Donna E. West

Piaget’s system of spatial logic: The semiosis of index

Abstract: Piaget’s system of cognitive development is analyzed, namely, the semiosis of indexical representation and use. His notion of scheme is discussed, capitalizing on index as the most primary semiotic tool in early ontogeny; afterward, advances in spatial skills (topological and projective reasoning) are discussed in light of the foundational role of index in unfolding these spatial concepts. Finally, index’s primary function in the onset and perpetuation of perspective-taking competencies constitutes the essential thrust. The claim is that index is the most essential component to ascertain advancements in spatial logic, in that it organizes and triggers the coalescence of temporal memories of different perceptual states. These memories, in turn, serve as the foundation for complex spatial cognitions (decentration and reversibility) necessary to understand points of view.

Keywords: index, semiosis, spatial development, Piaget, reversibility, deictics

DOI 10.1515/sem-2014-0064

1 Piaget’s general theory

The concept of embodied cognition pervades Piaget’s account of the ontogeny of logic. He insists that sensorimotor schemes underlie logical development throughout his later, invariant developmental stages: the preoperational, the concrete operational, and the formal operational stage. Sensorimotor schemes are constructed upon specific sensory-based perceptions and are coordinated with action-based motor behaviors that ultimately manipulate environmental stimuli. According to Vonèche (2007: 82) perception for Piaget is not “a passive registering of sensory impressions [rather] . . . visual perception is a form of action.” In view of the indexical nature of eye gaze as a primary visual-based index (used alone or in combination with other gestural or linguistic indexes), visual perception plays a critical role in location-based schemes. In fact, visually-based indexes (those directly dependent upon perception) have the power to elicit particular action schemes and to transform cognitions. Piaget and Inhelder (1967

Donna E. West: State University of New York. E-mail: westsimon@twcny.rr.com
[1948]: 455) refer to this process as assimilation and accommodation. In other words, schemes are augmented when the same action sequence (visual and tactile indexes) is applied to a different object, or when the scheme is altered consequent to unsuccessful implementation of an action scheme to a novel object. An example from Piaget (1952 [1936]: 336–337, observation 179) that is particularly poignant is opening and closing the lips, prior to and accompanied by opening a box to insert a watch chain. The scheme consists of the behavior sequence (reaching and lifting the box’s cover, while holding the chain in the other hand [fisted], and opening the fist to insert the chain [perhaps stuffing it within]). The objects (chain, box) become the integral part of the action sequence, which the lips imitate. This action scheme is afterward applied to other objects, perhaps placing a handkerchief in a pocket, illustrating the process of assimilation. Accommodation might occur when the action scheme is altered, as in squeezing (the handkerchief) to pull it between playpen bars. Hence, perceptual and motor activities are not disentanglable (Piaget 1969 [1961]: 324–325).

Involved indexes to action schemes may surface in diverse forms: as perceptual devices (eye gaze), as the action (movement of body part/pointer in a particular direction), or as both of the foregoing. In any case, these sensorimotor schemes (comprised often of two indexes) integrate recognized sensory impressions (often visual) with a directionalizing behavior/set of behaviors – typically motion aggregates committed to Lakoff and Johnson’s (1999) source, path, and goal phenomenon. Action schemes synthesize infants’ knowledge of perceptual and functional attributes of objects, and can even suggest the classification attributed to them, as individual but related to functionally similar others. To illustrate, actions performed on objects that are similar often indicate that they are included in the same class. Leaping off mother’s lap onto the sofa to retrieve a toy mimics the source, path, and goal of a cat leaping onto a table and out the window (after having observed the cat). The infant here classifies the scheme of flight pattern as applying to both cats and infants – both constitute “flighty creatures.” Schemes, in that they express source, path, and goal, qualify as quintessential indexes, illustrating origo (source), movement away from and toward (path), and accessing toy (goal).

The foregoing further validates the fact that Piaget’s perspective embraces an embodied cognition approach. Passage from one developmental stage to another is constructed ordinarily on direct experience of self as origo and intimates the body as the locus (Vonèche 2007: 73) of directional action. The body mediates spatial representations in that, according to Acredolo (1988: 369) at 0;6 infants are more likely to “look back at a landmark” when they associate it with a particular action. A primary property of action schemes here is index, establishing the directionality, location, and distance with respect to the landmark. Index ac-
quires a more permanent role in scheme development when it fashions behavioral tools that can modify schemes. In so doing, indexes such as: gazing, reaching, pushing, and pulling (in that they embody direction toward or away from an origo), mediate both assimilation and accommodation of action schemes. This mediating role of index to consolidate directional action encoding into schemes that express primary spatial relations (distance, location, and the like) underscores the primacy of index as an embodied tool giving rise to action in Secondness.

When assimilation and accommodation are balanced (when neither is instantiated more frequently than the other) a cognitive balance results in which dissonance or conflict is not primary. This state of relative cognitive stability is referred to as equilibration (Piaget 1971 [1967]: 36–37). During the state of equilibration schemes experience a certain homeostasis, in that their success in distinctive contexts, with different objects is relatively ensured. Indexical schemes such as extending the hand and arm to attain objects need not be altered significantly from one object access to another. The action scheme necessary to transfer food to the mouth via the hand is alike to that employed in food transfer via utensils – both depend upon closing the hand over an object and directing it to the bodily aperture. In this way, action schemes take on an iconic trajectory but the path from origo to goal of the scheme’s orchestration, embodying distance from and toward the point of origin. In so doing, the spatial construct of observed distance is transformed into motoric action/movement (Vonèche 2007: 73–82). When living indexes express movement trajectories, and especially when they incorporate origin followed by a course and culmination of perceptually informed action schemes, they can solidify and capture the essence of lived space.

