Principles of Representation: Why You Can’t Represent the Same Concept Twice

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Abstract

As embodied theories of cognition are increasingly formalized and tested, care must be taken to make informed assumptions regarding the nature of concepts and representations. In this study, we outline three reasons why one cannot, in effect, represent the same concept twice. First, online perception affects offline representation: Current representational content depends on how ongoing demands direct attention to modality-specific systems. Second, language is a fundamental facilitator of offline representation: Bootstrapping and shortcuts within the computationally cheaper linguistic system continuously modify representational content. Third, time itself is a source of representational change: As the content of underlying concepts shifts with the accumulation of direct and vicarious experience, so too does the content of representations that draw upon these concepts. We discuss the ramifications of these principles for research into both human and synthetic cognitive systems.

Keywords: Embodied cognition; Concepts; Representation; Perceptual simulation; Language; Linguistic shortcut; Linguistic bootstrapping

1. Introduction

“One cannot step in the same river twice” (Heraclitus).

Concepts are the basis of the human cognitive system. In online processing of the real-time environment, people’s ability to turn potential sensory overload into a set of recognizable percepts depends on top-down categorization of the car, street, and barking dog.
in front of them. In offline cognitive processing, the ability to discuss the relative musical merits of Shostakovich and dubstep, or to plan a different route home tomorrow to avoid the annoying barking dog, depends on coherent representation of the relevant conceptual information.

Recent evidence regarding the nature of mental representation suggests that the conceptual system is both linguistic and embodied (Barsalou, Santos, Simmons, & Wilson, 2008; Louwerse & Jeuniaux, 2008; Lynott & Connell, 2010; Vigliocco, Meteyard, Andrews, & Koura, 2009). In many ways, the conceptual system can be described as having co-opted the perceptual, motor, and affective systems (Connell & Lynott, 2010; Pecher, Zeelenberg, & Barsalou, 2003; Pulvermüller, 2005; Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011). The same neural systems that are involved in processing perceptual, motor, and affective online experience are responsible for representing (or simulating) this information in offline conceptual processing when people think about something not currently in front of them. For example, reading the word “cinnamon” activates olfactory processing areas in the piriform cortex (González et al., 2006; see also Hauk, Johnsrude, & Pulvermüller, 2004; Newman, Klatzky, Lederman, & Just, 2005), and many phenomena originally found in online perceptual processing have also been found to emerge in equivalent offline conceptual tasks (Connell & Lynott, 2010; Dils & Boroditsky, 2010; Pecher, Zeelenberg, & Barsalou, 2003). Furthermore, humans are a linguistic species, in that both online processing of ongoing experience and offline processing of past, future, and hypothetical situations can be labeled with words and phrases. The statistical associations between such linguistic labels are a rich source of information, and processing in a range of conceptual tasks is subject to both simulation and linguistic effects (Louwerse & Connell, 2011; Louwerse & Jeuniaux, 2008, 2010; Santos, Chaigneau, Simmons, & Barsalou, 2011; Solomon & Barsalou, 2004). For instance, there is a delay in judging that seaweed can be slimy if you have just judged that leaves can be rustling, both because there is a modality switching cost in shifting attention between auditory and haptic simulation systems, and because the words slimy and rustling rarely co-occur and belong to different linguistic clusters (Louwerse & Connell, 2011).

So, what is the difference between a representation and a concept? While these two terms are often used somewhat interchangeably, it is important for our present purposes to distinguish them. In this paper, we use the term representation to refer to a specific, situated, contextual instantiation of one or more concepts necessary for the current task. It is an ongoing conglomeration of neural activation patterns across perceptual, motor, affective, linguistic, and other areas, and, as such, includes both online (i.e., part of current experience) and offline (i.e., not part of current experience) information (see Principle 1). Moreover, since the conceptual system is both linguistic and simulation based, a representation also includes linguistic labels, which play important roles in conceptual processing (see Principle 2). If a friend tells you she has just acquired a new Labrador puppy, your representation of this particular dog, which you have never seen, will be situated in what you know of dogs in general and your friend’s circumstances in particular. It will draw upon your existing concepts of Labradors and puppies to form a coherent simulation of its likely appearance (e.g., visual information of golden fur), behavior (e.g.,
auditory information of whining; visual-haptic information of excited wriggling), and possible consequences of meeting your friend’s resident elderly cat (i.e., prediction: Barsalou, 2009), and this situated representation will also include relevant linguistic labels such as “puppy,” “labrador,” “cat,” and (for those exposed to U.K. advertising campaigns) “Andrex.”

