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Categories at the interface of cognition and action

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Grounded cognition offers a natural framework for studying categories that lie at the interface of cognition and action. From this perspective, cognition emerges from the coupling of the brain, the modalities, the body, and the environment. Situated action, in particular, links these domains together, as perceived entities and events in the world (e.g., hedonic stimuli, social agents) trigger self-relevant responses (e.g., goals, values, identities, norms), which in turn produce bodily states (e.g., affect, motivation) that initiate actions (e.g., bodily actions, vocalizations) and ultimately produce outcomes, again in the world (e.g., reward, punishment). Ad hoc and goal-derived categories emerge between the internal cognitive states and external physical states that arise during the pursuit of situated action. Although these categories behave similarly in some ways to conventional taxonomic categories (e.g., possessing graded structure), they differ in others, especially in their dependence on context (typically contexts of situated action). On many occasions, these categories are constructed to support current situated action (ad hoc categories), but when they become relevant to situated action across many occasions, they become well-established in memory (goal-derived categories). Across these categories, ideals play central roles in determining graded structure, supporting the goals that drive situated action. Event frames offer a natural means of understanding how ad hoc and goal-derived categories become constructed compositionally, and how they offer an interface between cognition and the world, essentially providing coordinated patterns of values for instantiating frame variables. Interestingly, this frame-based account can be naturally implemented in the simulation mechanisms of perceptual symbol systems, further grounding ad hoc categories in relations between the brain, modalities, body, and world during situated action.

Keywords: abstraction, ad hoc categories, frames, goal-derived categories, grounded cognition, ideals, situated action (goal-directed action), typicality (graded structure)

1. Introduction

Humans exhibit prolific abilities to generate and use categories. If we assume that every word has a potential category of instances associated with it, then the numerosity and diversity of human categories begins with the tens of thousands of words in a language. If we further assume that words can combine compositionally to form still more categories, then the number of human categories is essentially infinite (e.g., Barsalou 1999; Fodor & Pylyshyn 1988). Of interest in this chapter is the subset of these categories that support agents as they perform situated action to achieve goals in the world, what I will refer to as *ad hoc categories* and *goal-derived categories* – categories that lie at the interface of cognition and action.

Because the perspective of grounded cognition offers a natural framework for understanding categories that support action, I first review this perspective briefly (Section 2). From the grounded perspective, I then review basic properties of ad hoc and goal-derived categories (Section 3), including the factors that determine their internal graded structure (Section 4). I then turn to the compositional construction of ad hoc and goal-derived categories, focusing on the central roles of frames (Section 5). Finally, I explore how these categories might be grounded in the space-time regions of multimodal simulations (Section 6). An emerging theme will be that ad hoc and goal-derived categories constitute an interface between event frames in cognition and goal pursuit in the world. Section 7 concludes with limitations of work to date and potential directions for future work.

Regrettably, for reasons of time and space, I focus on my previous work in this area, omitting many other relevant articles and findings. It would be useful to have a comprehensive integrative review of the literature.

2. Grounded cognition

Perhaps the best way to understand the perspective of grounded cognition is to consider a significant alternative. The dominant approach to cognition since the Cognitive Revolution in the 1950s assumes that the cognitive system is a module in the brain, separate from other modules for perception, action, emotion, and so forth (Fodor 1975; Pylyshyn 1984). Hurley (2001) referred to this approach as the “sandwich model,” given that the module for cognition is sandwiched between modules for perception and action (see Figure 1A). From this perspective, researchers can study and understand cognition as an isolated system without taking perception and action into account. Rather than playing any significant roles in cognition, perception is primarily a means of getting information into the cognitive module, and action is primarily of means of getting information out. A further implication of this perspective – particularly relevant for the study of categories – is that semantics and conceptual processing are viewed as the activation of abstract

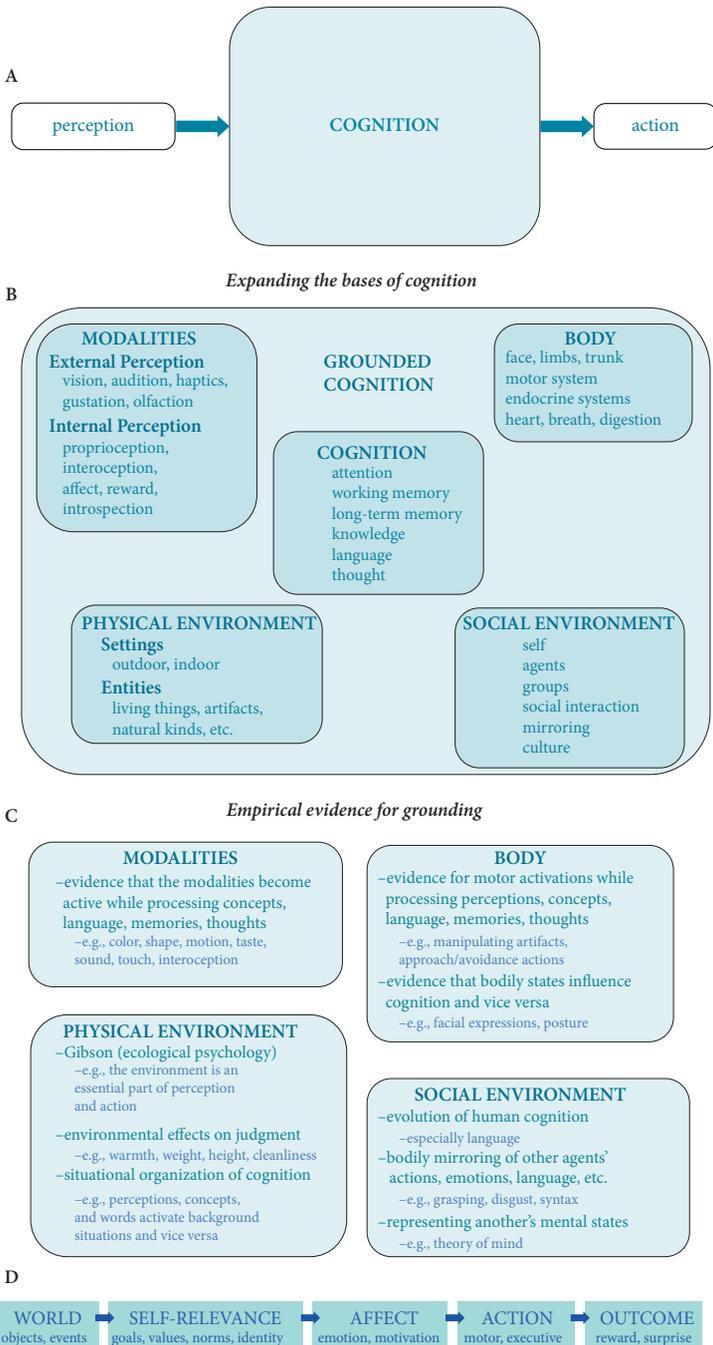


Figure 1. Panel A. The sandwich model of cognition (adapted from Hurley 2001). Panels B and C. Four domains that ground cognition (modalities, body, physical and social environment), and the general kinds of evidence for them. Panel D. The situated action cycle

symbolic structures in a cognitive module, without having any critical dependencies on perception and action (as well as on other potentially important domains, such as emotion, social cognition, etc.)

The perspective of grounded cognition rejects the assumption that cognition is an isolated module in the brain. Instead, the grounded perspective proposes that cognition emerges across diverse domains that become coupled together during situated action (e.g., Barsalou 1999, 2008, 2009; Clark 1998, 2008; Coello & Fischer 2016a, 2016b; De Vega, Glenberg & Graesser 2008; Pecher & Zwaan 2005). No doubt, the brain contains basic cognitive mechanisms associated with attention, memory, language, and thought. Rather than constituting a stand-alone module sufficient for producing cognition, however, these mechanisms depend intrinsically on interaction with mechanisms in other domains for cognition to emerge. The next four sections briefly review four domains that contribute to grounding cognition (summarized in Figures 1B and 1C).