In fact, Piaget asserts that these sensorimotor schemes serve as a necessary foundational component to the onset of their representational correlates, namely, mental images. The specific application here is to the primacy of indexical schemes in sensorimotor intelligence; and the claim emanating therefrom is that mental images of indexical action schemes directly originate from the performance of the scheme itself. Neuro-imaging data confirm such claims – the same areas of the brain are stimulated in calling up the mental image, as when performing the indexical action itself (Kosslyn et al. 1999: 167). While Kosslyn et al. (1999) argue that the same cortical area (occipital lobe) was stimulated on both accounts (action and its image), not all of the cortical areas utilized in scheme production are stimulated. Stimulation within the occipital lobe is associated with more static, visual behavior and images; whereas activity within the parietal lobe occurs consequent to implementation of more dynamic, movement-based spatial action schemes and their mental representations. Likewise, frontal lobe stimulation is activated in perceiving spatial arrays, since processing a visual
scheme and its location components relies on integration of the static visual data with the dynamic spatial cues, associated with the central executive function of working memory (WM; Baddeley 2007: 95–96). Kosslyn et al.’s (1999) claims demonstrate some underlying neurophysiological support for sameness between action and image; nonetheless, they simplify the nature of the connection. Because several cortical areas are typically stimulated in scheme production or in representing that scheme, given integration of spatial and visual information, neuro-imaging findings from other studies strongly suggest that activity is present in all three lobes: occipital, parietal, and frontal, not merely in the occipital lobe (cf. Baddeley 2007: 95–96 and 211–234). Hence, the state of the research demonstrates that behavioral and mental correlates of index result in similar neurological activity, in view of their reliance on visual and spatial coordination and processing. The visual component is realized in notice of co-occurring objects; while the spatial component is required for notice of distance and motion relationships between and across objects and manipulations orchestrated consonant with scheme operations.

Accordingly, as Vonèche (2007: 82) aptly observes, an action-based mental image bares similarity to the real action, not merely in terms of emitting similar neurophysiologic responses, but, in terms of isomorphism of affect. Apparently, identical affect based responses materialize upon emergence of the mental representation, as originally surface upon production of the indexical action scheme. This seeming residual affect that originates from deploying indexes in actual practice likewise is elicited upon retrieval of the correlate memory in WM. Because these memories are largely comprised of replicas of the original embodied event, they constitute internalized reflections of, not on, observed scenarios – a form of internal and external reckoning. Nevertheless, when mental indexes are of a more prospective nature, it is likely that less affect is applied to the representation from a predetermined embodied source.

An additional advantage of the former (retrospective mental representations) is their means to improve memory accuracy and retrieval of the original event. In other words, with the frequency of mental reference to an index-driven event arises further ease of its recall. Similarly, with increased occasions of retrieval of an event (tantamount to rehearsal) arises increased ease of retrieval and reenactment of the original event (Barr et al. 2005: 279). Even at 0;6, infants are able to benefit from three to six retrievals (cued by reintroduction of the original event stimuli) (Barr et al. 2005: 274). This increased capacity to call up events from long-term memory (LTM) via practice in retrieval of motion schemes (indexically motivated events) has an additional advantage – to refine subsequent performance of the embodied action scheme itself by increased means to access retrospective image schemes. The culminating effect of increased retrieval of these retrospec-
tive schemes into WM facilitates what Piaget (1962 [1945]: 62) refers to as “de-
ferred imitation.”

“Deferred imitations” consist in action schemes held in LTM for several
hours/days/weeks and even months; and given the salience of the original event
under observation, the infant re-enacts the event. While Piaget (1962 [1945]:
62–63) claims that this skill emerges at 1;4, other investigators indicate its onset to
be less protracted, emerging as early as 0;6, provided that the original stimulus
materializes six times within a sixty second interval (Barr et al. 1996: 167). Barr
et al.’s experimental approach appears rather like that of conditioning para-
digms; subsequent retrievals of the original event are dependent on environ-
mental cues, and do not reflect active, intentional recall. Conversely, Piaget’s
“deferred imitation” paradigm, together with his assumptions, namely, age of
onset, remain tenable, since cue interventions for purposes of increasing retrie-
val are not deployed in his approach – no intervention was administered to elicit
the memory of the action scheme. Instead, Piaget’s subjects retrieved and re-
enacted events spontaneously, based on salience and meaningfulness of the
respective event to the individual child. It is evident that passive association is
not responsible for the “deferred imitation”:

OBS. 52. At 1;4(3) J. had a visit from a little boy of 1;6, whom she used to see from time to
time, and who, in the course of the afternoon got into a terrible temper. He screamed as he
tried to get out of a play-pen and pushed it backwards, stamping his feet. J. stood watching
him in amazement, never having witnessed such a scene before. The next day, she herself
screamed in her play-pen and tried to move it, stamping her foot lightly several times in
succession. The imitation of the whole scene was most striking. (Piaget 1962 [1945]: 63)

The above illustration from Piaget’s own observations underscores the impor-
tance of affect in the schemes that are selected to be stored in LTM, retrieved from
WM and reenacted in lived experience. The fact that J. chose to imitate a temper
tantrum highlights the salience of affectually driven schemes for storage, retrieval
and enactment as “deferred imitations.” In any case, action schemes whose
source, path, and goal (in Secondness) are obviously fueled by affect which is
held in LTM (at minimum) for days, are most likely to be re-enacted. Clearly, these
schemes experience enhanced retrieval primarily because their directional na-
ture requires an affective component. In fact, affect plays a particularly critical

---

1 Piaget continues commenting on J.’s “deferred imitation” as follows: “Had it been immediate,
it would naturally not have involved representation, but coming as it did after an interval of more
than twelve hours, it must have involved some representative or pre-representative element”
(Piaget 1962 [1945]: 63).
role when interpreting schemes whose embodiment is primarily directional, namely, following indexical behaviors (movement) through a defined trajectory.

In sum, the effect of index (especially when driven by affect) in action schemes is profound. Index first makes cohesive the body with the physical surround, and afterward relative locations and distances relevant to the scheme are solidified in the mental representation through subsequent retrievals. Without indexes to make visual copies (both replicas and altered versions consonant with constructed images) of these directional components of the world, deictic systems would hardly materialize. It is just these indexical replicas (retrospective and prospective) that form the framework for developing points of view consonant with diverse origos.