A concept, on the other hand, refers to a general, aggregated, canonical (i.e., context-free) aspect of experience that has the potential to form the basis of an offline representation. A concept is formed when particular aspects of experience are attended to often enough that they lead to overlapping patterns of neural activation that can be re-activated relatively easily in an offline representation. For example, imagine your experience of patting a Labrador on the head at time $t_1$ includes visual experience of its size and golden color, haptic experience of its soft fur, and motor experience of reaching and scratching. Your next experience at time $t_2$ of walking a terrier in the rain is likely to include visual experience of a small, brown creature, olfactory experience of the effect of rain on fur, and motor experience of pulling on a lead. While these experiences at $t_1$ and $t_2$ are far from identical, over time there will be a large enough statistical overlap in the neural activation patterns, and this overlap will occur frequently enough that some version of the pattern can be re-activated relatively easily offline (i.e., without direct experience). Thus, the concept of *dog* is born, and will change over time as more experience is accumulated (see Principle 3). Since any aspect of experience that repeatedly receives attention can give rise to an easily reactivated activation pattern, any aspect of experience can be a concept. Red things, logarithmic curves, that feeling as you pull your front door shut that you might have forgotten your house keys—all are concepts to some extent, even if they do not all possess convenient linguistic labels in English. However, only common patterns with linguistic labels are likely to receive widespread agreement regarding their concept-hood. Indeed, following theories that the conceptual system is both linguistic and simulation based, we would argue that the label itself—“dog,” “chien,” “inu,” whatever your native language—will also form part of the concept of *dog*. Our definitions of long-term concepts and instantiated representations therefore follow the type-token distinction, but are not identical to Barsalou’s (1999, 2003) definitions of simulators and simulations in that we explicitly include linguistic information. We discuss this inclusion in more depth in Principle 2.

Many cognitive scientists working from the embodiment perspective agree that the content of mental representations changes dynamically with experiences, current goals, and available resources (Barsalou, 1999, 2008; Glenberg, 1997; Glenberg & Robertson, 2000; Lynott & Connell, 2010; Vigliocco et al., 2009; Wilson, 2002). However, the key embodied tenets that the conceptual system is central to both online and offline cognition, and that concepts are grounded in perceptual, motor, and affective systems, have some critical corollaries that must not be overlooked. In this paper, therefore, we outline three principles of representation that demonstrate why it is not possible to represent the same content on two separate occasions, and discuss the impact for theories and models of cognition. These principles are orthogonal in that each one independently
contributes to the assertion that one cannot, in effect, ever represent the same concept twice.

2. Principle 1: Online perception affects offline representation

Because the conceptual system co-opts the perceptual system for the purposes of representation, it means that concurrent perceptual and attentional processing of the surrounding environment affects what is conceptually retrieved and represented. Several studies have shown that representational content depends on how ongoing demands direct attention to modality-specific systems, and there are three different ways in which this can happen: strategic attention, implicit task demands, and perceptual stimulation.

2.1. Strategic attention

People can consciously and strategically direct endogenous attention to the perceptual modality of their choice (Spence, Nicholls, & Driver, 2001; Turatto, Bridgeman, Galfano, & Umiltà, 2004). For example, when we asked people in a recent study to judge whether a presented word related to a particular perceptual modality, we found that people were slower and less accurate for touch-related words than those relating to vision, sound, smell, or taste (Connell & Lynott, 2010). Critically, when it came to bimodal words like *jagged* or *fluffy* that relate equally strongly to vision and touch, we found that the tactile disadvantage persisted when people were asked to focus on the tactile modality (i.e., judging whether *jagged* could be perceived through touch) but disappeared for the visual modality (i.e., judging whether *jagged* could be perceived through sight). In other words, even when the same lexical item is presented, consciously directing attention to the sense of touch resulted in a more effortful and error-prone representation than when consciously directing attention to the sense of vision.