2.1 Grounding in perceptual systems and the construct of simulation

Much research implicates perceptual mechanisms across the modalities in cognition. When cognition represents perceptual properties conceptually, they typically appear to utilize mechanisms in the brain's relevant modality-specific systems. When the color of an object is represented conceptually, for example (e.g., yellow for lemons), the color perception system appears to play central roles (Hsu, Frankland & Thompson-Schill 2012; Martin 2016: 201; Simmons et al. 2007; Wang et al. 2013). When the sound of an object, animal, or event is represented conceptually (e.g., loud for explosion), the auditory system plays central roles (e.g., Hoenig et al. 2011; Kiefer, Sim, Herrnberger, Grothe & Hoenig 2008; Lewis 2010; Trumpp, Kliese, Hoenig, Haarmeier & Kiefer 2013; Yao, Belin & Scheepers 2011, 2012). Similarly, when people represent the taste of a food, taste and reward areas play central roles (e.g., Chen, Papies, & Barsalou 2016; Simmons, Martin, & Barsalou 2005; van der Laan, de Ridder, Viergever, & Smeets 2011). In general, cognition appears to “reuse” perceptual systems for representational purposes when processing many types of semantic information (e.g., Anderson 2010 2016; Barsalou 2016b) but not all (e.g., Barsalou 2016a; Barsalou, Dutriaux & Scheepers 2018).

Reenacting perceptual states to represent information conceptually is often referred to as *simulation* (Barsalou 1999, 2008, 2009, 2016b). While the brain is engaged in perceiving an entity or event, memory systems establish a record of the brain state active, including perceptual systems. When, for example, someone eats an apple, states of the visual, gustatory, olfactory, auditory, and tactile systems become superimposed together on memory as an associative pattern, accumulating

across interactions with the category of apples to establish an entrenched network that represents the category (Barsalou 2017). On later occasions, when cues associated with apples are encountered (e.g., seeing an apple, being in a snack situation, hearing the word “apple”), this network becomes active and reenacts the kind of state that the brain would be in if it were eating an apple (Papies & Barsalou 2015).

Simulations need not be complete, conscious, or veridical, often being vague, unconscious, and biased instead; they can potentially be implemented at varying levels of granularity and vividness (Barsalou 1999). Simulations are also highly task dependent and context-specific (Lebois, Wilson-Mendenhall & Barsalou 2015), and are not the only way conceptual information is represented (Barsalou 2016b). Regardless of these factors, simulations – in general – provide diverse inferences about a category that can be used for a wide variety of functions (Barsalou 2008, 2016d). As described later (Section 6.1), simulations may play central roles in the representation of ad hoc and goal-derived categories.

2.2 Grounding in the motor system and body

Much research similarly implicates the motor system and body in cognition (e.g., Glenberg 1997; Lewis 2006; Pulvermüller 1999, 2005; Pulvermüller, Moseley, Egorova, Shebani & Boulenger 2014). When people represent the semantics of action words, for example, they utilize the brain’s motor system to simulate motor properties and bodily states, often very rapidly (e.g., Shtyrov, Butorina, Nikolaeva & Stroganova 2014). Furthermore, engaging the action system affects conceptual processing, as when configuring the face into a smile produces liking (e.g., Barsalou, Niedenthal, Barbey & Ruppert 2003; Niedenthal, Barsalou, Winkielman, Krauth-Gruber & Ric 2005). Similar to how cognition reuses perceptual systems for representational purposes, it reuses the motor and other bodily systems in simulations that represent motor and body semantics.

2.3 Grounding cognition in the physical environment

Since Gibson’s (1966, 1979) classic arguments about the nature of perception, researchers have believed that much is to be gained from studying the coupling of perceptual systems with the physical environment. Because perception evolved in the physical environment, and because the two are coupled continually during situated action, it is impossible and misleading to study perceptual systems in isolation.

Researchers adopting the grounded perspective often make similar assumptions about cognition, namely, that it makes little sense to study cognition independently of the environment. Although cognition can become decoupled from the

environment during mind wandering and other forms of thought, cognition is typically coupled with the environment as agents pursue diverse forms of situated action in the world. As a consequence, the cognitive system establishes situational patterns in memory to guide goal-directed action effectively in familiar situations (e.g., Aydede & Robbins 2009; Barsalou 2016c, 2016d; Brooks 1991; Clark 1998, 2008). Because habitual behavior in familiar situations conditions cognitive patterns in the brain robustly, it makes sense to study cognition when it's actually coupled with these situations (analogous to Gibson's arguments for studying perception coupled with the environment). Research with the visual world paradigm makes similar arguments (e.g., Huettig, Rommers & Meyer 2011; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy 1995). From this perspective, full-blown cognition emerges when coupled with the physical situations it has learned to process in the support of situated action (Barsalou et al. 2018).

2.4 Grounding cognition in the social environment

Theories that aim to explain the evolution of human cognition often propose that significantly enhanced social cognition was critical (e.g., Donald 1993; Tomasello 2009). Although language clearly distinguishes humans from other animals, abilities associated with social cognition underlie language, making it possible, while further contributing to the unique and powerful cognition that humans exhibit (Tomasello, Kruger & Ratner 1993). In particular, humans are unique in establishing extensive joint attention, adopting the perspective of others, representing other minds, following social norms, performing social mirroring at multiple levels, establishing self-identities, establishing cultural identities, and so forth.

Because social interaction plays such central roles in human cognition, it follows that cognition is grounded in the social environment, analogous to how it is grounded in the physical environment. Social cognition primarily emerges as humans are coupled with relevant social agents and situations while engaged in social interaction. Attempting to understand social cognitive processes without understanding their coupling with the social environment is likely to limit and distort the conclusions reached. Only when these processes are assessed as they operate in the social environment is their full extent likely to be revealed (cf. Barsalou et al., 2018).

2.5 Cognition as emergent

Putting the previous sections together, cognition is not a module that can be studied successfully in isolation. Instead, it is better viewed as a set of processes that emerge when core cognitive mechanisms are coupled with the modalities, the body, the

physical environment, and the social environment (e.g., Barsalou, Breazeal & Smith 2007; Barsalou, et al. 2018; Clark 1998, 2008; Hutchins 1995). Cognition emerges when the brain, body, and environment are coupled together.

Sometimes this approach is referred to as “embodied cognition.” One problem with this description, however, is that it only refers to one form of grounding (the body), failing to capture other important forms, namely, perceptual systems, the physical environment, and the social environment. For this reason, “grounded cognition” describes this approach more comprehensively, covering all relevant forms of grounding (also see 4E cognition; Newen, Bruin & Gallagher 2018).

2.6 The situated action cycle

As we have seen, a central theme of grounded cognition is that most basically (although not exclusively) cognition supports goal-directed action (e.g., Clark 1998, 2008; Glenberg 1997). Rather than simply being an information processor that implements symbol manipulation, cognition most fundamentally enables agents to interact effectively in physical and social environments. Indeed, one could argue that cognition evolved to implement the unusually powerful forms of action that humans exhibit (Barsalou 2016a).

What I will call the *situated action cycle* offers one way of conceptualizing the relation between cognition and action (see Figure 1D). The basic idea is follows: As entities and events are encountered in the environment, they activate (cue) cognitive states of self-relevance, including goals, values, norms, identities, and so forth. As these cognitive states become active, they in turn elicit relevant affective and motivational states in the body, which in turn may induce a wide variety of actions in the motor system (from eye movements, to hand movements, to full body movements) and in the executive system (e.g., inhibition, reappraisal, planning, problem solving). Finally, the actions performed change the environment, leading to diverse outcomes including reward, surprise, and so forth. Once the environment has changed, the situated action cycle iterates, as new cognitive and bodily states lead to new actions and outcomes.

Interestingly, the situated action cycle links together the various domains of grounded cognition in Figures 1B and 1C: As events occur in the *physical* and *social environment*, the *modalities* perceive them and activate *cognitive mechanisms* that produce states of *self-relevance* (with *cognition* often using the *modalities* to simulate relevant predictions and related information). In turn, these cognitions produce *bodily states* that induce *actions*, which finally lead to outcomes in the *environment*. Given the central role of the situated action cycle across everyday activities, it’s no accident that cognition emerges from all the domains in Figures 1B and 1C.

Various forms of the situated action cycle have played central roles in theories of psychology and cognitive science for decades. Behaviorist theories of conditioning, for example, focused on how cues, bodily states, actions, and outcomes become organized to implement learning and habit acquisition (while typically omitting cognitive and affective states; e.g., Bouton & Todd 2014; Domjan 2014). Early theories in cognitive science added cognitive and affective states to the Behaviorist version of the situated action cycle to explain plans, goal-directed behavior, and problem solving (e.g., Miller, Galanter & Pribram 1960; Newell & Simon 1972). Since then, theories of narrative and text processing have incorporated the basic form of the situated action cycle into how people understand and produce language about diverse forms of goal-directed events, including stories, autobiographical memories, and so forth (e.g., Baerger & McAdams 1999; Edson Escalas 2004; Reese et al. 2011; Stein & Hernandez 2007). As we will see in the remainder of this chapter, the situated action cycle offers a natural framework for understanding ad hoc and goal-derived categories.