2 Topological versus projective space

Piaget supplies a firm theoretical basis within which all individual claims cohere to form a system whose components do not contravene one another. Confidence, then, can be placed in Piaget’s theory, since it has internal validity. What is incumbent upon experimental semioticians is to test his claims rigorously on relatively large and random samples of children. Piaget’s theory of the development of logical operations governs all of his assertions vis-à-vis how number, quantity, and spatial concepts unfold. Hence, it is experimentally ripe to measure the semiosis of orientational (inherently spatial and indexical) signs, especially those deictic devices which track perspective-taking advances.

According to Piaget and Inhelder (1967 [1948]: 67–79; 209–246), two types of spatial perspectives exist: the topological and the projective. While the former characterizes younger children’s spatial system (until approximately 8;0; Piaget and Inhelder 1967 [1948]: 209), the latter represents their system thereafter. Nonetheless, early concepts of space are topological and are defined by an adherence to a single origo as the point of orientation with respect to static object location. This topological space is characterized by an exclusively ego-centered point of view, in that a single origo only is recognized— that of the self. As young as 0;11, the self is employed as a landmark (Huttenlocher and Lourenco 2007: 5), demonstrating a rudimentary ego-centered basis for determining spatial relations. Whereas, a system founded on projective principles validates dynamic, shifting origos and the possibility of object displacement:

It will be remembered that at the level where he tends to make every perspective a facsimile of his own momentary viewpoint, the child also shows himself unable to draw things according to the laws of perspective (“visual realism”) but gives them an invariant shape,
Piaget’s system of spatial logic

topological rather than euclidean (“intellectual realism”). Thus it is not until he begins to be able to distinguish between other perspectives and his own that he becomes conscious of his own viewpoint as a particular one and is able to indicate it by means of relationships which are specifically projective (an explicit rendering of perspective). (Piaget and Inhelder 1967 [1948]: 220)

A topological perspective is maintained during Piaget’s Preoperational stage, from approximately 2;0 until 6;0 (Piaget and Inhelder 1967 [1948]: 168–169). Examining how topological space develops at early stages via children’s drawings of geometric figures constitutes Piaget’s experimental approach. Prior to 3;0 scribbles represent the only attempt to reproduce a model drawing of separated lines (straight or curved), crossed lines, or closed figures (quadrilaterals, circles; Piaget and Inhelder 1967 [1948]: 55–57). Children’s lack of means to produce a replica at this age does not demonstrate that mental indexes are absent, but that coordination between fine motor schemes (hand to utensil to paper) and mental image of index is still unrefined. In fact, refinement of closed figures may draw upon similar cognitive advances to those which materialize with the development of metacognitive renderings, since both depend upon how source, path, and goal are connected in space and time.

Nevertheless, between 3;0 and nearly 4;0 children draw models of lines but, do not demonstrate the means to reproduce replicas, since the vertical and horizontal lines within the drawings remain unconnected (Piaget and Inhelder 1967 [1948]: 56). By 4;0, figure representations are connected, such that open line figures and closed circles are copied with the model present (Piaget and Inhelder 1967 [1948]: 52); whereas between 4;4 and 5;6 children are able to produce certain closed quadrilateral figures but not other quadrilaterals – a square but not a rhombus (Piaget 1967 [1948]: 68–72). Gruber and Vonèche (1977: 609) assert that the rhombus presents particular difficulties, given the orientation of its sides (i.e., their slant or slope), together with the fact that the figure is not symmetrical. “Adjustment according to reverse order of the symmetries” is responsible for accurate production of the rhombus (Gruber and Vonèche 1977: 609–610). In light of this rationale, it may well be the case that sensorimotor, embodied experience biases children’s means to conceive of a pathway which diverges from either a vertical or horizontal trajectory. Especially in early experience, movement of the body ordinarily directly follows canonical planes, namely, movement through

2 Cf. West (2013) for findings that confirm that mental index is present at 0;6 with the advent of the object file, and that index becomes operationalized further at 0;11 with recognition of landmarks.
space is not typically projected as a diagonal path, but is horizontal or vertical. Hence, early directional experience appears to constrain mental representations of same, making for protracted graphic representations. This constitutes still another instance in which early indexical experience with canonical locomotive paths (horizontal or vertical) affects the later path of indexical representations. In this case, experience has a restricting effect, rather than a facilitating one.

Accordingly, preoperational reasoning is characterized by a strict reliance on perceptual appearances based in experience, rather than on systems of inference based logic. In the face of a perceptual alteration which does not affect a change in the essence or substance of the object/object array, preoperational thinking notices the former to the exclusion of the latter, likewise limiting mental representations. Piaget refers to this perseverative focus on a single issue/attribute as “centration” (Piaget and Inhelder 1967 [1948]: 16, 364). Children remain centered on one dimension; and the logic that could liberate them from this biased notice is ignored. Piaget and Inhelder (1967 [1948]: 364) claim that centration is a universal phenomenon until approximately 6;0–7;0, and have constructed methods to measure whether and to what degree children can decenter and deliver their reasoning from the wholly graphic and myopic to embrace diverse variables. Although he has generated several experimental paradigms to test this: conservation of number tasks, conservation of quantity, among them, it is his conservation of space task which is most complex for Concrete Operational children; and it is this logic that represents the most advanced thought processes within the Concrete Operational stage (Piaget and Inhelder 1969 [1966]: 106–107).

Conservation of quantity (realized in either mass or liquid),\(^3\) entails ignoring form alterations (external characteristics) in favor of acceptance of internal logic) is less complex than is conservation of space,\(^4\) in that more variables must be coordinated and logically balanced for the latter. For conservation of mass, only two dimensions need be held in WM simultaneously – either the distinct shapes of the objects (often made of clay), or their two dimensions (height and width).

---

\(^3\) Piaget’s experimental design to measure conservation of mass uses two balls of clay equal in mass, one of which is later fashioned into a different shape. At the outset, children agree that the same amount of clay is contained within each ball; afterward, reshaping of one of the balls into a snake or a pancake is orchestrated in the children’s presence. Children are then asked whether each clay object contains the same amount of clay or whether more or less clay is contained in either. Piaget’s conservation of liquid experiment is identical, except that clear containers containing the same amount of water constitute the operation under consideration (Piaget and Inhelder 1969 [1966]: 97–98).