2.2. Implicit task demands

Perceptual attention does not have to be consciously directed to elicit modality-specific effects in conceptual processing. A second means of attentional capture comes from the perceptual nature of the stimuli or task. Modality switching effects have robustly demonstrated that there is a processing cost involved in re-allocating attentional resources from one modality-specific system (e.g., verifying the auditory property that a *blender can be loud*) to another (e.g., gustatory *cucumber can be bland*: Collins, Pecher, Zeelenberg, & Coulson, 2011; Connell & Lynott, 2011; Hald, Marshall, Janssen, & Garnham, 2011; Lynott & Connell, 2009; Marques, 2006; Pecher et al., 2003). Furthermore, the nature of the task itself can implicitly direct attention. Lexical decision tasks involve recognition of visual word forms, and thus preferentially direct attention to the visual modality; hence, words that refer to concepts with a strong visual component (e.g., *small*) show
faster and more accurate lexical decision performance than weakly visual words (e.g., *husky*), even when length, frequency, and other variables have been controlled (Connell & Lynott, 2014). By contrast, saying the same words aloud in a naming task preferentially directs attention to the auditory modality, since the goal is correct pronunciation, and hence strongly auditory words (e.g., *husky*) are faster and more accurate to name than weakly auditory words (e.g., *small*). Directing attention to a particular perceptual modality facilitates processing in that modality, and so differential attentional demands of each task interact with the strength of perceptual experience in the referent concepts to produce different representations of *small* and *husky* during lexical decision and naming.

### 2.3. Perceptual stimulation

Finally, attentional demands can be driven by concurrent perception in affecting representation, even when the task at hand remains constant. Whether concurrent perception facilitates or interferes with conceptual processing depends on the extent to which the perceptual stimulus tends to monopolize shared attentional and representational resources (Connell & Lynott, 2012). In particular, the temporal dynamics of a moving perceptual stimulus require continuous attention to monitor it for change, and hence leave few attentional resources in the input modality free for simultaneous conceptual processing (i.e., resulting in interference). For example, Kaschak et al. (2005) asked people to listen to sentences describing upward or downward motion (e.g., “The cat climbed the tree”) while simultaneously watching a high-contrast display scroll upwards or downwards. People were slower to judge that the sentences made sense when the directions of motion were congruent, leading Kaschak and colleagues to conclude that when the neural systems for processing a particular direction of motion were involved in perception, they were less available for simulating that same direction of motion in the sentence representation. Similar effects have been shown for single motion verbs rather than sentences (Meteyard, Bahrami, & Vigliocco, 2007), and for concurrent perception of auditory rather than visual motion (i.e., when the spatial source of a sound appears to change location: Kaschak, Zwaan, Aveyard, & Yaxley, 2006).

In contrast, some perceptual stimuli do not require continuous monitoring, and instead serve to direct attention to the input modality while leaving resources free for concurrent conceptual processing (i.e., resulting in facilitation). In a recent study, we showed that stimulating the hands with tactile vibrations made it easier for people to represent and compare small, manipulable objects like *wallet* and *key*, because the concepts included modality-specific information about touch that specifically related to the hands (Connell, Lynott, & Dreyer, 2012). Objects that were too large to be physically manipulable, like *cottage* and *mansion*, lacked relevant tactile information in their concepts and hence were unaffected by tactile stimulation. We found the same effects for proprioceptive stimulation (i.e., passive arm/hand positioning). Indeed, bodily posture has also been shown to facilitate retrieval of autobiographical memories, such that people’s recounting of their first visit to the dentist is more prompt and detailed when lying supine on a
couch than when standing upright (Dijkstra, Kaschak, & Zwaan, 2007; see also Riskind & Gotay, 1983). In short, ongoing perception of the body and external stimuli influences the content of mental representations because they effectively share patterns of activation.

2.4. Summary

Since conceptual information is perceptually grounded, attention on modality-specific perceptual systems—whether directed strategically, unconsciously by implicit task demands, or directly by perceptual stimuli—has profound effects on the content of simulated representations. One cannot be expected to represent the same concept twice when the task, goals, motivations, surrounding environment, and bodily configuration all converge to shape the resulting simulation.