3. Ad hoc and goal-derived categories

The traditional study of categories in cognitive psychology and cognitive science has tended to focus on common taxonomic categories such as *animals*, *plants*, *tools*, *clothing*, *furniture*, and so forth (e.g., Hampton 1979; Murphy 2002; Rosch & Mervis 1975; Rosch, Mervis, Gray, Johnson & Boyes-Braem 1976; Smith & Medin 1981). Interestingly, and perhaps tellingly, a wide variety of less conventional categories populate cognition as well, such as *things to pack in a suitcase*, *ways to get from San Francisco to New York*, *foods not to eat on a diet*, and *things to take from one's house during a fire*. At first blush, this latter kind of category might appear to simply be a quaint idiosyncrasy of human cognition. A closer look, however, reveals that these categories are ubiquitous. As we will see, they play central roles in situated action and share important properties with common taxonomic categories.

Barsalou (1983) initially dubbed these as “ad hoc categories,” given that they appear to be constructed spontaneously in an ad hoc manner when needed to achieve goals (during the situated action cycle). Of interest in this early assessment of ad hoc categories was how they differed from common taxonomic categories, and also how they might be similar. The next several sections document important properties of ad hoc categories and how they relate to the properties of taxonomic categories, beginning with dissimilarities before turning to similarities.

3.1 The correlational structure of the environment

One important difference is that ad hoc categories violate “the correlational structure of the environment,” something to which common taxonomic categories often conform (Rosch & Mervis 1975; Rosch et al. 1976). “Correlational structure” refers to clusters of features that different taxonomic categories circumscribe, such as *feathers, wings, nests, and flying for birds*, contrasted with *scales, gills, fins, and swimming for fish*. As Rosch and her colleagues proposed, common taxonomic categories capture and convey the correlated patterns of features in the environment, especially at the basic (generic) level (for a definitive review, see Malt 1995). In contrast, ad hoc categories typically organize exemplars that don’t exhibit similar features while instead exhibiting considerable dissimilarity, cutting across correlational structure and thereby violating it. *Things to take on a vacation*, for example, might include *shirt, apple, toothbrush, iPad, and snorkel*. Rather than emerging from a correlated set of properties, this category instead emerges from the context of planning a vacation. This category might not appear to share any significant overlapping features (especially physical). As described later (Sections 5.1, 5.2), however, these kinds of categories appear to be defined by abstractions that integrate frame attributes with optimizations and constraints relevant to performing situated action.

3.2 Contexts of situated action

Another important difference is that the salience of common taxonomic categories is often largely independent of context, whereas the salience of ad hoc categories typically appears to depend on it. Barsalou (1982, 1983) showed, for example, that when receiving *apple, orange, banana, and peach*, people immediately recognize them as belonging to the category *fruit*, without requiring any supporting context to do so (see Lebois, Wilson-Mendenhall & Barsalou 2015, for an alternative perspective). In contrast, when receiving *move to the remote reaches of Wyoming, sail around the world, go to Mexico, and become a drunk in Detroit*, people have no idea what category they instantiate. Interestingly, however, when participants receive a relevant context about situated action, such as, “Roy was in big trouble. The Mafia had a contract out on him. He knew he couldn’t continue living in Las Vegas or he’d be dead in a week,” they immediately generate the category, *ways to escape being killed by the Mafia* (Barsalou 1982, 1983).

The importance of context illustrates the potential relevance of grounded cognition for understanding ad hoc categories: These categories often only appear to become salient in a relevant context of situated action (Section 2.6). Once a relevant environmental setting has been established, along with its self-relevance

for an agent, useful categories in this context become apparent. The ability to construct such categories prolifically is no small computational achievement (imagine building computer intelligence that could do this). It is truly impressive how readily people construct new categories to support the situated action they're pursuing. Chrysikou (2006) found that the ability to construct ad hoc categories plays a central role in successful goal pursuit.

3.3 Establishment in memory

Barsalou (1983) also demonstrated that ad hoc categories can be much less established in memory than taxonomic categories. For example, participants generated members of taxonomic categories much more consistently than they did for ad hoc categories, suggesting that only taxonomic categories were represented by well-established networks of instances in memory (i.e., which produced consistent retrieval). Similarly, when participants were presented with a set of instances from a category and later asked to recall them, they tended to recall them better for taxonomic categories than for ad hoc categories. Together these findings suggested that ad hoc categories are constructed temporarily when relevant and do not become established well in memory unless processed repeatedly on later occasions. This issue will be explored further when goal-derived categories are introduced shortly (Section 3.5).

3.4 Typicality gradients

Perhaps the most surprising initial result about ad hoc categories was that they not only exhibit typicality gradients, but exhibit ones that tend to be as stable as those found in taxonomic categories (Barsalou 1983). When the intraclass correlation is used to measure the average agreement between participants in their typicality judgments for the members of a category, the values are comparable for both category types (typically values in the range of .30 to .60, depending on the study). As Table 1 illustrates (from Barsalou 1991), ad hoc categories unexpectedly exhibit typicality gradients that are comparable in stability to those in taxonomic categories.

One explanation of this equivalence is that a common process of constructing prototypes is responsible for typicality gradients in both category types (Barsalou 1983, 1987, 1989, 1991, 1993). For both taxonomic and ad hoc categories, people construct prototypes to represent them. Whereas the prototype for *birds* might be a *sparrow*, the prototype for *foods not to eat on a diet* might be a *bacon cheeseburger* (alternatively, instead of the prototypes being actual instances, they could simply be *features* of these instances). Once the prototype for a category is established, the

Table 1. Average measures of stability for prototype structure*

Experiment	Between-subject agreement		Within-subject agreement		Contextual shift	
	Common taxonomic	Goal-derived	Common taxonomic	Goal-derived	Common taxonomic	Goal-derived
Barsalou (1983)						
Experiment 2 ratings	.50	.56	–	–	–	–
Experiment 2 rankings	.57	.54	–	–	–	–
Barsalou and Sewell (1984)						
Experiment 1a	.33	.36	–	–	.58	.64
Experiment 1b	.41	.40	–	–	.70	.86
Experiment 1c	.46 ^a	.39 ^a	–	–	.28 ^f	.48 ^f
Barsalou (1985)						
Experiment 1	.45 ^b	.32 ^b	–	–	–	–
Barsalou (1986)						
Experiment 1	.60	.49	.82 ^d	.76 ^d	.97	.88
Barsalou et al. (1986)						
Experiment 1	.57 ^c	.44 ^c	.81 ^c	.76 ^c	.04	.37
Experiment 3	.47	.40	.74	.74	–.20	–.08
Experiment 4	.49	.44	.85	.84	–.39	–.37
Experiment 7	.48	.42	.81	.82	.99	.64
Average	.48	.42	.81	.78	.28	.40

* Pairs of means indexed by the same superscript differ reliably at $p < .05$.

Reprinted from Table 1 in Barsalou (1991)

typicality of the category's members varies as a function of how similar they are to the prototype. As individual birds become increasingly similar to *sparrow* (or to its features), they become increasingly typical of *birds*; as individual foods become increasingly similar to *bacon cheeseburger*, they become increasingly typical of *foods not to eat on a diet*.

An additional possibility is that the prototype construction process dynamically depends on context (Barsalou 1983, 1987, 1989, 1991, 1993). Consistent with the perspective of grounded cognition, prototypes for categories are constructed to support situated action in the current context. As a result, prototypes vary widely both between and within individuals as the goals and action currently relevant vary. This assumption explains the considerable variability in typicality gradients that occurs not only between different individuals (again, agreement in the .30 to .60 range) but within the same individual over time (agreement in the .70 to .85 range). It is further consistent with strong effects of context on what's currently typical for a

category. When participants are asked to judge typicality from the perspective of the average US citizen, for example, they construct typicality gradients for categories that differ substantially from those constructed when asked to adopt the perspective of the average Chinese citizen. People's ability to dynamically reconfigure a category is consistent with the proposal that categories are typically conceptualized in the context of the situated action cycle, with current goals and actions determining what's prototypical. Rather than exhibiting rigid typicality gradients, categories exhibit typicality dynamically in a manner that supports current situated action.