\(^4\) Piaget (1969 [1961]: 210–211) claims that conservation of mass is not fully operational until 7;0, although other researchers observe its ontogeny at 2;0 (Piaget 1969 [1961]: 208–209).
Whereas, to determine space relations based on logic alone assignment of origo, origo's location, origo's orientation and origo's distance to objects or landmarks is necessary. It is the indexical and deictic character of space conservation that accounts for its rather complex logical nature.

The primary test paradigm developed and used by Piaget and Inhelder to measure whether conservation of space is fully operationalized, is the “Three Mountain Task” (Piaget and Inhelder 1967 [1948]: 210–246). The mountains are initially depicted as three-dimensional props, two in the foreground (a green mountain topped by a house model and a brown mountain with a red cross at the summit) and one in the background (a gray mountain capped with snow). Each mountain is of a different color and size with another distinctive feature, for purposes of identification and association with their respective locations. Ten cards depicting the mountains two-dimensionally from distinct orientations were likewise provided for selection of the doll’s point of view at each orientation to the mountains. Several trials represent different orientations of the doll with respect to the mountain array – sharing the child’s orientation, reverse to it, or to the right/left (ninety degrees) from that of the child. Children were required to select the card that represents the appropriate depiction of the mountains, i.e., how the doll would “see” the mountain array (in which the mountains were not moved) from the particular place and orientation of the moment. Piaget and Inhelder (1967 [1948]: 223) found that while the accurate card was selected (that which represented the doll’s actual perspective toward the mountain array) when the doll’s orientation matched the child’s (at 6;0–7;0), the same reliability of performance was not observed when the doll’s and the child’s physical orientation to the mountain array was distinctive. One of Piaget and Inhelder’s subjects, at 6;3, “when asked to make a picture of what the observer (the doll) can see from a particular position, the child confines himself to reproducing with his pieces of card what he sees from his own position” (Piaget and Inhelder 1967 [1948]: 214). Piaget and Inhelder (1967 [1948]: 215) suggest that children similar in age and in logic to the aforementioned, are unable to formulate deductions that fashion logical arguments in which the child can transform himself (via mental imagery in WM) in space to assume the orientation of the other (the doll in this case). Even after physically altering positions/orientations to match those of the doll upon each relocation, the child still assembles the cards to represent the mountain array from his own original vantage point, upon returning to the original position (Piaget and Inhelder 1967 [1948]: 215).

Together with this persistence of egocentric perspective, Piaget and Inhelder (1967 [1948]: 215–216) assert that a topological approach gives rise to indecision consequent to conflicts within the child’s reasoning system. The former conclusion (egocentrism is responsible for adherence to self’s perspective) appears to
be confounded by a design feature of the study. The doll was faceless and hair-
less; and it is not clear that children had access to any arm/leg orientations
(Piaget and Inhelder 1967 [1948]: 211). The absence of these features created an
origo seemingly without inherent sides; consequently, it could not even “see” in
pretend scenarios, nor could it have a specific orientation to the mountains. 
Hence, adherence to their own perspective may merely represent a default orien-
tation. In other words, children select the card reflecting their own point of view,
in the absence of feasible alternatives. To improve this design, use of representa-
tional objects without obscuring sides is recommended (as in West 1986; Tanz
2009 [1980]).

With respect to the latter (indecision consequent to reasoning conflicts) Piaget and Inhelder (1967 [1948]; 217) acknowledge that a topological perspective can recall prior orientations of self as origo. The upshot is that at this early substage, children can reconstruct retrospective memories of themselves in previous orientations to the mountains. What they are not able to accomplish is to anticipate what they might see from an orientation distinctive from what has been actualized. What Piaget and Inhelder seem to intimate is that the indecision results from children’s lack of capacity to generate prospective mental images required for projective space reasoning. This lack of prospective memory devices that supply the means to imagine self in constructed places proves to be the stumbling block to reaching full concrete operational logic. Without prospective memory capacity, reliance on retrospective lived experience determines the spatial relations. Any retrospective images do not draw upon pure logic; rather, they are dependent upon replicas of embodied perceptions – without imaginative representations. Children’s explanation at this age indicates that their metaskills adhere to a false absolute – that they did, in fact, match the card depictions to the actual perspective of the doll, not to their own: “The child has not yet begun to think in terms or groupings of projective relations and correspondences, to discern the invariance of the correspondences amid the endless transformations of the projective relationships. Instead, he fixes upon some kind of rigid, ideal picture” (Piaget and Inhelder 1967 [1948]: 225).

The foregoing performance factors indicate the lack of refinement of three mental operations: reversibility, formation of superordinate classes, and decen-
tration. Reversibility entails mentally reversing the spatial sequence from a prospective vantage point. Were it refined, projecting the self into an orientation not already experienced would be ascertainable. An additional competency is likewise unascertainable at 6;0 – the means to reproduce a portion of a familiar series, although the means to reproduce the entire series is intact (Piaget and Inhelder 1967 [1948]: 226). The lack of this last skill demonstrates the unalterability of static topological spatial perspectives, and underscores the replica nature of
mental image aggregates. The lack of means to decenter further accounts for the inability to reconfigure the mountain depictions from another’s vantage point (Piaget and Inhelder 1967 [1948]: 228). Younger concrete operational children focus on the color or shape of a foregrounded mountain, while failing to consider the dimensions/qualities of other mountains.

While Piaget and Inhelder’s design has been criticized as measuring cognitive skills beyond those of perspective-taking in that their paradigm likewise requires attribution of animacy to inanimate, representational objects (Flavell 2004: 281) and may elicit responses that are counterfactual in nature from within the pretend design scenario, its legitimacy to measure full-fledged perspective-taking and deictic competencies is unmistakable. What Piaget and Inhelder (1967 [1948]) did not track, however, is the emergence of these skills leading to knowledge of projective spatial competencies.

