Infant A-not-B errors: A case for conceptual dynamics

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Abstract

Infants often erroneously search for an object at a previously found location (A) despite seeing it hidden at a new location (B). Smith et al (1999) deny such A-not-B errors arise from internal object-related conceptual states. Instead, they arise from the dynamics of goal-related perception and action. We show that their model does not account for *cup orientation*, and suggest augmenting dynamics with conceptual/relational structure to account for this effect.

Infant A-not-B errors

Object occlusion tasks are thought to probe the conceptual mind. The canonical form of one such task, called *A-not-B*, consists of two hiding locations and a retrievable object (e.g., toy). On the first trial, the infant sees the toy hidden at one of the two occluding locations (A). The infant is allowed to retrieve the toy. On the second trial, the same toy is seen hidden at the other location (B). Typically, on the second trial, the infant will search for the toy where it was successfully retrieved on the first trial. This behaviour is called A-not-B, or perseverative error. Many factors are known to affect performance, for example: age; delay between occlusion and retrieval; spatial separation of locations; and their visual distinctiveness. While theoretical accounts are almost equally prolific, they generally assume some form of internal object representation upon which the infant acts in forming a response (see Smith, Thelen, Titzer, & McLin, 1999, for a recent review). A systematic program varying task parameters, then, should finally illuminate the most basic component of human cognition, concepts.

The dynamical systems model

That infants are accessing concepts is not, however, universally accepted. Smith et al. (1999) argue that infant errors are the result of a complex interaction between their desire to retrieve the object, and a dynamically changing environment. Support for their *dynamic systems* model comes from three sorts of experimental observations: (1) The likelihood of a reach in one direction was an increasing/decreasing function of the number of previous reaches in the same/other direction. (2) The direction of reach was "pulled" by a visual distractor. (3) Greater amounts of experience with occluders resulted in fewer errors (Smith et al., 1999). They concluded that behaviour is far too fluid, too easily altered by extraneous events to be the result of some enduring structure corresponding to an "object concept" in infants, or even adults. Instead, behaviour is just an interaction between goal-directed perception, action and their prior states.

No explanation for cup orientation

Denial of concepts challenges one of the most generally held assumptions of cognitive science. Yet, empirical support for concepts is itself difficult to find unequivocally. While concepts are supposed to capture certain invariant environmental properties, concepts must arise from specific environmental states to be effective. This confound is potentially resolvable by looking for generalizations that span experience in a way that necessitates internal structure. For example, generalization over relations between certain perceptual states is not possible with "standard function approximation" style connectionism without some form of structured representation (Phillips, 2000). In a similar vein, empirical evidence recalled here is not accounted for without supposing some form of internal concept representation.

Freeman, Lloyd, and Sinha (1980) provided evidence that occluder *functionality* (cup used as a container) affects performance. Infants were tested on an A-not-B task with three conditions, where: (1) flat opaque screens - *baseline*; (2) *upright*; and (3) *inverted* cups were used as occluders. In the cup conditions, the object was placed *behind* the cup. The critical result was that infant errors were significantly less than baseline errors in the *upright* condition, but significantly more than baseline in the *inverted* condition. A series of control experiments ruled out accounts based purely on perceptual features, such as the location of the cavity; and motor requirements such as reaching *in* versus reaching *behind* the occluder. Therefore, something other than the perceptual or motor aspects of the task must affect performance.

In a dynamic systems model, performance is also affected by experience. Smith et al. (1999) reported that infants given additional playtime with transparent containers performed significantly better than otherwise normal infants. However, experience alone cannot explain the orientation effect. A simple one factor account (occluder) citing differential experience with cups and screens cannot explain why errors with cups were both significantly greater and fewer than screens. A two factor account (occluder, orientation) citing greater experience with upright cups than screens than inverted cups accounts for the significant difference in error in the *transposed* movement condition,[1] but it also predicts a difference in the *static* movement condition,[2] where none was found. A three factor explanation (occluder, orientation, movement) could account for the above profile of errors, but only by anchoring to several unlikely conditions on the infant's world: First, cups are typically used as containers, whereas screens are used as partitions. But experience driven error requires there having been more cases of cups used as partitioners/occluders than screens, even though their primary role is as containers. Second, when used in their secondary role, as partitions, orientation is not significant. But, errors require there having been more experience with upright than inverted cups as partitioners/occluders. Last, if role reduces to experience, fewer errors should occur when the object was hidden *under/in* the cup than *behind* it, but no difference was found. Unable to guarantee these conditions means their dynamic systems model cannot sustain a realistic explanation of infant errors due to cup orientation.