3.5 Goal-derived categories

Barsalou (1985) noted that many categories violating the correlational structure of the environment nevertheless appear to be well established in memory. In particular, when people repeatedly perform the same situated action over and over again, the categories constructed to support it are likely to become well established. When individuals travel frequently, for example, *things to pack in a suitcase* might become well established, as might *foods not to eat on a diet* for people who diet regularly. Certainly, these categories may vary somewhat from occasion to occasion, reflecting the particular constraints of each situation. For a particular traveler, however, the category of *things to pack in a suitcase* may contain a relatively habitual set of exemplars that instantiate the category regularly, or that are at least usually considered when instantiating it.

Based on this observation, Barsalou (1985) introduced the construct of *goal-derived categories*, namely, categories constructed to achieve goals that violate the correlational structure of the environment, regardless of how well established they are in memory. Within this definition, ad hoc categories constitute the subset of goal-derived categories that are not well established. Rather than being retrieved from memory, they are constructed temporarily on-the-fly to meet current processing demands associated with a course of situated action not pursued previously.

To the extent, however, that the same course of situated action is performed habitually, what was once an ad hoc category becomes increasingly established in memory to streamline situated action. Rather than having to construct relevant categories anew on each occasion, well-established categories are retrieved that facilitate processing (see Sections 5.3, 5.4). Not only does situated action become faster, it may also become more optimal as the learning process converges on prototypes for the categories that maximize goal achievement (see Sections 4.2, 5.2).

4. Determinants of graded structure in ad hoc and goal-derived categories

As we have seen, ad hoc categories exhibit typicality gradients, even when not well established in memory (Barsalou 1983), perhaps reflecting the dynamic construction of context-dependent prototypes. Furthermore, the stability of the typicality gradients in ad hoc categories is comparable to their stability in taxonomic categories (Table 1). An important question, however, is whether the determinants of typicality gradients are common for both category types. Essentially, this boils down to the question of whether prototypes for the two category types are similar in content (assuming that comparison to prototypes determines typicality; Section 3.4).

4.1 Family resemblance and central tendency

Barsalou (1985) investigated this issue (Barsalou 1991, provided a subsequent review). At the time, it was widely believed that typicality reflects *family resemblance*, based on classic work by Rosch and Mervis (1975) and Hampton (1979). As a category member increasingly resembles other category members, it becomes increasingly typical. A roughly equivalent way of describing this proposal is that as a category member becomes increasingly similar to the *central tendency* of its category, it becomes increasingly typical (where average similarity to a category's members – family resemblance – is roughly the same as similarity to a category's central tendency; Barsalou 1985, 1990). Thus, sparrow is a typical bird because it is more similar to other birds on the average than are most other birds (or more similar to the central tendency of birds as represented by their most common features).

Although previous work had shown clearly that similarity to central tendency is an important determinant of typicality for taxonomic categories (Hampton 1979; Rosch & Mervis 1975), it wasn't clear that central tendency also determined typicality in goal-derived categories. Because these categories violate the correlational structure of the environment, the central tendency of correlational structure may be irrelevant. Furthermore, because goal-derived categories support situated action, other kinds of information that support successful situated action may be important instead.

4.2 Ideals

In this spirit, Barsalou (1985) proposed that two new factors might be important for determining typicality in goal-derived categories: (1) ideals, and (2) frequency of instantiation. Ideals are features that exemplars should have to optimally achieve goals associated with their category during situated action. In *foods not to eat on*

a diet, for example, *minimal calories* is an ideal that category members should approximate to be good category members. Note that *minimal categories* is *not* the central tendency, which would be the *average* number of calories that *foods to eat on a diet* have. Most importantly, category members become increasingly typical as they approximate the ideal of minimal calories, rather than as they approximate the central tendency.

4.3 Frequency of instantiation

Another potential determinant of typicality in goal-derived categories is how frequently specific members are used to instantiate their respective categories during situated action. Perhaps the more often an exemplar from a goal-derived category is selected to support situated action, the more typical it becomes (i.e., because it becomes increasingly habitual). Because certain members are used frequently, they become typical.

4.4 Contrasting central tendency, ideals, and frequency of instantiation

Barsalou (1985) assessed central tendency (CT), ideals (I), and frequency of instantiation (FOI) as potential determinants of typicality in samples of taxonomic and goal-derived categories. Whereas central tendency was predicted to be the best predictor of typicality in taxonomic categories (because it captures correlational structure), ideals and frequency of instantiation were predicted to be the best predictors in goal-derived categories (because they support optimal and habitual situated action, respectively).

The results of an initial quasi-experiment (correlational in nature) strongly supported these predictions, with Table 2 presenting the results. For each category, the second-order partial correlations relevant to predicting its typicality are shown, where each predictor of interest (CT, I, or FOI) was correlated with typicality (i.e., exemplar goodness, EG), with the other two predictors partialled out. Central tendency was only associated with typicality in taxonomic categories, not in goal-derived categories (average partial correlations of .71 vs. .05). For goal-derived categories, typicality was associated with both ideals and frequency of instantiation (average partial correlations of .51 and .44). Surprisingly, however, ideals and frequency of instantiation were also important for taxonomic categories (average partial correlations of .36 and .45). This unexpected finding suggests that taxonomic categories also become organized to support goal-pursuit during situated action – not simply to represent the correlational structure of the environment. Vallee-Tourangeau, Anthony, and Austin (1998) further demonstrated the importance of situated action in organizing *both* taxonomic and ad hoc categories.

Table 2. Second-Order partial correlations by categories from experiment 1

	Correlation	EG-CT	EG-I	EG-FOI
Goal-derived categories				
Birthday presents (how happy people are to receive it)		.42	.53	.80
Camping equipment (importance to survival)		.15	-.12	.66
Transportation for getting from San Francisco to New York (how fast it gets people there)		-.51	.56	.40
Personality characteristics in people that prevent someone from being friends with them (how much people dislike it)		-.06	.78	.45
Things to do for weekend entertainment (how much people enjoy doing it)		.34	.43	.08
Foods not to eat on a diet (how many calories it has)		.31	.53	.62
Clothes to wear in the snow (how warm it keeps people)		-.22	.64	.34
Picnic activities (how much fun people think it is)		-.28	.17	.83
Things to take from one's home during a fire (how valuable people think it is)		.29	.47	.41
Common taxonomic categories				
Vehicles (how efficient a type of transportation it is)		.86	.63	.53
Clothing (how necessary it is to wear it)		.71	.81	-.10
Birds (how much people like it)		.75	.42	.78
Weapons (how effective it is)		.59	.91	.68
Vegetables (how much people like it)		.69	-.02	.29
Sports (how much people enjoy it)		.74	.53	.11
Fruit (how much people like it)		.71	.34	.49
Furniture (how necessary it is to have)		.84	.03	.14
Tools (how important it is to have)		.49	.37	.29

Note. Ideal dimensions are in parentheses. EG is exemplar goodness, CT is central tendency, FOI is frequency of instantiation, and I is ideals.

Reprinted from Table 3 in Barsalou (1985)

Together, these results suggest that all categories become organized to support situated action. A subsequent experiment with artificial categories in Barsalou (1985) demonstrated that central tendency, ideals, and frequency of instantiation causally determine typicality gradients (i.e., aren't simply correlated with them).

Much subsequent work, using more sophisticated and ambitious methods, has confirmed these initial results (e.g., Borkenau 1990; Chaplin, John & Goldberg 1988; Loken & Ward 1990; Lynch, Coley & Medin 2000; Read, Jones & Miller 1990; Voorspoels, Storms & Vanpaemel 2013; Voorspoels, Vanpaemel & Storms 2010, 2011). Perhaps most surprisingly, ideals tend to emerge as not only important determinants of typicality, but often as the *most* important determinants, even for taxonomic categories. This robust finding again highlights the importance of situated action in cognition. Because ideals optimally support situated action, their centrality in determining typicality strongly implicates the pervasive influence of situated action on cognition.

5. Deriving categories from frames to achieve goals

As we have seen, goal-derived categories are coherent categories that exhibit many of the same properties as taxonomic categories, but with important differences as well. An emerging theme is that situated action plays central roles in creating and organizing all categories, not just goal-derived categories. On the one hand, goal-derived categories are constructed to support goal achievement; on the other, categories in general become organized around ideals and frequency of instantiation to optimize goal pursuit during situated action.