Determining children’s mode of “seeing” with the mind’s eye (either topologically or projectively) indicates the state of semiosis of indexical signs. Nonetheless, tracking this shift in spatial thinking requires a single instrument with sufficient sensitivity. Tracing the onset and use of demonstratives represents a more sensitive tool to measure perspective-taking from its inception, given that alterations in demonstrative use reflect qualitative advances from an early age in perspective-taking – skills that directly illustrate indexical sign use. Entering the mind’s eye of the child to determine when “that” becomes a contrastive, deictically used index constitutes the initial indicator of some movement from a topological spatial system (in which self is origo) toward a more projective one. Demonstrative use and its comprehension requires the realization that the self can be origo; and when self is so, self can orient differently to objects, and objects can likewise move or be propelled. Contrary to Piaget and Inhelder’s (1967 [1948]: 213–216) claim that self perseverates as origo until 6;0, the process away from egocentrism begins as early as 0;6 (Newcombe and Huttenlocher 2000: 40). According to Acredolo (1978: 228) infants use their body as the point of reference at 0;6 such that despite an orientational change of one hundred and eighty degrees with respect to an object, they still looked toward the same side of their body for an object that remained stationary; and at 1;4 a shift from egocentric to allocentric reference points becomes operational (Acredolo 1978: 232). At this age (1;4) infants demonstrate the means to “compensate for their change in position” when their location and orientation change with respect to already observed objects which remain stationary. Expanding on Acredolo’s (1988: 369) interpretation of her findings, the shift from egocentric to allocentric points of reference materializes with the apprehension that the location of a landmark indexes either the location of an object (when the object is at or within the landmark) or its relative distance from the object. In fact, isomorphism of place for both landmark and
related object is the best means to enhance indexical associations; afterward, indexical associations can be made with small distances between the two. Hence, recognition of landmarks as a kind of origo that heralds allocation of origo to another, (beyond the self) highlights the vital role of attributing an indexical function to objects. In fact, with increased notice of spatial relations relative to different origos – landmarks and the like, comes appreciation of deictically driven perspective-taking competencies. It appears, then, that some apprehension of self as origo surfaces prior to Piaget’s acknowledgement thereof in the preoperational stage. Alternative measures that are not dependent on linguistic skills may better establish when topological space emerges.

The next milestone is apprehension that alterations in the location of objects can affect what constitutes near and far space, and consequently what had originally been objects within near/far space may no longer be classified as such, consequent to origo allocation. At this juncture, at approximately 3;4 (West 1986: 51; Tanz 2009 [1980]: 87, 125) children recognize at least two distinctive origos and two contrastive locations with objects in those locations from origo’s point of view, proximal and distal. That which still requires notice in the process of semiosis toward ascertaining the system of projective space is decreased dependence on the perceptual and the actual. Children must not rely merely on the appearance from their mind’s eye, but must acknowledge, however unconsciously, that instantiations of their own observations (of themselves and of others) make up but an incomplete picture of: who can serve as origo, the diverse orientations of those origos within places (existent and nonexistent), and varying distances, trajectories and locations of objects within those places. In other words, anticipating the locomotability of origo and that origo can assign a secondary origo, coupled with predicting the relative movability of objects with respect to one another and with respect to the designated origo represent critical cognitive precursors to deictic perspective-taking.

3 Reversibility and decentration

Piaget posits that until children can articulate arguments of identity, reversibility, and/or compensation they have insufficient means to utilize conservational logic, controlling its many-faceted abstract variables. These three forms of logic demonstrate the onset of concrete operational thinking that appears between 6;0 and 8;0 (Piaget and Inhelder 1969 [1966]: 96–97). This kind of thought relies on the means to develop arguments that render appearances/perceptual arrays to be deceiving. To conserve in the Piagetian sense, it is not that children must ignore the perceptual; rather, they must not be misled by their direct and salient perceptions.
(Ginsburg and Opper 1979: 151). In actuality, children need to consider the perceptual array as but a single variable in the problem solving feat. They must apprehend that the perceptual array is but the resultant state, and that other variables which are not observable in the moment play into the equation. In other words, the effect is observable in the altered spatial array of two objects, e.g., the clay ball versus the altered state of the ball (the pancake); or the tall slim glass versus the short wide glass; but, the factors contributing to the effect are primarily propositional. Concrete operational thinking incorporates sensorimotor intelligence with the logical operation of going “beyond the information given” (Bruner 1973). Nonetheless, this departure from dependence wholly on the observable must take a particular form which requires holding not merely two conditions (states) of the objects in memory (the retrospective image of the previous condition, and the perceptual image of the current condition) but entails a certain mental organization of the cause-effect sequence which holds between the object states. To determine such, recognition of the agent and substance of the transformation from the original state, e.g., two balls of clay, is imperative.

The simplest rationale to explain how the resultant state is still substantially identical to the original state, despite the fact that its appearance indicates otherwise, is the identity argument. Encapsulated, it asserts that the water when poured into different glasses (acquiring different dimensions) is essentially the same amount as its original condition (in differently shaped glasses) since: “nothing was taken away or added” (Piaget and Inhelder 1969 [1966]: 98). This logic is founded rather on the transformation itself than on a comparison between the original and the current state of the containers (change in shape). This argument is premised upon an action scheme performed upon the substances, not on extrapolating as to the dimension-based variables that contribute to the lack of quantity differential. In sum, given its dependence on action schemes in sensorimotor intelligence (focus on the action-based transformation performed on the new containers) the identity argument is most likely to be embodied in perception, and the least likely to rely on non-observable mental processes.

Reversibility operations, on the other hand, require extraction of the image of the original substance’s state from LTM to set up a kind of pretense scenario in the present, such that the perceptual image of the substance is converted in the mind to the original one. Consequently, reversibility-based logic relies more heavily upon the means to abstract from the action scheme performed on the substance; and it utilizes increased WM capacity for the conversion. Reversibility represents more advanced logic, since it demonstrates a form of mental travel from the current perception to memory of the previous container’s shape, in the case of conservation of liquid. To make the mental transfer, one must be convinced that the LTM image is more valid than the perceptually available image – exhibiting
not merely less dependence on the observable, but a means to consider the perceptual to be deceiving. This form of logic still does not contain rationale for how it is that the perceptual change and the transformation which caused it do not result in a change in substance. In other words, despite the fact that the appearance after the alteration (after pouring the liquid into a shorter glass with a greater diameter) seems to have added or subtracted from the original amount of liquid; the amount, nonetheless, remains constant because of the comparably greater legitimacy attributed to the LTM image.

