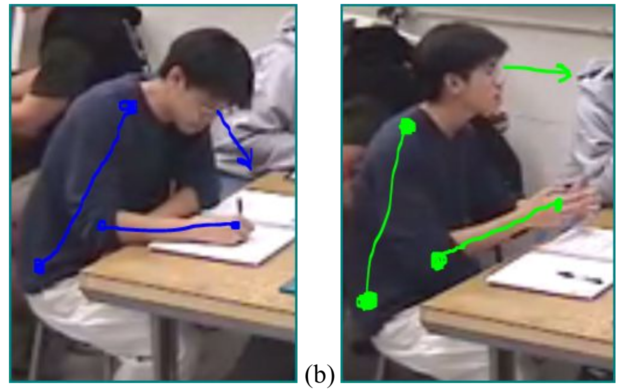
The data comes from an algebra-based introductory physics course in which the students participated in worksheet-guided inquiry discussions (i.e., 'tutorials'). The students were mostly pre-med majors, and the worksheets focused on conceptual and epistemological issues in physics.

The students get many conflicting metamessages from the tutorials—messages about how to interpret what sort of activity they are engaged in and how to act accordingly. For example, students are given a worksheet, and this document can be framed in many contrasting ways. For instance, they may see the worksheet as "something to be completed," an interpretation they have long associated with worksheets in their school experience. On the other hand, they may see them as "something to guide them through their discussion," which was explicitly encouraged in several ways. One metamessage meant to encourage such a framing is the seating arrangement: there are four stools placed around a table so that the students faced inward, which is a common way of setting up a classroom for a discussion.

The tension between these alternate interpretations is typically never resolved once-and-for-all by the students. Rather, what we have found is that their behaviors indicate that their framing of the tutorial changes over multiple time scales—over the course of a few minutes, or over the whole hour of tutorial, or over the course of the semester. We have focused primarily on the minute-to-minute dynamics in framing.

Clustering heuristic applied to the individual

Throughout the course of the tutorial, the students exhibit a range of behaviors. It has been observed that a small set of behaviors tend to cluster together for each individual student in the tutorial. For instance, a student's gaze angle, hand position, and posture do not vary independently from each other but rather consistently cluster together in a few distinct sets. Two such sets are depicted in Figure 1. A downward gaze tends to cluster with hands on the table (often writing or resting) and a hunched-over posture (Fig 1a), while a horizontal gaze angle clusters with hands off the table (often gesturing) and an upright posture.



(a) (b)

Figure 1: (a) and (b) Two different behavior clusters for an individual

Clustering heuristic applied to the group

The same clusters of behaviors that are found on the individual level also are found at the group level. In fact, it was at the group level the behavioral clusters first drew Scherr's attention via abrupt and synchronous transitions by the group from one cluster to another. The clusters persist across individuals from tens to hundreds of seconds and just four distinct group-level behavioral clusters were enough to account for about 86% of time spent in a single tutorial session.

The tutorial groups' behavioral clusters serve as a robust and reliable indicator of the group's framing of the activity. There is a high degree of inter rater reliability (95% on the cluster code, 90% on the timing of the transitions). The coding is done without a transcript[3] and the analysis of discourse confirms the nature of the frame. The fact that the group spends most of the tutorial transitioning back and forth synchronously between the same set of activities indicates that it is appropriate to take the group (as well as the individual students) as the unit of analysis.

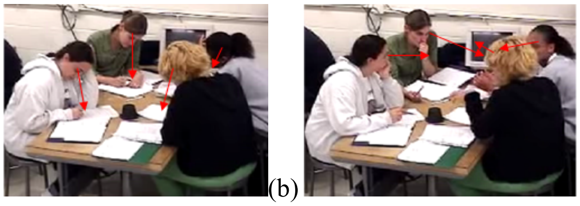
In what follows, we present two cases from our corpus of data and analyze them in light of our empirical heuristics. The first case supports taking the group to be the unit of cognitive analysis, while the second does not.

Case of group level cognitive analysis

This case comes from a tutorial on Newton's third law, during which the students are to find the speed a car gains when hit by a truck of twice the mass that loses 5m/s. In the first part of clip, the students are all looking down, so there is clustering of gaze angle across students. They are also hunched over, speaking softly, with their hands on their desks and their eyes on their worksheet. This is what Scherr and Hammer (2009) called the *blue* behavioral cluster (Fig 2a).

There is a sharp transition in behavior, in which the students all sit up, make eye contact, use animated voices, and gesture prolifically. This is what Scherr & Hammer (2009) called the *green* behavioral cluster (Fig 2b).

[3] The coding can be reliably done without even listening to the content of the speech.


(a) (b)
Figure 2: The *blue* (a) and *green* (b) behavioral clusters.