Moving beyond these initial results, the issue arises as to how goal-derived categories originate in the cognitive system. In addressing this issue, Barsalou (1991) first distinguished between two modes of establishing categories. Most basically, categories can be induced from *exemplar learning*. As the members of a category are encountered, memories of them become superimposed on memory (perhaps producing abstractions in the process). In this bottom-up form of relatively receptive learning, knowledge about the world develops. To a large extent, this may be how taxonomic categories are acquired (e.g., Barsalou 1990, 2012, 2016b; Barsalou & Hale 1993; Goldstone, Kersten & Carvalho 2018; Malt 1995; McRae & Jones 2013; Murphy 2002; Smith & Medin 1981). As people encounter various kinds of plants and animals, for example, they induce categories at multiple taxonomic levels about them in a relatively bottom-up manner (although various types of top-down constraint surely contribute; e.g., Carey 2009; Malt 1995; Murphy & Medin 1985).

Alternatively, humans can readily construct new categories via top-down compositional processes typically under the control of language (e.g., Barsalou 2017;

Hinzen, Machery & Werning 2012; Winter & Hampton 2017). In this mode of category construction, language is likely to play central roles indexing combined concepts and specifying their relational structure. We next turn to Barsalou's (1991) account of how people use compositional mechanisms to produce ad hoc and goal-derived categories.

5.1 A general procedure for deriving an ad hoc category

Based on protocol analyses of people planning events (e.g., vacations), Barsalou (1991) developed an account of how ad hoc categories are newly constructed (summarized in Table 3). According to this account, an agent has currently activated a frame used to represent an event being planned. Following standard linguistic theory (e.g., Fillmore 1985), a frame is an interrelated set of attributes that become bound to a set of values in a specific situation. Barsalou (1992) presents the specific account of frames adopted here. Barsalou and Hale (1993) provide further discussion of this account, and Barsalou (1999) describes how it can be implemented in simulation mechanisms. Figure 2 illustrates an example of an event frame from a participant planning a vacation, showing only attributes of the frame mentioned, not other frame components including values, relations, and constraints (where attributes can be nested in sub-frames as shown).

Table 3. A general procedure for deriving an ad hoc category

-
1. Select a frame.
 2. Select an attribute in a frame.
 3. Identify optimizations that bear on the attribute.
 4. Identify constraints that bear on the attribute.
 5. Combine the attribute with the optimizations and constraints that bear on it to form a category description.
 6. Search for exemplars that satisfy the category description.
 7. Order exemplars according to how well they satisfy the category description, i.e., prototype structure.
 8. Store information about the category.
-

Reprinted from Table VI in Barsalou (1991).

As participants' protocols revealed, planning an event typically involved instantiating attributes in the relevant event frame with one or more specific values. Planning a vacation, for example, typically required instantiating the attribute for *locations* with one or more specific values, such as *beach*, which were often focused hierarchically (e.g., *beach, Florida, Panhandle, Navarre Beach*). Notably, a potential set of values for a frame attribute constitutes a goal-derived category, such as *locations to visit on a vacation*. Fully planning an event, such as a vacation, typically

requires instantiating many attribute values like this in advance, although some may be instantiated on the fly during the event itself, and some may be inadvertently passed over, perhaps disrupting the event when discovered later. When planning a vacation, for example, agents must establish values for *departure time*, *duration*, *companions*, *lodging*, *transportation*, *cost*, *activities*, *preparations*, and so forth. In the process, many goal-derived categories may become active to support the process of instantiating relevant frame attributes with suitable values. Language appears to play central roles in specifying these categories, as describing *locations to visit on a vacation* illustrates.

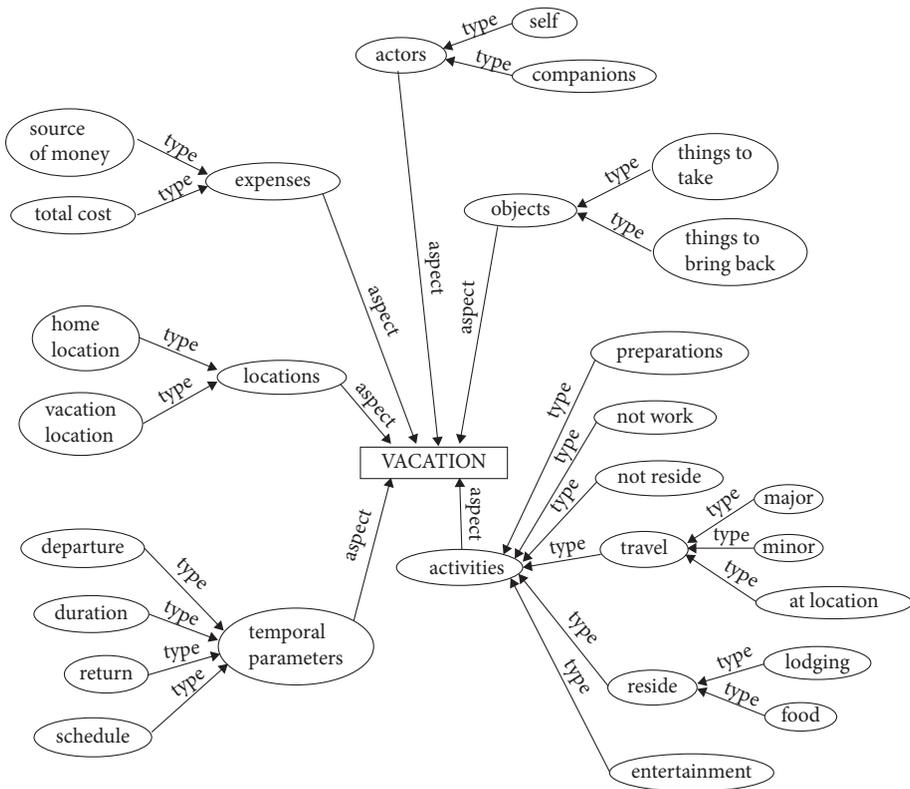


Figure 2. Attributes in a partial frame for vacation.
 Reprinted from Figure 1 in Barsalou (1991)

5.2 Specifying an abstraction for an ad hoc category: Optimizations and constraints

Prior to instantiating a frame attribute with specific values, planners in Barsalou (1991) often conceptualized an abstraction that described potential values that the attribute could take (e.g., an abstraction that described potential values of *locations to visit on vacation*). Typically, these abstractions incorporated two kinds of information: *optimizations* (illustrated in Table 4), and *constraints* (illustrated in Table 5). Again, language processes appeared to play central roles in combining optimizations and constraints to establish increasingly specified frame attributes. The processes of optimization and constraint are addressed next in turn.

Table 4. Examples of optimizations from participants planning a vacation

Type of goal	Goal-derived category	Optimization
Achievement		
Knowledge	Entertainment	Maximize educational Value
Enjoyment	Location	Minimize crowdedness
Preservation		
Abandoned system	Departure	Minimize work disruption
Comfort	Vacation location	Optimize temperature
Health	Actors	Maximize immunizations
Personal security	Things to take	Maximize emergency phone numbers
Resource		
Money	Transportation	Minimize cost
Time	Things to take	Minimize time to pack
Meta-planning		
Knowledge	Vacation location	Maximize amount of knowledge
Adaptability	Schedule	Maximize flexibility of schedule
Preparations	Lodging	Maximize timing of reservations

Reprinted from Table V in Barsalou (1991)

While instantiating event frame attributes during event planning, participants generally attempted to *optimize* various goals. When planning a vacation, for example, people often attempted to optimize goals associated with money, health, security, and enjoyment. As Table 4 illustrates for vacation, participants sometimes tried to optimize the warmth of a location, minimize the cost of transportation, maximize the flexibility of vacation activities, and so forth. Essentially, this optimization process establishes *ideals* that determine typicality gradients in ad hoc and goal-derived

Table 5. Examples of constraints from participants planning vacations that utilised the partial frame for vacation in Figure 1. Note that verbal descriptions of the constraints are not direct quotes from the protocols. Instead they are redescriptions that capture the constraint directly and often incorporate surrounding context. In addition, these examples of primitive relations were sometimes extracted from constraint chains. Key: EX, exemplars; LOC, location; OBJ, object. Adapted from Figure 2 in Barsalou (1991)

Requires

Possible companions must be able to take off from work at the time I can go.