The means to reverse on a more abstract, cognitive plane is attributable to engagement in early social or interpsychological reciprocal exchanges. Such schemes consist in: movement propelled by and away from agent, receiver accepting the overture, and the receiver afterward assuming an agentive role – orchestrating the exchange in reverse. Consequently, even though reversibility rationale consists in dependence on access to the original condition of the identical shapes of the containers in LTM, it likewise draws some foundational efficacy from sensorimotor experience. Lived, directional action-based scenarios (e.g., rolling a ball from one partner to the other and back, and conversational interactions) are pivotal to reversing on a higher, logical level. Despite increased reasoning, the reversibility argument appears not to employ decentration skills, since referencing one image and holding it in WM is all that is necessary to return to the original image to operationalize the reversal. Sufficient to its logic is access to the original dimensional conditions from an LTM image alone, provided that it is tagged as such. Hence, keeping two images/dimensions/conditions in WM (although possible) is not obligatory to validate the reversal – the new conditions are readily available in the perceptual field.

Compensation may characterize the most complex conservation-based logic (especially when compared with negation-based reversibility). The reasoning articulated for this form of logic presupposes that the perceptual change is not deceiving – the comparison is between two attributes of two glasses/pieces of clay, which are entirely present/observable. WM holds online the belief that the original dimensions of the clay or glasses may be immaterial to whether the new dimensions constitute a change in quantity. This argument is not founded heavily in sensorimotor action schemes, but, instead, hinges on states and dimensions of defining spaces (containers), clearly differentiating compensation arguments from the other two. It recognizes that other factors (those less action-based) contribute to whether the new shape contains the same amount of liquid/mass – its more amplified diameter makes up for its reduction in height. Recognition that the seeming mismatch on the perceptual plane (new dimensions) does, in fact, have validity is likewise critical. In some cases children must reconfigure their reversibility-based assumption of the primacy of the original LTM image, and
must now apply primacy to what is perceptually before them. Decentration skills are paramount in this effort.

To express the compensation argument, children must hold two or more characteristics/arrays/conditions in WM simultaneously that are not action-based. In fact, they represent states, or propositions characterizing the cause of states. Moreover, although one or both members of the pair are observable, reliance on states of affairs and not action schemes places higher demands on mental operations (memory and logic) to formulate the compensation between the dimensions. It is when both are unobservable that notional thinking can further direct children’s reasoning – when two abstract contributing causes are considered to produce an effect. Although the dimensions of the clay/glasses are observable, focus must entail a non-motion-based comparison between them – determining that what one dimension lacks the other has gained. Despite the fact that both dimensions are perceptually apparent, the reduction/augmentation in their form is less apparent, since analyses depend on form changes, rather than action scheme alterations. Spatial decentration (the means to consider, at minimum, two aspects of an array simultaneously) exceeds what is starkly present, in that the comparison which surfaces implicates both commonalities and differences on several, more abstract planes. These conceptual vertexes are not substantially based on lived experience; hence comparisons founded on them are less salient. Allowing one aspect of the perceivable spatial array to distract and to mislead is a likely result when decentration skills are not in place. Nonetheless, competency conserving via compensation-based reasoning demonstrates precisely how perceptual decentration and notional decentration are linked.

According to Piaget (1969 [1961]: 327), perceptual decentration “prefigures” notional decentration. The rationale is that decentration does not surface for the first time upon children’s means to articulate the compensation argument; rather, the development of object permanence/constancy by 1;0 entails some form of decentration. In other words, decentration skills are necessary to the concept that an object which is hidden (or “out of mind”) still exists. What Piaget appears to mean is that two representations of the same object exist, one perceptual in Secondness, while the other exists in Thirdness as an image in the mind. In this way, perceptual decentration “prefigures” notional decentration. Piaget asserts that:

Consequently, the conditions under which this scheme [object permanence] develops are very similar to those of the perceptual constancies (which explains its precocity) except that an element of comprehension, which goes beyond mere perception, is involved when the object passes out of the perceptual field . . . It can therefore be understood in what sense
both perceptual constancies “prefigure” notional conservations without the latter being in any way abstracted from them, and how conservations introduce relations which were not previously included in the constancies. (Piaget 1969 [1961]: 327)

Similarly, the objectivity inherent in compensation logic is constructed from and in proportion to the activity of the subject in perceptually-based sensorimotor schemes (Piaget 1969 [1961]: 364). In this way, subjective and objective schemes are so integrated that they are not disentanglable – such that subjectively experienced schemes remain undefined from objectively experienced ones, independent of whether they consist in observed or unobserved phenomena. Initially, the contributions of the subject and the object are perceived as an undifferentiated interplay (Piaget 1969 [1961]: 364–365). Later, when children embrace full-fledged concrete operational reasoning (when they conserve people’s vantage-points), subjectively and objectively derived knowledge is differentiated, as demonstrated by the compensation argument. The latter (objective reasoning) provides little, if anything, about perceptual knowledge or properties of objects. What it does supply is the means to distinguish physical and social interactions from logical ones, i.e., unobserved cause-effect relations.

Recognizing via metacognitive skills (demonstrated by concrete operational rationale), action-based social relations that are subjective in nature, are differentiated from objective, propositional relations that are based in logic. Piaget (1969 [1961]: 364) implies that the means to objectify utilizing decentration skills, in turn, affects subjective thought. It permits subjectively selected but objectively derived propositions to become internalized into children’s own knowledge constructs. These constructs, in turn, are employed to self-regulate, internal processes of thought, feelings, and the like. These propositions can then be instrumental in determining which perceptual arrays are deceiving, making it necessary to revert to logic in the form of notional decentration to derive a believable rationale for the particular resultant state. Piaget (1969 [1961]: 366) refers to the deceptive nature of appearances as “deformation.” The rationale is that while appearances of spatial arrays can “deform” reasoning, the propositions present in conservational logic can liberate it. This form of liberation leaves children free to decenter notionally, not ignoring perceptual arrays, but utilizing them when appropriate. This alternative decision-making becomes a means to regulate what children think and how they reason interpersonally and intrapersonally.