3. Principle 2: Language is a fundamental facilitator of offline representation

The co-option of perceptual and other systems for offline simulation enables powerful conceptual processing, but human offline representational capacity is nonetheless limited and is even subject to further encroachment by online, real-time experience (Principle 1). However, because humans are equipped with language, it means that some of these resource limitations can be circumvented. Natural languages are full of statistical regularities: Words and phrases tend to occur repeatedly in similar contexts, just as their referents tend to occur repeatedly in similar situations, and people’s sensitivity to such regularities (e.g., Aslin, Saffran, & Newport, 1998; Louwerse & Connell, 2011; Solomon & Barsalou, 2004) allows them to build up substantial distributional knowledge of linguistic associations. This dynamic web of word-to-word (and word-to-phrase, phrase-to-phrase, etc.) associations constitutes the linguistic system, which is just as central to human conceptualization as the simulation system (Andrews, Vigliocco, & Vinson, 2009; Barsalou et al., 2008; Johns & Jones, 2012; Louwerse & Jeuniaux, 2008, 2010; Lynott & Connell, 2010). The linguistic and simulation systems are closely interconnected and mutually supportive; linguistic information can activate simulation information, which may in turn activate further linguistic information, and so on. For example, hearing the word “dog” will simultaneously activate closely associated linguistic tokens (i.e., a word or phrase, such as “cat,” “puppy,” “tail”) and the simulation of our aforementioned barking, drooling, tail-wagging mammal. These activated tokens will, in their turn, begin to activate their relevant simulations, whereas the various aspects of the simulated dog will activate their own linguistic labels (e.g., “barking,” “woof,” “tail”). This rolling wave of linguistic and simulation activations help to form a stable, situated simulation of dog for the task at hand. Here, we outline two ways that the linguistic system leads to representational differences by helping to circumvent unavoidable resource limitations: linguistic bootstrapping and the linguistic shortcut.
3.1. Linguistic bootstrapping

Representations are continuously modified by linguistic bootstrapping, where words and phrases act as pointers or placeholders in a limited-resource cognitive system. When a linguistic label is associated with the neural activation pattern that constitutes a particular concept, it no longer becomes necessary to re-activate the entire pattern as part of a simulated representation. Rather, when there are insufficient representational resources to maintain a simulation in full, such as when online processing demands attention (see Principle 1) or when the representation itself is highly complex or detailed, a word or phrase can replace a portion of the simulation with a linguistic placeholder that preserves structure but frees up resources to extend the simulation in other directions as needed. A linguistic label consequently acts as a temporary proxy for a simulated concept in an ongoing representation, and can be fleshed out into a simulation again at any time if resources are available. Having linguistic labels for concepts, particularly complex concepts, therefore allows us to build up recursive layers of representational depth that would not be possible if we were not a linguistic species (Lynott & Connell, 2010).

In this sense, linguistic bootstrapping helps to overcome the problems that ensue when the sheer complexity of what one is trying to represent outstrips the capacity available. An increasingly larger vocabulary therefore facilitates increasingly complex thought, at least up to some presumed threshold beyond which the cost of learning and retaining new words is larger than the savings made by using these words as linguistic placeholders. For example, children with larger vocabularies are better able to identify atypical examples of objects (Smith, 2003) and show greater flexibility in recategorizing objects (Jaswal, 2007). Individual differences in vocabulary size are also strongly related to more general tests of intelligence (e.g., Dunn & Dunn, 1997; Raven, 1948). The simulation system may be relatively continuous from humans to nonhumans (Barsalou, 2005), but the ability of linguistic bootstrapping to facilitate complex representation is major advantage for humans and offers a strong mechanism for how the evolution of language—whether spoken or gestural in nature—could have accelerated cognitive evolution. While we are not attempting to claim that all complex cognition is impossible without language, we would nevertheless argue that some complex thought—particularly that which suffers from limits of representational capacity—relies on linguistic bootstrapping.

