Title
Tracking Meaning Change Over Time: A Dynamic Field Theory Model

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 39(0)

Authors
Coventry1, Kenny R.
Gudde, Harmen B.
Schultheis, Holger

Publication Date
2017

Peer reviewed

Tracking Meaning Change Over Time: A Dynamic Field Theory Model

Kenny R. Coventry[1] (k.coventry@uea.ac.uk)
School of Psychology, University of East Anglia,
Norwich, UK

Harmen B. Gudde (h.gudde@uea.ac.uk**)**
School of Psychology, University of East Anglia,
Norwich, UK

Holger Schultheis (schulth@informatik.uni-bremen.de)
Cognitive Systems Group, University of Bremen,
Bremen, Germany

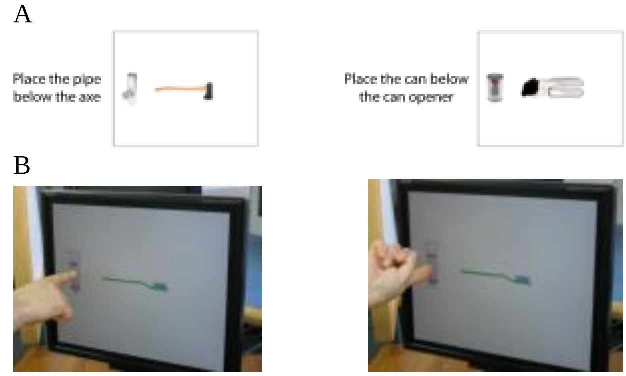
Keywords: meaning; spatial language; dynamic field theory

Meaning Change

Words are often regarded as "slippery customers" (Labov, 1973). First, it is difficult to come up with a fixed content that seems to apply across all uses of a single word (Wittgensten, 1953). Second, the meaning of a word is subject to wider contextual constraints beyond the company it keeps with other words within a sentence. Third, the assumption that a word means a fixed thing is at odds with the fact that word meaning shifts over time, as do the objects a word refers to. Taken together, theories of word meaning need to be able to account for the intuition that words have content associated with them, while allowing for variation in how a word is used in context, and how word meaning can change over time.

We provide an approach to word meaning within the spirit of dynamic systems theory (DST) models of cognition that accounts for the slipperiness of words. First, we draw an analogy between models of (non-linguistic) spatial behavior and how the meaning of language changes over time while exhibiting regularity. In particular, we identify two key features of DST models – *multicausality* and the building of temporally-bound *attractor states* - that afford application to theories of meaning. Second, we take these features of DST models and test them in experiments examining the comprehension of spatial expressions over time using object placement behavior as a measure (e.g. "Place the oil paint tube over the toothbrush"). Building on earlier work examining the constraints in which spatial language is used (Carlson-Radvansky et al., 1999; Coventry, 2013, 2015; Coventry & Garrod, 2004; Coventry et al., 2001, 2010, 2013, 2016; Gudde et al. 2016), we present a programme of studies mirroring early models of spatial memory, with experimental data showing striking similarity with results from other (non-linguistic) spatial tasks (namely the A not B error tasks and associated model produced by Smith & Thelen; e.g. Smith & Thelen, 2003; Thelen et al., 2001). Third, we take these data, and show that a previous DST model originally developed to account for infant perseverative reaching behavior (Thelen et al., 2001) provides an elegant model of the changing meaning of spatial expressions over time.

Figure 1: Examples of scenes used (A) and movement manipulation



The programme of experiments involved using placement behavior as a proxy for situation-specific meaning (adapting a method from Carlson-Radvansky et al., 1999). Participants were given spatial expressions of the form PLACE OBJECT A 'PREPOSITION' OBJECT B, followed by a picture displayed on a computer screen. The task was to move OBJECT A so that the relation between objects matched the location denoted by the sentence (prepositions used were *over*/*under*/*above*/*below*). OBJECT B was always an object with a functional part at one end (e.g. a toothbrush), and these objects were always displayed in sideways view (Figure 1). Critically the similarity between the probe and the prime trials was manipulated – analogous to the different object locations in the A not B error task (Thelen et al., 2001). The objects to be placed were either functionally related (e.g. a toothpaste tube and a toothbrush, hereafter F) or non-functionally related (e.g. a tube of paint and a toothbrush, hereafter NF). Previously it has been shown that placement behavior for F object pairs is different from placement behavior for NF object pairs when participants are given spatial sentences with the preposition *above* in them. Placements for an F object were nearer the

[1] Publication-based author.

functional part of the other object than for NF objects; placements for NF objects were nearer the mid-point (centre of mass) of the other object than for F objects (Carlson-Radvansky et al., 1999).