time (departure (ex = my_departure_time)) -R-> actor (companion (work (vacation_departure (ex = my_departure_time))))

The amount of luggage I take depends on how I travel.

activity (travel (major (ex = X (max_luggage = Y)))) -R-> objects (things_to_take (amount ≤ Y))

Disallows

If my girlfriend goes with me (this requires romance with her), there can be no romances with strangers.

actor (self (goal = activity (entertainment (ex = romance (companion = girlfriend))) & companion (ex = girlfriend)) -D-> activity (entertainment (ex = romance (companion = stranger)))

If the vacation location is far (this requires long travel), I cannot drive.

location (vacation (ex = X (distance = far))) -D-> activity (travel (major (ex = car (rate = slow))))

Enables

I can go on vacation when I have saved enough money.

expenses (source = self (time = X, savings = Y > expenses (totalcost = Z))) -E-> time (departure (ex = X))

Being at the vacation location will enable visiting friends who live there, assuming they're home.

time (schedule (loc = X, time = Y)) -E-> activity (entertainment (ex = visit (time = X, loc = Y, obj = friends (loc = x, time = Y)))

Prevents

If I'm going to be flying, then I won't have my car at the vacation location.

activity (travel (major (ex = fly))) -P-> activity (travel (at_loc (ex = my_car)))

If I'm only going to be there a short time, this makes renting a boat unfeasible.

time (duration (ex = X)) -P-> activity (entertainment (ex = rented_boat (required duration = Y > X)))

Leaves

Because I will be taking my car (this prevents distant vacation locations), I must go some place close to home.

activity (travel (major (ex = my_car))) -L-> location (vacation (distance_from_home = close))

Because I want to spend little money on accommodations (this prevents going at the peak season), I can only afford going in the off season.

location (vacation (accommodations (cost = low))) -L-> time (departure (ex = off_season))

Cooccurs

The amount of money I have available depends on the time of year.

expenses (source (ex = self (available_money = X)) <-C-> time (departure (ex = Y)))

The climate a person wants to escape to depends on their current climate.

actor (companion (ex = X (like (obj = climate (ex = Y)))) <-C-> actor (companion (ex = X (climate (ex = Z))))

categories (Sections 4.2, 4.4). As attributes of event frames are instantiated, background goals being optimized establish attractive features – ideals – of potential attribute values. Once ideals become established for an attribute, they guide the generation and selection of the values considered, structuring these values around an ideal-based typicality gradient. As a consequence, values that best support these ideals become selected as instantiations of the frame attribute. Once again, we see the importance of situated action in category formation and use, where the categories in this case are instantiations of potential frame attributes relevant to planning a specific event.

As a frame's attributes become increasingly established over the course of planning, they increasingly *constrain* the instantiation of other attribute values instantiated subsequently. If, for example, a participant decides to vacation in December, this constrains vacation activities to be winter sports and other winter activities (unless the location is instantiated in the southern hemisphere, thereby constraining vacation activities to be summer activities). Table 5 illustrates the diverse sorts of constraints that participants mentioned while planning vacations, where the underlying constraint relations typically took the form of *requires*, *disallows*, *enables*, *prevents*, *leaves*, and *cooccurs*. Vacationing with a particular companion who works, for example, requires that the companion can get off work. Once again, we see the importance of situated action in category formation and use, where the potential category of instantiations for a frame attribute is constrained by the entire course of situated action being planned. Every possible phase of the situated action cycle, from the setting to possible outcomes, potentially constrains every category of attribute instantiations.

Finally, as optimizations and constraints are initially established for a frame attribute before instantiating it, they combine (via compositional mechanisms) to form an abstraction that covers the potential category of relevant instances. When instantiating the *location* attribute, for example, optimizations for *nearby* and *not too crowded* might be combined with constraints for *in July* (time) and *hiking* (activity) to form the abstraction, *nearby locations with hiking trails that aren't too crowded in July*. A new ad hoc category emerges from the process of combining a frame attribute with relevant optimizations and constraints. Once the abstraction has been created, it can then be used to guide the process of selecting possible instantiations. Members of the category must first satisfy the constraints, and then become organized along a typicality gradient defined by relevant ideals (originating in the optimizations). Once a potential category exists and has been structured in this manner, it supports selecting instances that will not only satisfy constraints on goal achievement but attempt to optimize it.

5.3 Roles of goal-derived categories in expertise

When an ad hoc category is first created, it is likely to become established in memory, at least weakly. If, however, the same kind of event is planned repeatedly, the category may become increasingly entrenched in memory. If someone regularly planned the same kind of vacation every summer, a category like *nearby locations with hiking trails that aren't too crowded in July* could become well established. Moreover, many other categories associated with the event might similarly become well established, such as *places to stay*, *things to take*, *preparations to make*, and so forth. All these increasingly established categories, together with their ideal-based typicality gradients, create expertise, streamlining the planning process on subsequent occasions, hopefully leading to increasingly optimal event outcomes. What were once ad hoc categories become well-established goal-derived categories, with these categories constituting fundamental mechanisms of planning expertise (for this specific kind of event).

Barsalou (1991) further proposed that planning expertise can produce complex *fields* of categories *within* individual frame attributes. To the extent that a particular individual plans many different versions of the same event, different subcategories of possible values develop that support different versions of the event, each subcategory associated with different optimizations and constraints. A travel agent, for example, might develop complex fields of categories for attributes of the vacation frame as a result of frequently planning vacations of many kinds. The *location* attribute, for example, would become associated with many sets of locations that support different kinds of vacations. In a given planning context, the relevant subset would be indexed by first establishing relevant optimizations and constraints for the specific vacation being planned, which then activate the relevant set of attribute values for *vacation location*. With increasing expertise, the ease and precision of activating optimal categories for all relevant frame attributes may make planning relatively easy and effective. In this manner, the continual use of relevant goal-derived categories plays a central role in developing expertise at performing a specific kind of situated action.

5.4 Habitual goal-derived categories and their adaptation

It follows from the above account that every adult has an extensive set of well-established goal-derived categories that support everyday activities they perform habitually. For example, people generally establish goal-derived categories that support the clothes they wear each day (at different times of year; for different occasions), the foods they tend to eat (both at home and eating out), the entertainment

and health activities pursued regularly (during the week and on weekends), the social activities pursued in social networks, and so forth. For any daily activity to become habitual and routinized, it must develop relevant goal-derived categories that efficiently and optimally instantiate relevant frame attributes. As situations for performing the activity arise, the relevant goal-derived categories become active quickly, guiding frame instantiation such that the activity can be performed as effectively and optimally as possible. On deciding what to have for breakfast at home, goal-derived categories for relevant foods, preparation methods, utensils, and so forth become active immediately to support the activity (even before consuming sufficient caffeine).

Rather than being applied rigidly, the goal-derived categories that support habitual activities are often adapted to current individual and situational constraints. When having breakfast, for example, if one is in a hurry or out of a typical breakfast food, selecting instantiations from supporting goal-derived categories is likely to proceed differently than usual. Dual-process frameworks offer a natural cognitive architecture for thinking about how habitual processing and regulatory processing combine when habits are adapted to current contextual constraints (e.g., Chaiken & Trope 1999; Sherman, Gawronski & Trope 2014). Better understanding how goal-derived categories are processed from this perspective offers an important direction for future work.

5.5 Lexicalization of goal-derived categories

As Barsalou (1991) noted, a surprising number of goal-derived categories are lexicalized. For culturally normative activities, lexemes often develop for attributes of the underlying event frames to designate important goal-derived categories. Consider the activity of *eating* and lexicalizations of categories associated with its important semantic roles, such as *diner* (agent), *food* (object), *utensil* (instrument), *eatery* (location), and *breakfast* (time). Similarly, for the activity of *farming*, lexicalizations develop for *farmer* (agent), *crop* (object), and *farm* (location); for *purchasing*, lexicalizations develop for *buyer* (agent), *seller* (indirect object), *merchandise* (object), and *payment* (instrument). Interestingly, some common taxonomic categories appear to be goal-derived categories, such as *clothing* and *tools*, where *clothing* can be viewed as the category of *wear* objects, and *tools* can be viewed as the category of *work* instruments.

Lexicalized goal-derived categories can become contextualized just like their non-lexicalized counterparts. By adding optimizations and constraints to lexicalized categories, abstractions become tailored to current contexts of situated action (Section 5.2). *Food*, for example, can be contextualized to *tasty food to be consumed*

on a diet, and *clothing* can be contextualized to *warm clothing to be worn while hiking in winter*. Barsalou (1991) explores a variety of issues associated lexicalizing and contextualizing goal-derived categories, including their joint use with taxonomic categories during situated action.