According to Diewald, interpersonal competencies (the social and psychological means to take perspectives beyond one’s own) are a precursor to deictic thinking: “Infantile egocentrism as a mindset in which the child, without being aware of it, organizes everything from its own point of view, which it considers to be the only one possible, is the precursor of reversible egocentrism, which is
one of the foundations of the deictic process” (Diewald 1991: 43). In actuality, Diewald’s claim represents the developmental picture in reverse, misapprehending that reversibility influences the onset of deictic thinking. Rather, it is deictic thinking via use of deictic terms in representational exchange scenarios (pretend and real-world) which is the linchpin, hastening reciprocal reversible processes (West 2010: 14–15).

4 Operations upon operations

According to Piaget and Inhelder (1969 [1966]: 94–95), at approximately 11;0 logic supersedes the visual array when relations can be reversed (at the outset of Piaget’s formal operational stage), marking the ontogeny of operations upon operations within spatial logic. Reasoning inherent in operations upon operations entails the means to “decenter,” to consider several dimensions or attributes of an event concurrently in the mind’s eye, and to employ reciprocity-based reversibility, when determining which components must be drawn upon to successfully problem-solve. While reversibility skills emerge during the concrete operational stage (between 8;0 and 10;0) they are incomplete (Piaget and Inhelder 1969 [1966]: 99). In concrete operational thinking only one kind of reversibility is operational, that of negation. This initial kind considers inverse operations in which the reversal constitutes a sort of nullification of the original scheme (Piaget and Inhelder 1969 [1966]: 136). Intrinsic to negation-based reversibility is an action scheme, in which movement of objects (not people) is salient – demonstrating children’s focus on subjective, embodied schemes. In contrast, reciprocal reversibility whose onset occurs at approximately 11;0 (Piaget and Inhelder 1969 [1966]: 136–140), requires an appreciation of less observable reversals that do not cancel one another out. Rather, each point of origin can exist simultaneously and independently, indicating a liberation from observables and lived experience.

Employing negation but not reciprocal reversibility is a consequence of either of two independent factors: juxtaposing elements of an event that should not be categorized separately; or fusing components that should be distinguished for purposes of determining cause-effect and relational issues (Piaget 5

5 Since an English translation of Diewald’s (1991) text is not available, this author sought out the assistance of a native German speaker familiar with issues of deixis to derive a translation of this passage: “Der kindliche Egozentrismus als eine Haltung, in der das Kind, ohne sich dessen bewusst zu sein, alles von seinem Gesichtspunkt aus ordnet, den es für den einzig möglichen hält, ist die Vorstufe des reversiblen Egozentrismus, der eine der Grundlagen des deiktischen Prozesses darstellt.”
The former draws upon less complex cognitive and world knowledge skills, given its reliance on class inclusion and exclusion competencies which are relatively concrete or observable. This form of reversibility can be characterized as a kind of gestalt, in which objects are classified together based on an observable similarity, be it physical or functional. Conversely, relation-based reversibility requires formulating generalizations in the face of less observable characteristics, i.e., connections among variables based on distance or on causation.

This accounts for how it is that logic can bind issues such that the basis for the binding is other than simply co-occurrence spatially or temporally. Full-fledged reversibility precludes the determination that simultaneity of events and their proximity necessarily indicate that one contributes to another co-occurring event. Prior to the onset of reversibility (before 7;0), children's reasoning fails to be deductive; it merely proceeds from a particular case to another particular case (Piaget 1959 [1924]: 186). In fact, capitalizing on the work of William Stern, Piaget characterizes this early thought as “transductive.” “Transductive” thought assumes either that each effect has a different cause, or that effects have the same cause by virtue of some coincidental factor (simply because of their co-occurrence in space and time) – without examining non-observable factors. The following interchange between child and adult from Piaget’s own data illustrates the cause-effect application:

Roy (age 8) tells us that the moon grows. “Half” of the moon (its crescent) becomes “the whole.” “How does the moon grow? – Because it gets bigger. – How does it happen? – Because we grow ourselves. – What makes it grow? – The clouds. – How did it begin? – Because we began to be alive. – How did the moon make herself be there? – Because we made ourselves be there. – And did that make the moon grow? – Yes. – How? – . . . – Why? – The clouds made it grow,” etc., etc. (Piaget 1959 [1924]: 188)

According to Piaget (1959 [1924]: 188), a form of synchronous thought pervades transductive (pre-conservational and pre-formal operational) reasoning, in that children are restricted to thinking about the immediate context of the experience. This adherence appears to result in an undifferentiated, overly holistic perspective of the role of immediate factors, that the co-occurrence of events is motivated by common causal influences (the cause of moon and human growth is identical because they coexist). With the onset of concrete and formal operational reasoning arises objective means to logically determine (using synchronous factors) which factors have influence on the effect in question. Formal operational thought in particular, supplies the means to hold constant in WM all other potential influences, while varying one possible contributor, as well as reconciling the perceptually apparent with factors that are less so.
Piaget’s system of spatial logic

147–148) own paradigm to measure children’s means to reason in this fashion is
the “Pendulum experiment.” The design is as follows: Variables in the experi-
ment (Piaget and Inhelder 1969 [1966]: 148) consist in: string length, differences
in the attached weight, the height from which the weight is dropped, and/or the
initial force with which the pendulum is thrust. All other variables must remain
constant in the face of alteration of one variable; and children need to recognize
that more than a single factor can be responsible for the rate at which the pen-
dulum swings. Concrete operational reasoning is characterized by a lack of sys-
tematic variation—all/some factors are varied, many simultaneously (Piaget and
Inhelder 1969 [1966]: 148). Demonstrating systematic variation in this experiment
is but one of the competencies necessary to formal operational thought, and
hence to coordinating operations upon operations.