The programme of studies varied the similarity between prime and probe trials (in terms of same/different spatial relations, functional relations between objects, and the way in which objects are moved) as well as the number of prime trials (i.e. the extent to which an attractor state is built prior to probe placements). Among the results in the series of studies we find evidence that object placements on a probe trial are affected by the number of prime trials presented first, and the nature of the similarity between prime and probe trials. For example, when a probe involves functionally related objects, placements are more functional (i.e. more over the bristles of the toothbrush) following previous functional prime trials with different objects than when the primes trials were non-functionally related objects, etc.

We also manipulated *how* participants placed objects (Figure 1B). Consistent with DST and the A not B error model, we postulated that the temporal binding of spatial language to objects might also involve interaction with those objects. Placing a toothpaste tube over a toothbrush may call up an attractor state involving an action component as the toothpaste tube and toothbrush are held in specific ways associated with a brushing routine when those objects are in that relation. Participants either moved the objects on the touch screen with their hand upright (palm pointing downwards, Figure 1B, left panel), in a manner affording normal interaction with that object, or they moved the object with hand rotated in a manner that did not afford interaction (Figure 1B, right panel). We predicted that placements would be nearer the functional part of the other object when the movement was one that afforded action. Critically, we wanted to test whether this effect, if present, occurs for both functionally related and non-functionally related objects. If the effect only occurs for functionally related objects, one can argue that it is the action at encoding that it is important rather than any affordance to do with how the objects are moved per se. This was indeed what we found.

Overall results mirror the results from the A not B error task. Following the building of an attractor state over four prime trials, placement behavior reflecting comprehension of spatial language on the critical probe trials is dragged in the direction of previous object placements for incongruent prime-probe combinations – analogous to an infant searching in the wrong location on the A not B task. Second, the (incidental) way in which an object was moved on the screen also affected placement behavior, but only reliably so for F objects. This is consistent with the view that what objects are, how they interact, and how we interact with them becomes temporally coupled during learning, and forms a multimodal attractor state for spatial language.

Taking this data, we present a working DST computational model that also makes predictions tested in further later experiments. Overall, the novel approach to word meaning allows the appearance of stable underlying "senses' of words while accounting for changes in meaning on a moment-to-moment basis.

References/Indicative Publications

Carlson-Radvansky, L. A., Covey, E. S., & Lattanzi, K. M. (1999). "What" effects on "where": Functional influences on spatial relations. *Psychological Science, 10*, 516-521.

Coventry, K. R., Prat-Sala, M., & Richards, L. V. (2001). The interplay between geometry and function in the comprehension of "over", "under", "above" and "below". *Journal of Memory and Language, 44*, 376-398.

Coventry, K. R. (2013). On the mapping between spatial language and the vision and action systems. In Y. Coello & A. Bartolo (Eds.), *Language and Action in Cognitive Neuroscience*, pp.209-223. Psychology Press.

Coventry, K. R. (2015). Space. In E. Dabrowska & D. Divjak (Eds.), *Handbook of Cognitive Linguistics*, pp.489-507. De Gruyter Mouton.

Coventry, K. R., Christophel, T., Fehr, T., Valdés-Conroy, B., & Herrmann, M. (2013). Multiple routes to mental animation: Language and functional relations drive motion processing for static images. *Psychological Science, 24(8),* 1379-1388.

Coventry, K. R. & Garrod, S. C. (2004). *Seeing, saying and acting. The psychological semantics of spatial prepositions*. Psychology press: Taylor Francis.

Coventry, K. R., Griffiths, D., & Hamilton, C. J. (2014). Spatial demonstratives and perceptual space: Describing and remembering object location. *Cognitive Psychology, 69*, 46-70.

Coventry, K. R., Lynott, D., Cangelosi, A., Monrouxe, L., Joyce, D., & Richardson, D. C. (2010). Spatial language, visual attention, and perceptual simulation. *Brain & Language, 112(3),* 202-213.

Gudde, H. B., **Coventry, K. R.**, & Engelhardt, P. E. (2016). Language and memory for object location. *Cognition, 153*, 199-207.

Labov, W. (1973). The boundaries of words and their meanings. In C. J. Bailey & R. Shuy (Eds.), *New ways of analyzing variation in English.* Washington, DC: Georgetown University Press.

Smith, L. B. & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Science, 7(8*), 343-348.

Thelen, E. et al. (2001) The dynamics of embodiment: a field theory of infant perseverative reaching. *Behavioural and Brain Sciences, 24,* 1 – 86

Wittgenstein, L. (1997). *Philosophical investigations*. Oxford, England: Blackwell Publishers. (Original work published 1953)