6. Grounding ad hoc and goal-derived categories

We have seen multiple ways that situated action permeates not only goal-derived categories, but taxonomic categories as well. Ideals structure members of both category types. Ad hoc categories depend critically on having a context of situated action present. All types of categories can be optimized and constrained to produce subsets of category members that support specific courses of situated action in particular contexts. All types of categories can become associated with fields of subcategories that provide expertise as the same category becomes embedded in different situational contexts.

6.1 Instantiating space-time regions in simulations

This next section explores another potential connection of goal-derived categories to grounded cognition, illustrating how these categories could emerge naturally from processing simulations that support situated action (Barsalou 1999; also see Barsalou 2003). Although no empirical evidence exists for this grounded account of ad hoc categories, the proposal here is potentially useful because it illustrates how goal-derived categories could originate in simulation – perhaps the most basic cognitive mechanism associated with grounded cognition.

Figure 3 illustrates Barsalou's (1999) proposal. Imagine that an agent wants to change a light bulb that has gone out and must stand on something to reach it. Further imagine that the agent constructs a simulation of changing the light bulb that includes reaching up to unscrew it, followed by inserting a new bulb (Figure 3A). Finally, imagine that the agent doesn't have a specific object in mind to stand on, but simply realizes that an appropriate object will be needed. Because the agent possesses a rough idea of what could be stood upon, the approximate size and position of a potential object is included in the simulation within a relevant space-time region (i.e., a 3D spatial region of the simulation that evolves over some period of time as the simulation runs). Nevertheless, the simulation for changing the light bulb is incomplete because the details of this space-time region have not been specified fully. Although the simulation represents changing the bulb with some precision, it only simulates the object to be stood upon in a sketchy manner (see Barsalou 1999, Section 2.2 for discussion of simulation sketchiness).

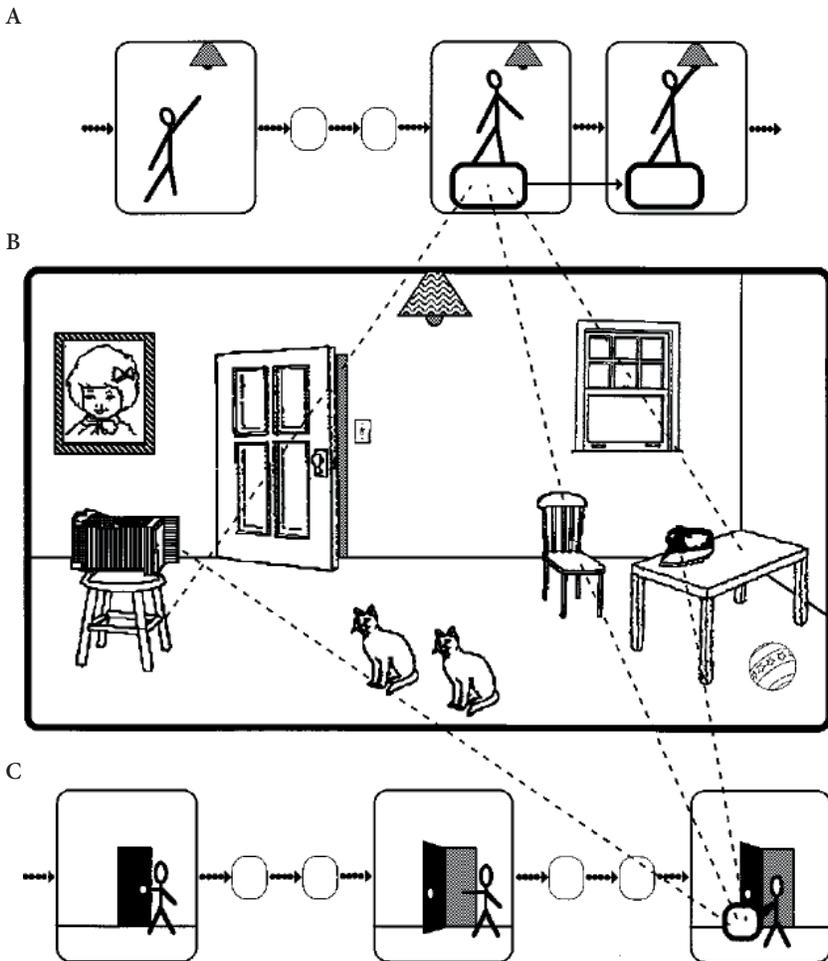


Figure 3. Within the simulation framework of perceptual symbol systems, accounting for the ad hoc categories of *things to stand on to change a light bulb* (A) and *things that could hold a door open* (C), which construe common entities in the same scene differently (B). Reprinted from Figure 9 in Barsalou (1999)

Further imagine, however, that the agent attempts to instantiate this sketchy space-time region of the simulation by simulating potentially relevant objects as instantiations *within it*. Doing so essentially instantiates the instrument attribute of the frame for changing a light bulb by generating relevant values of the goal-derived hoc category, *things to stand on to change a light bulb*. Rather than performing this instantiation process symbolically as in classic frame theories, however, the instantiation is implemented as simulating different possible objects in the relevant space-time region of an action simulation.

Prior to actually simulating objects in this space-time region, the agent may first try to specify relevant optimizations (e.g., *sturdy* and *safe*) and constraints (e.g., *should be located in the home*). Interestingly, both can be implemented via simulation as well. *Sturdy* and *safe* can be simulated as specific outcomes of standing on potential instrument objects in the space-time region and comparing their relative amounts of support and subsequent injury. *In the home* can be simulated as searching within a circumscribed region of space.

Using this abstraction for the category, the agent might then examine the environment for possible members. As Figure 3B illustrates, the agent in this particular example finds a stool, a chair, and table that all satisfy the constraint of being in the home. The agent can then simulate using each of these objects to stand on and change the light bulb in the space-time region for the instrument, thereby making the original simulation in Figure 3A more complete. In the process, the simulations of different objects can be compared with respect to the relevant optimizations, perhaps inferring that the chair would be sturdiest and safest. The chair could then be used to actually change the light bulb as situated action proceeds. Figure 3C further illustrates how the same chair could be differently construed in the ad hoc category of *things that could be used to hold a door open*.

This example illustrates how ad hoc and goal-derived categories can be implemented within a simulation architecture. From this perspective, a given ad hoc or goal-derived category contains a disjunctive set of simulations that instantiate the same space-time region of a larger simulation to support a particular form of situated action. By virtue of their relation to other space-time regions in a simulation, each particular space-time region plays a specific semantic role, such as *agent*, *theme*, *instrument*, and so forth, implicitly implementing a frame attribute. Although these roles and attributes may remain implicit within the simulation's overall structure, they may often become explicit when described linguistically (e.g., space-time regions for *food* and *utensil* in simulations of *eating*). Additionally, abstractions can develop for these regions (attributes) that include both optimizations and constraints, which again may be represented implicitly in simulations, as well as explicitly in language. Finally, a disjunctive set of simulations that effectively instantiate a space-time region constitutes a goal-derived category to support the situated action being simulated. Language is likely to play important roles throughout the category construction process. In this manner, the simulation architecture naturally and powerfully offers a way of understanding and conceptualizing goal-derived categories from the perspective of grounded cognition.

6.2 The interface between cognition and action

On the one hand, we have seen how people can establish goal-derived categories in memory to support situated action performed habitually (Sections 3.5, 5.3). On the other, we have seen how goal-derived categories can be implemented in space-time regions of simulations for situated action (Section 6.1). As we will see next, these two principles can be combined with the situated action cycle itself (Section 2.6) to develop a proposal of how goal-derived categories provide an interface between cognition and action (Barsalou 2003; see Barsalou 1991, for an earlier “pre-simulation” account).

As we saw for Figure 1D, the situated action cycle begins with the perception of entities and events in the environment, which activate relevant cognitive states of self-relevance associated with goals, values, norms, identities, and so forth. In turn, these cognitions induce bodily states for affect and motivation that produce diverse actions at many levels of behavior, with these actions ultimately causing outcomes in the world, which then initiate another situated action cycle.