Essential to reasoning at a formal operational level is the coordination of
three systems: connecting logical causes to effects, recognition of the displace-
ability of movable objects (relative to one another) from their location in fact, and
apprehension of the system of points of view or perspective legitimacy. The for-
ermer, as illustrated above, is enhanced when children have begun to coordinate
the object and perspective-taking systems, since consideration of shifting origos
with respect to objects’ locations facilitates envisionment of perspectives that
are not physically apparent. Given that often in objective logic (based on law
governing problem-solving) several potential contributors to the effect need to
be systematically varied, considering perspectives beyond one’s own advances
reasoning from the concrete and the actual (in ego’s observance) to the non-
observable and potential (assuming another’s or all other’s perspective from their
orientation) is paramount. Hence, perspective-taking or the means to assume
other origos appears to be a precursor to the systematic reasoning necessary for
scientifically-based formal operational intelligence. This assertion is supported
by the fact that perspective-taking competencies are mastered after all other con-
servation skills have been demonstrated, at the threshold of formal operational

Piaget and Inhelder illustrate the coordination of the object with the origo
system by means of their “Three Mountain Task” in which three mountains of
distinct colors are arranged three dimensionally – two in the foreground and one
in the background or the reverse. The children being questioned are expected to
perceive the array of the mountains either from their own perspective were they
to alter their orientation to the mountains or from a doll’s perspective. The chil-
dren must select a depiction which best represents the view of the mountains
as either origo (the child or the doll) would see them. The doll’s or the child’s
perspective is varied when it is displaced (volitionally or otherwise) to another
orientation with respect to the mountains (cf. section 1 for a more elaborated
description of this experiment and its implications). Piaget and Inhelder (1967 [1948]: 217) describe the skills necessary to this perspective-taking experiment as follows: "When the child moves from position A to position B and, by means of his pieces of card, reproduces his present view together with his previous one, he is simply co-ordinating a perceptual notion (the view from B) with an imaginal one (the memory of the view from A)." This elevated form of coordination constitutes a late acquisitional process during the close of the Concrete Operational Stage, being realized at approximately 9;0 (Piaget and Inhelder 1966: 106–107).

The means to assume other origos’ perspectives without direct exposure to what they can see, is the most complex of the conservation skills, e.g., seriation, number, quantity, etc., in view of its dependence on heightened reversibility in which memory skills are exacted. Absolutely necessary to perspective-shifting is reciprocal reversibility competencies, not merely negation-based reversibility. Taking one perspective does not cancel out another’s, as in negation reversibility; rather, many, if not all perspectives, can be valid even simultaneously, if origos are oriented differently in the same spatio-temporal context. Certainly at distinct moments in time even the same origo can locomote and find him/herself in different places and/or in different orientations with respect to object arrays, directly altering their perspective. For this reason, reliance on reciprocal reversibility, (envisioning different perspectives) provides the rudimentary tools to engage in formal operational thought (operations upon operations). This kind of reversibility (involving reciprocal mental operations) is likewise constructed upon relatively advanced decentering skills, further confirming its pivotal role in formal operational thought. Children need to recognize that two or more concurrent or non-concurrent origos can have legitimacy, together with Bühler’s notion that one origo can allocate another. Consequently, both origos can determine distinctive relations to their individual contexts, given their orientations and relative location to objects. Each origo’s directional gaze (as index) establishes the perspective.

Foundational to these mental operations is a systematic and objective (law-driven) comparison between two or more locations, orientations, time coordinates, or cause-effect scenarios. Particular to perspective-taking is a systematic and objectified comparison of reciprocal vantage points intrinsic to operations upon operations. Such provides children with the awareness that two or more factors contribute to indexing an object as either proximate or distant – the particular origo and its orientation, the location of the objects in question (relative to each other and to the given origo), and the likelihood of movement/displacement of the origo or of the object(s). With respect to demonstratives which demarcate near from far space/locations of objects, “this”-objects can become “that”-objects if one of three conditions is met: 1) self as origo changes orientation, 2) origo is...
other than self and changes orientation, or 3) the objects’ placement alters. It is
evident that deictic demonstrative use is foundational to expressing distinctive
perspectives – demonstratives encode the potentiality of the existence of differ-
et origos, of shifting locomotion of origos, and ultimately of shifting movement
of objects to other locations. Hence, the necessity of deictic comprehension, re-
lected in full-fledged demonstrative use, unquestionably represents a primary
catalyst to heightened cognitive competencies present in operations upon opera-
tions. Clearly, the semiosis of index is an essential trigger toward coordinating
these higher level mental operations.

References

Acredolo, Linda. 1988. From signal to “symbol”: The development of landmark knowledge from
Barr, Rachel, Anne Dowden, & Harlene Hayne. 1996. Developmental changes in deferred
imitation by six- to twenty-four-month-old infants. Infant Behavior and Development 19,
159–170.
Bruner, Jerome. 1973. Beyond the information given: Studies in the psychology of knowing,
Verlag.
Quarterly 50(3), 274–290.
Cliffs, NJ: Prentice-Hall.
Huttenlocher, Janellen, & Stella Lourenco. 2007. Using spatial categories to reason about
location. In J. Plumert & J. Spencer (eds.), The emerging spatial mind, 3–24. New York:
Oxford University Press.
Kosslyn, Stephen M., Alvaro Pascual-Leone, Olivier Felician, Susana Camposano, Julian Keenan,
William L. Thompson, Giorgio Ganis, Katherine Sukel, & Nathaniel Alpert. 1999. The role of
Area 17 in visual imagery: Convergent evidence from PET and rTMS. Science 284. 167–170.
Piaget, Jean 1959 [1924]. Judgment and reasoning in the child, M. Warden (trans.). Paterson,
NJ: Littlefield Adams.


**Bionote**

*Donna E. West* (b. 1955) is associate professor at State University of New York at Cortland <westsimon@twcny.rr.com>. Her research interests include developmental cognitive linguistics, deictics, semiotics, psychological implications of Peirce’s model. Her publications include “Deixis as a symbolic phenomenon” (2011); “Elicited imitation to measure morphemic accuracy: Evidence from L2 Spanish” (2012); “Peircean triadicity: Application to deictic use” (2012); and “Indexical reference to absent objects” (2012).