3.2. Linguistic shortcut

An important difference between the linguistic and simulation systems is one of relative speed: Responses based on shallow, linguistic distributional information tend to be faster than responses that rely on deeper, situated simulation (Barsalou et al., 2008; Connell & Lynott, 2013; Louwerse & Connell, 2011; Louwerse & Jeuniaux, 2008, 2010; Lynott & Connell, 2010). When a word such as “dog” is heard or read, both systems are initiated but the linguistic system peaks in activation (i.e., spreads activation to other tokens, such as “cat” or “tail”) before the simulation system peaks (e.g., forms a visual, haptic, olfactory, affective situated simulation of a dog). However, the linguistic speed
advantage does not mean that simulation is slow; for example, words like kick can activate the leg region of the primary motor cortex in less than 200 ms (e.g., Hauk & Pulvermüller, 2004; Pulvermüller, Shtyrov, & Ilmoniemi, 2005). Rather, the relative importance of each type of system will change according to the current context or specific task demands. Information from the linguistic system is both faster to access and less precise than simulation information (Louwerse & Connell, 2011; Louwerse & Hutchinson, 2012), and hence has the hallmark of a “quick and dirty,” computationally cheap heuristic. The linguistic system therefore has the potential to act as a shortcut and provide a response before the relatively more expensive simulation system is fully engaged.

Support for the linguistic shortcut comes from a number of empirical studies. One approach has focused on the content of what people retrieve when asked to generate properties for a particular concept. When given the cue word “bee,” Santos et al. (2011) found that the first properties that people listed tended to be close linguistic associates like “sting,” “honey,” or “hive,” whereas later properties tended to describe details of the broader situation such as “flowers,” “wings,” or “summer.” In an imaging version of this study (Simmons, Hamann, Harenski, Hu, & Barsalou, 2008), properties that people listed in the first 7.5 s after seeing a cue word produced greater activation in Broca’s area and other regions usually associated with classic language tasks. In contrast, properties that people listed 7.5–15 s after a cue word preferentially activated areas usually involved in mental imagery, episodic memory, and location processing (precuneus and right middle temporal gyrus). Simmons and colleagues conclude that while both systems were active in conceptual processing throughout the 15 s range, the linguistic system dominated for the first half of property generation and the simulation systems dominated for the second half. In other words, people tended to rely on the computationally cheap linguistic shortcut to provide responses for as long as possible, and they drew more heavily upon the simulation system as linguistic responses ran out.

An alternative approach has been to use large-scale corpora to model the kind of linguistic distributional associations that are likely to be captured by the human linguistic system. For example, in Louwerse and Connell (2011), we used the Google Web 1T corpus (a trillion-word snapshot of Google-indexed pages from 2006: Brants & Franz, 2006) to calculate associative frequencies of modality-specific words such as scarlet (visual), loud (auditory), or pungent (olfactory). Using a modality switching cost paradigm (e.g., Pecher et al., 2003; Lynott & Connell, 2009) to compare the predictive abilities of linguistic and perceptual information, we found that the linguistic shortcut was the best predictor of fast responses, whereas perceptual simulation was the best predictor of slow responses (see also Louwerse & Hutchinson, 2012; for related ERP evidence). Further work in our laboratory has shown that use of the linguistic shortcut is not merely restricted to relatively shallow conceptual retrieval (i.e., verifying a known property of a known concept; see also Solomon & Barsalou, 2004) but is also useful in deeper conceptual processing as a form of cognitive triage. When dealing with novel stimuli in conceptual combination, the frequency with which two words have previously appeared in close proximity affects not only the time course of successful processing but also the time course and likelihood of failure (Connell & Lynott, 2013). The less often two words have
appeared close together (e.g., octopus and apartment), the more likely people are to reject their compound (e.g., octopus apartment) as nonsensical or uninterpretable rather than risk costly failure in the simulation system.

3.3. Summary

Via linguistic bootstrapping and the linguistic shortcut, language can help to circumvent resources limitations caused by online processing (see Principle 1), although the utility of these mechanisms will vary according to whether there are suitable linguistic labels for the relevant patterns of activation in the task at hand. An important implication of both linguistic bootstrapping and shortcut is that although the concept to which a word refers is ultimately grounded in the simulation system, a word does not need to be fully grounded every time it is processed (Louwerse & Connell, 2011). In this sense, words can help to overcome the representational bottleneck that ensues “when situations demand fast and continuously evolving responses, there may simply not be time to build up a full-blown mental model of the environment” (Wilson, 2002, p. 628). Because the linguistic system is faster and computationally cheaper than basing a judgment on the simulation system, and because on-the-fly conceptual processing does not have to be perfect (only “good enough”: Ferreira, Bailey, & Ferraro, 2002), people can safely exploit the linguistic system much of the time.