Analysis of the group's discourse also falls in line with this transition. While in the blue cluster, the students are making intuitive guesses of the answer to a tutorial question (e.g., "Car speeds up by five"), with little or no justification provided. Along with the transition to the green behavioral cluster comes a corresponding transition in the substance of their discourse. They begin to describe the mechanism at work in the physical situation described in the worksheet question, as evidenced by metaphorical gestures of the collision as well as an analysis of the group's mechanistic reasoning (Russ, Scherr, Hammer, & Mikeska, 2008). When taking the behavior and discourse in conjunction, it becomes apparent that the group as a whole is changing activities from what might be called *completing the worksheet* to one of *having a discussion*. This transition also comprises a shift in activated conceptual and epistemological resources that are distributed across individuals, such that the activities of *completing the worksheet* and *having a discussion* are frames definable at the group level.

Case of individual level cognitive analysis

A contrasting example comes from a different group, working on a shadows and light tutorial, in which they are asked whether the light made by a bulb shining through a through an aperture onto a screen will move up or down when the bulb is lifted, and why (Lising & Elby, 2005).

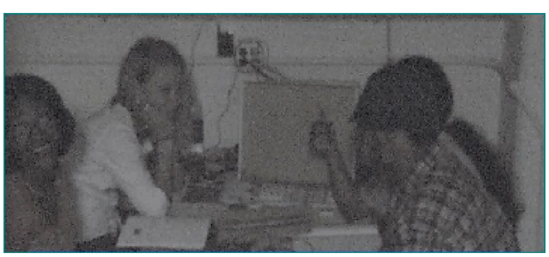


Figure 3: Lack of clustering of behaviors across students.

In this clip, there is no cohesive clustering of behaviors across students, and there is a lack of cohesion in their speech. Although their discourse centers on the same conceptual content , they are at this moment engaged in very different epistemological activities.

One student, Veronica, provides an intuitive explanation for why the light would go down as the bulb goes up, using gestures and colloquial speech. Another student, Jan, provides an 'explanation' that amounts to a gerrymandered list of physics vocabulary. When Veronica objects, "you're making it too complicated," Jan explains that she is "just trying to make it more physics oriented." Veronica retorts, "It *is* physics oriented. It's just how it is." Even though they both report taking part in a 'physics oriented' activity, through their activities and speech they express very different notions of what 'physics oriented' entails. For Veronica it apparently means explaining 'how it is,' while Jan thinks using words like "vectors" and "polarized" make it more 'physics oriented.' Their individual behaviors cluster with individualized epistemological and conceptual stances, and thus do not warrant a group level of analysis (for this interaction).

A Common Basis for Cognition in Action

There has been disagreement over the nature of the distinction between cognitivist, situated, and distributed accounts of cognition. This disagreement has fueled debate over how the debate can be settled, whether it can be settled, and even whether it *should* be resolved. While Anderson, Reder, and Simon (1996) have suggested the debate largely concerns the use of language, Greeno (1997) has contended that the issue can be settled as it becomes clear which tradition is better equipped for doing productive empirical work.

Others have argued that the distinction between cognitive and situated accounts of cognition lie with their preferred metaphors for learning. According to Sfard (1998) cognitivists follow a long tradition of viewing learning as an *acquisition* of knowledge, while situativity theorist view learning as an evolution of *participation* within a community of knowing. Rather than resolve their apparently incompatible ontological claims, she argues that they should be considered incommensurable and complementary. She thereby advocates for the peaceful coexistence of the paradigms, since "empirical evidence is unlikely to serve as an effective weapon in paradigm wars" (1998, p. 12).

We argue that our alternative account affords an ontological continuity between the cognitivist and situated/distributed traditions. Thus, in our account we can avoid the metaphorical paradigm war by distilling the choice of metaphor to an empirically informed decision about the unit of analysis. We therefore avoid surrendering to incommensurability, which if taken seriously leads to formidable methodological problems (and if taken *too* seriously descends into naïve relativism). Cobb and Bowers (1999) have also noted the need for a common basis for communication between these paradigms in order to avoid methodological problems. We hope that our account will provide such a basis, since it is founded upon established theories of cognition and is compatible with the connectionist principles that undergird both sides of the cognitivist/situativist divide.

Conclusion

We have described an account of cognition, in terms of resources & framing (Hammer, et. al., 2005), that provides an ontological and epistemological basis for connecting these traditions within cognitive science. This connection is made possible by adopting a dynamic unit of analysis that can be grounded in the data, rather than based on entrenched theoretical commitments. We have provided empirical heuristics for assessing the unit of analysis. Finally, we have shown two contrasting empirical analyses to demonstrate the empirical nature of the unit of analysis as afforded by the resources & framing account.

One of the most remarkable aspects of cognition that science has uncovered is its decentralized nature—we have learned that there is no one place where our perception, thought, and conscious experience all 'come together.' Given the decentralized, distributed, and contextually sensitive functioning of the brain during cognition, it is not such a stretch to extend the distributed nature of cognition past the skull and into the surrounding environment. Although this may seem counterintuitive, the empirical and theoretical gains made by doing so may warrant the refinement of that persistent intuition that our minds reside in—and are confined to—our heads.

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