The account of goal-derived categories developed in preceding sections can be integrated with the situated action cycle as follows. As cognitive states of self-relevance become active, they activate habitual forms of situated action (referred to as *situated conceptualizations* in related articles; e.g., Barsalou 2003, 2016d, 2016c; Lebois, Wilson-Mendenhall, Simmons, Barrett & Barsalou 2018). As the situated conceptualization for a habitual form of situated action becomes active, it reinstates itself as a *simulation* in relevant brain areas active previously active when performing the relevant situated action (Sections 2.1, 2.2). In the process, relevant objects and events in the environment are simulated, along with actions to be performed, followed by possible outcomes. Most importantly, each simulated object, event, and action occupies a space-time region in the simulation that, more generally, can be instantiated with a well-established goal-derived category having a typicality gradient (Section 6.1). As the simulation unfolds, it is likely to instantiate each of these space-time regions with a simulation of the most typical member, as defined by frequency and ideals. These simulated inferences about likely category members provide inferences about what’s likely to be occurring in the world as the situated action is performed (Barsalou 2009; Barsalou et al. 2007). Relevant objects and events are anticipated; potential actions are planned; likely outcomes are predicted. In other words, these simulations attempt to link cognition with the world. Once actual (as opposed to simulated) actions begin to be executed, these simulations run and are used to monitor actions performed in the situated action cycle.

If the habitual activity goes as planned, the overall simulation – including anticipated members of goal-derived categories – creates an interface between the original states of self-relevance that initiated the situated action and the actual actions

and outcomes that follow in the environment. What's simulated in anticipation of situated action maps successfully onto what is actually perceived and done as the event unfolds. Default simulations in the space-time regions for goal-derived categories create accurate anticipations and guide appropriate actions to streamline performance of situated action, providing a successful interface between cognition and action. Cognition and the world become aligned through instantiations of relevant goal-derived categories.

Various factors can decrease the effectiveness of this interface. If the physical environment contains objects and events that aren't anticipated via initial simulations, the respective defaults of the relevant space-time regions must be modified with simulations of less typical category members down the typicality gradient. Similarly, if the agent's goals and the situational constraints are somewhat atypical, again default simulations may not optimally anticipate what needs to be done, therefore requiring revision. Under these conditions, alternative members of relevant goal-derived categories may become active and simulated in their respective space-time regions. If necessary, more laborious search may be conducted in memory or in the environment to find appropriate members. The interface needs to be tuned before cognition and the world are aligned.

In general, situated action cannot run to completion unless all relevant space-time regions for relevant goal-derived categories are instantiated with effective simulations. To the extent that the agent has expertise in the domain, rich fields for all the relevant goal-derived categories may quickly and efficiently index relevant instantiations across most situations (Section 5.3). Only occasionally may significant work be required to find instantiations that bring simulations and the world into alignment. Regardless, a requirement for successful situated action is establishing an interface that aligns cognition and the world, where this interface revolves around simulated instantiations of goal-derived categories.

7. Outstanding issues

Many proposals made in this chapter about ad hoc and goal-derived categories have rested on relatively preliminary (and sometimes no) evidence, except perhaps for the determinants of typicality gradients, where much literature exists. Clearly, these categories appear to be interesting and important for effective human cognition. Thus, developing more sophisticated accounts, together with empirical evidence that do these accounts justice, has the potential to significantly increase our understanding of human cognition, especially as it plays out in situated action. The following sections highlight a few of the potential proposals made here that could be developed further.

7.1 The concept composition process that creates ad hoc categories

Section 5.1 proposed that ad hoc categories originally develop to instantiate attributes in frames that organize situated action. As agents begin to instantiate these categories, they integrate optimizations and constraints with attributes to create abstractions, which then guide the process of finding and selecting category members. Because this proposal rests on a preliminary set of protocol data, much more ambitious assessments could be made of both the representations and processes assumed in this account of how goal-derived categories originate compositionally. Establishing the roles of language in the composition process will be essential.

7.2 The development of expertise

Several proposals were made about expertise, with none of them supported by empirical data. Section 3.5 suggested that as ad hoc categories are used repeatedly, they become well established in memory. Section 5.3 suggested that as expertise develops, these categories become increasingly well established and optimized (in terms of their graded structures) to streamline expert performance. Section 5.3 further proposed that experts develop fields of attribute values for a goal-derived category, which support efficient performance across different contexts of situated action. Given the potential importance of such processes to expertise, especially in applied areas, examining and developing these proposals has potential for significant impact.

7.3 Use and adaptation of goal-derived categories in habitual behaviors at the interface of cognition and action

Sections 5.4 and 6.2 suggested that goal-derived categories support everyday habits by providing an interface between cognition and action during habit performance. Section 5.4 further suggested that top-down regulation of these habitual categories could play central roles in adapting habits to individual and situational constraints that vary across contexts. When eating daily meals, for example, well-established goal-derived categories associated with frame attributes for eating anticipate foods to be eaten, along with how to prepare and consume them. As contextual factors vary, however, regulatory processes adapt habitually generated categories to best accommodate the current situation (with dual-process theory offering a useful way to think about the adaptation process).

Assessing goal-derived categories in everyday habits may have considerable potential for both understanding health behaviors (e.g., eating) and changing them.

Because these categories appear to operate at the interface of cognition and action, changing their activation during cognitive processing has significant potential for changing subsequent action in the world that emanates from their specific instantiations in anticipatory simulations. Changing the foods that someone anticipates eating at breakfast, for example, could move one's morning food intake in a healthier direction. For these reasons, developing assessments of goal-derived categories in health habits, and further developing interventions to change them, seem like important future goals.

Another possibility in this area would be to use goal-derived categories for assessing individual differences in health domains. By establishing the foods that an individual eats habitually, and then characterizing these foods on various dimensions (e.g., healthiness, tastiness), profiles of individual eating behavior could be established. Similar kinds of profiles based on goal-derived categories could be similarly be established for many other kinds of domains, such as stress, physical activity, sustainability, and so forth.

7.4 Grounding goal-derived categories in space-time regions of simulations

No direct evidence supports the proposal in Section 6.1 that ad hoc and goal-derived categories are implemented as disjunctive sets of possible instantiations of space-time regions (although Wu and Barsalou 2009, offer indirectly related evidence). Nevertheless, this seems like a particularly provocative and potentially significant proposal. From the perspective of grounded cognition, this account offers a powerful implicit mechanism for producing categories (i.e., via variations in what instantiates a space-time region of a simulation). It also establishes a natural interface between cognition and action, as simulations map onto entities and events in the world. Again, establishing the roles of language in this process will be essential.

7.5 Establishing the neural bases of goal-derived categories

As far as I know, we have virtually no understanding yet of how goal-derived categories are implemented in the brain. Presumably frontal control areas are important when ad hoc categories are constructed initially, with these areas falling away as goal-derived categories become well established in memory. If these categories are implemented as instantiations of space-time regions, then a given type of goal-derived category should be implemented in relevant modalities. Goal-derived categories of objects should be implemented in the ventral stream; goal-derived categories of actions should be implemented in the motor system; goal-derived

categories of locations should be implemented in the parahippocampal place area; and so forth. Establishing the neural resources used to implement goal-derived categories should offer useful constraints on cognitive-level accounts of the relevant representations and processes.

7.6 Establishing relations between cognitive and linguistic mechanisms

Perhaps the most exciting new work on ad hoc and goal-derived categories is being performed in linguistics (e.g., Barotto & Mauri 2018; Mauri 2017; Mauri & Sansò 2018). Powerful new techniques are being developed to detect and collect ad hoc categories, goal-derived categories, and related constructions found ubiquitously in linguistic corpora. The resulting data offer important new sources of insight into the structure and use of these categories that can be readily integrated with what we already know. Just the specific categories observed in this new work are provocative in illustrating the kinds of categories that people entertain on the fly during everyday activities. Rather than cherry picking ad hoc and goal-derived categories for specific research purposes, searching linguistic corpora systematically is likely to provide much more representative sampling.

Perhaps more significantly, much potential exists for integrating insights from linguistic work with insights from psychological work to better understand important processes such as abstraction and concept composition (Section 5.1). Another exciting possibility is developing linguistically-informed measures that establish individual differences and behavior change in health habits (Section 7.3). Finally, there is much to learn about how people use language to coordinate cognition through the categories they use during social interaction. Indeed, much of the recent data collected in the linguistic literature illustrates social coordination exquisitely. As is often the case, language provides a unique window onto cognition that offers much potential for developing and testing hypotheses about its underlying mechanisms.

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