While some parallels may be drawn between the fast linguistic system/slow simulation system and dual processing theories of reasoning and cognition (Evans & Over, 1996; Kahneman, 2003; Sloman, 1996; Stanovich, 1999; cf. Carruthers, 2006; for an opposite perspective linking language to system 2), it is important to note that they are not the same. The main contrast between system 1 and system 2 in dual processing theories is that the first is fast and unconsciously automatic, whereas the latter is slow and consciously deliberative (Evans, 2008). However, both linguistic and simulation systems are fast, unconscious, and automatically engaged, albeit with relative differences in speed (Barsalou et al., 2008; Louwerse & Jeuniaux, 2008; Lynott & Connell, 2010), meaning that there is little about the usual system 1/system 2 distinction that can map onto the roles of linguistic and simulation systems in human cognition. One cannot represent the same concept twice when different aspects of the situation may be represented in linguistic and/or simulated form according to available resources, task demands, and processing goals.

4. Principle 3: Time itself is a source of representational change

Even if online perceptual constraints (Principle 1) and linguistic bootstrapping/shortcuts (Principle 2) are replicated exactly on two separate occasions (i.e., trying to retrieve the same thing under precisely the same circumstances), the representation formed at $t_1$ will never be identical to that formed at $t_2$ because the pattern of activation that constitutes the concept to be retrieved (i.e., instantiated) is subject to change over time. Because
Concepts alter with the accumulation of direct and vicarious experience, and with the act of retrieval itself, the representations that draw on such conceptual content are also inevitably mutable. Or, in other words, one of the drivers of representational change over time is conceptual change over time.

Borges’s (1962) fictional creation of Funes the Memorious has become one of the most famous examples in cognitive science of the importance of categorization and abstraction in memory. Funes, afflicted by separately encoding every instance of every item he encountered, “was disturbed by the fact that a dog at three-fourteen (seen in profile) should have the same name as the dog at three-fifteen (seen from the front)” (Borges, 1962, p. 70). In many ways, of course, the representation Funes formed of a dog at 3:14 differed profoundly from his representation of a dog at 3:15, but where things go wrong for Funes is his inability to draw upon a general, canonical concept of dog to help situate his representation. Even within such a short time window, however, there will still be differences between a person’s concept of dog at 3:14 and 3:15, because every further experience alters the nature of experience-based concepts.

The act of conceptual retrieval is not a passive read-only access of memory, but actively alters what is being retrieved, both in strength and content. In this sense, encoding and retrieval cannot be clearly separated because “retrieval transfers memory into a state of transient plasticity” (Hardt, Einarsson, & Nader, 2010; p. 151) in which conceptual content is malleable. Every single representation of a dog draws upon the dog concept with a slightly different focus; if one moved to a city where handbag dogs were prevalent, every sighting of a chihuahua would not only activate one’s concept of dog, but subtly change it by reinforcing perceptual experience of small, yappy creatures. Furthermore, every offline thought of dogs may be influenced by this chihuahua-laden environment, because the perceptual information that was most recently represented in a concept is preferentially re-activated the next time that concept is retrieved, even after a delay, and even when it is not strategically useful to the task at hand (Pecher, Zanolie, & Zeelenberg, 2007; Pecher, Zeelenberg, & Barsalou, 2004; van Dantzig, Cowell, Zeelenberg, & Pecher, 2011). Indeed, since simulated and experienced reality are not encoded differently (e.g., Loftus, 1975, 1996), vicarious experience of dogs (e.g., reading Stephen King’s Cujo) would have a similar effect in influencing the perceptual, motor, and affective information that makes up the dog concept. Even if one managed to spend a year without seeing or thinking about dogs, experience of related concepts and situations, including that triggered by exposure to related words, would still serve to shift the pattern of activation in the dog concept. In other words, the constant and subtle shifting in the composition of concepts influences the content of representations, since different information is available to instantiate on each occasion.