Conceptual dynamics

The suggestion sketched here is to suppose internal representations that correspond to the concepts of *containment* and *occlusion*. The representation of containment may emerge from the perceptual features and motor actions associated with filling/emptying cups. Similarly, occlusion may emerge from perceptual features and motor actions associated with one object moving behind/emerging out of another object.

The importance of positing these two internal representations is that containment and occlusion events overlap. When an object is place inside an opaque cup, the object is also occluded by the cup. Conversely, when the contents of the cup are emptied, the now uncontained object is also unoccluded. This overlap in events creates an internal correlation between the two concept representations, so that the activity of one may partially activate the other.

The second supposition is that concepts are the semantic elements of relations, which are central to theories of cognition and development (Halford, Wilson, & Phillips, 1998), and that containment and occlusion events cause a (partial) binding between the container/occluder and contained/occluded objects.

These elements, together, serve to explain the effect of cup orientation on A-not-B errors. When the target object is seen dissappearing behind a screen only the occlusion concept is activated, since the screen does not have the perceptual features (e.g., cavity) necessary to satisfy the containment concept, causing a binding of strength b_o between the occluding screen (B) and the occluded object. When upright cups are used as occluders, the containment concept is also partially activated because of the cup's perceptual features. Although, no containment event occurred, since the object was not seen moving into the cup, the correlation between containment and occlusion concepts creates an additional activation of the occlusion concept. The increased activation of the occlusion concept results in an increased binding strength $b_o + b_c$, where b_c is the contribution due to the containment concept. In contrast, features associated with an inverted cup activate *uncontainment*, the opposite of containment. Since containment is correlated with occlusion, uncontainment activates unocclusion, which triggers the (partial) unbinding of occluder and occluded objects. In this case, the two objects are bound with weakened strength $b_o - b_c$.

In a relational model, any element partaking in a binding is retrievable by supplying the other element(s). In this case, location of the occluded object is retrieved by cuing with the two possible occluding objects. The binding strength determines the probability of retrieval. Therefore, the probability of a correct response (B) is: $P_u(B) = b_o + b_c > P_s(B) = b_o > P_i(B) = b_o - b_c$, in each condition, consistent with Freeman et al. (1980). This explanation does not require unrealistic assumptions about relative experience with cups and screens. It only requires that infants have some experience with both types of events to establish the corresponding internal concepts. The correlation between concepts is implied by the physical nature of the two event types.

We have argued that Smith et al's (1999) dynamic systems model does not account for effects relating to occluder functionality. Instead, we have suggested the effect is due to representing the semantic (conceptual) properties of the relations over occluding and occluded objects. Critically, infant behaviour is *also* a dynamic interaction between conceptual/relational structures.

[1] Occluder and object moved from A to B on second trial.

[2] Object moved to and hidden at B on second trial.

References

Freeman, N. H., Lloyd, S., & Sinha, C. G. (1980). Infant search tasks reveal early concepts of containment and canonical usage of objects. *Cognition*, *8*, 243–262.

Halford, G. S., Wilson, W. H., & Phillips, S. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *Behavioral and Brain Sciences*, *21*(6), 803–831.

Phillips, S. (2000). Constituent similarity and systematicity: The limits of first-order connectionism. *Connection Science*, *12*(1), 1–19.

Smith, L. B., Thelen, E., Titzer, R., & McLin, D. (1999). Knowing in the context of acting: The task dynamics of the A not-B error. *Psychological Review*, *106*(2), 235–260.