4.1. Summary

Concepts are subject to constant change throughout the lifespan, even though the notion of invariance is often implicit in discussions of the adult conceptual system. For example, in their critique of perceptually grounded concepts, Mahon and Caramazza
(2008) argue that incorporating differing sensory information as part of a concept creates a problem where “the same person may not instantiate the same concept at different points in time” (p. 68). However, since concepts are formed from direct and vicarious experience, there is no reason to expect the same person’s representations of a concept to remain invariant from one occasion to the next. Concepts (i.e., the generic *dog*) will always vary by personal experience both within and between individuals. Instantiated representations (i.e., a specific example of a real or imaginary *dog*) will therefore always vary according to the current form of the underlying concept, as well as task goals, available resources, and so on.

5. Discussion

As embodied theories of cognition are increasingly formalized and tested (Pezzulo et al., 2011), care must be taken to make informed assumptions regarding the nature of concepts and representation. In this paper, we have argued that three principles of representation dictate why one cannot, in effect, ever represent the same concept twice. As theoretical constraints, our principles state that (a) online perception affects offline representation, (b) language is a fundamental facilitator of offline representation, and (c) time itself is a source of representational change. The principles we outline therefore have important ramifications for research into both human and synthetic representational systems.

5.1. Representation in communication

All three of our principles highlight the variability of mental representations, whereby representational change is driven by a diverse range of sources. Capacity for change, however, does not mean instability. Like an attractor in a dynamical system, a long-term concept may be stable (i.e., not subject to massive changes from small perturbations) while still being subject to gradual drift over time (Principle 3). That an offline representation of such a stable concept is subject to further influences from both online perception (Principle 1) and language (Principle 2) does not render it unstable; rather, as long as the ongoing representation can appropriately fulfill current task goals, it is fit for purpose.

For example, a common task that makes heavy use of the conceptual system is that of communication. Since the cumulative experience that makes up the conceptual system will differ between individuals, often considerably so, the ability of two individuals to communicate effectively depends on there being a minimum degree of overlap between their ongoing representations and, therefore, the concepts from which these representations derive. The question then becomes: How much overlap is enough? Critically, understanding one another in communication does not require identical representations between speaker and listener (cf. Mahon & Caramazza, 2008, p. 68), just representations that overlap enough to achieve the current communicative goal. In dialog, speakers can negotiate to ensure that they share enough common ground to communicate effectively (Clark,
1996). Nonetheless, even single-word utterances are embedded in valuable situational and nonverbal cues. Take the word “fire”: a person running from a building shouting “fire” is likely to be well understood by passers-by, unlike (for instance) a person standing on a street corner quietly speaking the same word. In the first case, the representation of a building on fire in the minds of passers-by will be close enough to that of the fleeing speaker to achieve the communicative goal of warning. In the second case, there is insufficient situational context to constrain what the speaker intends and passers-by are not very likely to arrive at the same representation.

Furthermore, we propose that the linguistic system also plays a critical role in providing conceptual and representational overlap. Since the conceptual system comprises both linguistic and simulation information (Principle 2), linguistic labels provide a valuable source of shared experience in their own right. Words are not just the vehicles of meaning, but, because of their ability to bootstrap representations by acting as placeholders and shape representations by their distributional information, actually contribute to overlap of representation between speaker and listener. Indeed, one could argue that the linguistic label is the only truly identical element between the concepts and representations of two individuals. It is entirely possible for two individuals to communicate smoothly, and believe they understand one another very well, while having very little overlap in the content of what they are mentally representing. For example, imagine your lifetime experience of dogs has been entirely of the small, handbag-dog variety, and that you are unaware that dogs come in any form larger than a chihuahua. You then meet someone who has only ever experienced large working dogs and is unaware that dogs come in any form smaller than a German shepherd. An exchange such as “Do you like dogs?,” “Yes, we have one at home,” “Same here, we just got one last week from the shelter,” is perfectly effective communication where each party understands the other, even though each individual is representing quite a different dog in both canonical (i.e., liking dogs in general) and specific (i.e., my pet dog at home) forms. Without the convenient label of “dog,” however, it is unlikely that communication about such different concepts would succeed so easily. In other words, however much the underlying concept might vary between individuals, a shared communicative context will help considerably in forming representations that overlap enough for the purposes of the current goal.

5.2. Representation in cognitive models

As modeling constraints, our principles can be restated to imply that (a) offline processing is continuously subject to online perceptual inputs, (b) language is not just a system input/output but is part of representation and processing, and (c) experience over time means that identical inputs at $t_1$ and $t_2$ will not give rise to identical outputs. These constraints impact upon both the high-level assumptions and practical design of cognitive models that attempt to implement human conceptual representations.

Regarding constraint 1, it is, of course, not trivial to include online perceptual inputs into the offline representations of a cognitive model: most models are physically disembodied (regardless of their underlying design principles) in that they are hardware-independent
software that is disconnected from the external, real-time environment. Since perceptual inputs are not just adding noise in the system, but systematically altering whether and how information is represented, their absence means that a significant source of variance in human data is not being captured. One way to deal with this constraint is to take the embodied robotics approach; models such as the iCub (Marocco, Cangelosi, Fischer, & Belpaeme, 2010) possess external sensory systems and at least theoretically have the capacity to enfold perceptual inputs into offline simulations. However, all is not lost for creators of software cognitive models. If the attentional demands a particular task and paradigm places on modality-specific processing are sufficiently well understood (e.g., see Connell & Lynott, 2012, for discussion of processing sentences about visual motion under primed versus occupied visual attention), then a model can be designed to capture human performance under these different conditions.

Regarding constraint 2, the cognitive sciences have seen much debate over the last 15 years regarding the role of language and linguistic information in conceptual processing. Early work with models such as LSA (Landauer & Dumais, 1997) and HAL (Burgess & Lund, 1997) proposed the ambitious claim that the distributional information contained in word-to-word (and word-to-phrase, etc.) associations could constitute word meaning in conceptual processing, but this claim was quickly checked by demonstrations that distributional information could not explain everything (e.g., novel use of objects: Glenberg & Robertson, 2000). The majority of cognitive models currently omit linguistic distributional information (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Dilksina, McClelland, & Plaut, 2008; Dry & Storms, 2010; Minda & Smith, 2010). However, as with perceptual inputs, linguistic information systematically alters whether and how information is represented, and so its absence means a significant source of variance in human data is not being captured. The best way for cognitive models to deal with the constraint that language forms a part of representation is to actually include both a linguistic and a grounded component in the model. Indeed, some recent cognitive models have begun to do so (Andrews et al., 2009; Johns & Jones, 2012), showing that models with both a linguistic distributional component and a grounded simulation component predict human data better than either component alone. While such a modeling approach is still in the minority, we believe that the importance of the language constraint has been hitherto underestimated, and we look forward to seeing its inclusion more often in the future.

Finally, regarding constraint 3, many existing theoretical and computational models of human cognitive processes implicitly treat conceptual knowledge as invariant (e.g., Coltheart et al., 2001; Dry & Storms, 2010; Johns & Jones, 2012; Machery, 2007; Mahon & Caramazza, 2008; Markman, 2012; Minda & Smith, 2010; Pinker, 1999; cf. Elman, 2009; Marocco et al., 2010). Once something has been learned or is known, invariant models assume that it will be always retrieved and represented in the same way for the same cue: cat always primes dog, spoons are typically metal, a job is always like a jail. Invariant representation, however, is not possible: Task-specific representations change from $t_1$ to $t_2$ because the underlying concept itself changes from $t_1$ to $t_2$. One way to step around this constraint is to regard invariant models as snapshots of cognition—that is, an isolated
time slice of the conceptual system at a point of commencing a particular task that resets to $t_0$ before every new input—because a snapshot assumption is arguably less harmful to a model’s psychological validity than an invariance assumption. Ideally, however, a cognitive model would be able to deal with this representational change constraint by continually evolving; rather than having separate training and testing phases, each new stimulus would have the ability to shift the underlying concept while still maintaining its fit to human performance.

6. Conclusions

In sum, one should be cautious about the broader generalizability of any cognitive account that implicitly treats the unendingly malleable human conceptual system as a static state space, blind to concurrent perception, or linguistic information. Humans do not work like that. If we wish to build a proper understanding of human cognition, then we must allow for the fact that people are attentionally limited, linguistic entities whose representations continuously change over time. Similarly, if we hope to model how humans learn about and represent the world, then we may well see new generations of distractable, language-reliant, inconstant, embodied robots. Whether human or synthetic, a cognizer can get by quite well without ever representing the same concept twice.

References


