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Action as developmental process – a commentary on Iverson's 'Developing language in a developing body: the relationship between motor development and language development'*

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In 1628, Descartes told us how to do science: in studying any phenomenon, simplify it to its essential components, dissect away everything else. In this way, by separately studying the well-defined parts, we might fully analyze the building blocks themselves. The success of this method in modern science has been undeniable, leading, for example, to unprecedented knowledge of the molecular components of living organisms. This approach has also clearly advanced our understanding of the multiple levels of structure in language. Yet, over the years, many developmental theorists, including Baldwin (1894), Piaget (1952), Werner (Werner & Kaplan, 1963), Gottlieb (e.g. Gottlieb & Lickliter, 2007), Thelen (2002) and in the study of language, Bloom (1993), have balked at this divide and conquer approach. They argue that development needs to be understood as a system of complex interactions among many components, and in terms of the whole child in context. Iverson's call (this issue) to consider language development in the context of motor development follows this tradition. One example provided by Iverson, rattle-shaking as a precursor to babbling, provides the theme for this commentary: that action (and thus motor development) is essential to understanding mechanisms of change.

MULTIMODAL INTEGRATION

Piaget (1952) also saw rattle-shaking as deeply revealing and an example of what he called a secondary circular reaction. Young infants, aged 0;4, do not reach for rattles, and if given one, do not necessarily shake it. But if the infant accidentally moves it, and sees and hears the consequences, the infant will become captured by the activity – moving and shaking, looking and listening. Through action, the infant discovers the task AND THE INTENTION

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to shake to make noise. Piaget believed this pattern of activity – an accidental action that leads to the goal-driven re-experience of the outcome – to be a core mechanism of change.

Contemporary theorizing in computational neuroscience agrees and also sees multimodal perception–action loops as driving neural change and connectivity (Lungarella, Pegors, Bullwinkle & Sporns, 2005; Lungarella & Sporns, 2005; McIntosh, Fitzpatrick & Friston, 2001; Metta & Fitzpatrick, 2003; James, 2009). These analyses show that coupled HETEROGENEOUS systems – systems such as vision, audition and action, each with fundamentally different properties and sensitivities – when coupled in a task to each other and to the physical world, create a dynamic complex system that learns on its own, discovers higher-order regularities, and changes the internal properties of the subsystems as well as their connections to each other.

Critically, the motor system and action is special as this component does not just receive information from the physical world but also causes change in the physical word and in so doing selects and creates the input to other sensory systems. The importance of action in coupling sensory systems and in driving change was demonstrated in the classic work of Held & Hein (1963; see also Hein & Diamond, 1972; Landrigan & Forsyth, 1974), who showed that active exploration but not passive viewing led to change in the visual system of kittens. Analogous results have been shown in humans (Harman, Humphrey & Goodale, 1999; González, Bach-y-Rita & Haase, 2005) and are also supported by evidence from cognitive neuroscience (Barsalou, Pecher, Zeelenberg, Simmons & Hamann, 2005; Chao & Martin, 2000; Martin & Chao, 2001; Pulvermüller, Hauk, Nikulin & Ilmoniemi, 2005; James, 2009). It is action that creates the task, that couples component systems in the moment, and that selects and creates the momentary dynamic input on which learning must depend.

CASCADING CONSEQUENCES

Even so, one might ask how or why rattle shaking has anything to do with language. In her review, Iverson points to the common rhythmic properties of arm movements in rattle-shaking and mouth movements in babbling. However, the potential developmental relation between rhythmic arm shaking and babbling may be a specific example of a much more general developmental principle of developmental process. Children are not developing in one domain at a time. Instead, each day, moment to moment, they perform many different tasks, all interlaced with each other: They shake things, they bang things, they socially flirt with parents, they play peek-a-boo, they sit, they crawl. The different integrations of component systems by these different actions in different tasks creates overlapping

coordinations that assemble subsystems in different ways (Clark, 1997; 2008; Thelen & Smith, 1994; Honey, Kötter, Breakspear & Sporns, 2007; Sheya & Smith, in press). Consider the following hypothetical example: Systems A and B are coordinated in Task 1 (e.g. rattle-shaking), creating change in the engaged component systems and in their connections. Systems B and C are coordinated in the service of some other, second task (e.g. peek-a-boo). If this conceptualization is correct, the changes in System B wrought via coordination with System A in Task 1 will influence learning and performance in Task 2, constraining solutions to the search space in that task. This is how seemingly quite separate domains of development may, rattle-shaking and babbling, or nesting cups and syntax, could be both deeply different but deeply interdependent in development nonetheless.

Needham and colleagues provide an empirical demonstration of this idea (Needham, Barrett & Peterman, 2002; Fitzpatrick, Needham, Natale & Metta, 2008; Barrett & Needham, 2008). They gave infants aged 0;2 to 0;5 Velcro-covered 'sticky mittens'. These mittens enable infants to grab objects merely by swiping at them, enabling them to precociously coordinate vision and reaching. Infants who were given two weeks of experiences with sticky mittens subsequently showed more sophisticated object exploration even with the mittens off. They looked at objects more, made more visually coordinated swipes at objects, and more mature grasps earlier than did control infants who had no exploratory experiences with sticky mittens. Moreover, these precocious experiences in coordinating vision and action led to measurable advances in seemingly separate skills months later, including the more mature parsing of causal events in visual scenes, a development that may connect sticky mittens to later language learning (Sommerville, Woodward & Needham, 2005; see also Barrett, Traupman & Needham, 2008).

ACTIONS ARE ABSTRACTIONS

All this is also relevant to language development because actions are inherently relational, abstract and variabilized over objects. A push of a car and a push of a ball share only intention, the velocity profiles of the movement, contact and (in a quite abstract way) consequences. Doing things with lots of different things – shaking, banging, hitting, putting objects on and in and under – may be at the core of the relational ideas that hold sentences together and underlie language. There is remarkably little contemporary work on these activities of children and on their relation to language learning. In her article, Iverson reviews the few and mostly descriptive studies that show developmental progression in play linking to language learning. But there are growing indications that a close look at children's actions (and their perceptions of actions) may show close links

between the processing and interpretation of common verbs and the abstract nature of actions themselves (e.g. Maouene, Hidaka & Smith, 2008; Seston, Golinkoff, Ma & Hirsh-Pasek, 2009; James & Maouene, 2009; Smith, Maouene & Hidaka, 2007). One intriguing finding reported by Maouene *et al*. (2008) shows that for 100 common verbs that children typically learn before the age of 3;0, there is a strong and systematic relation between age-of-acquisition of the verb and the body-part that does the action. This may be important because different kinds of body parts are associated with different kinds of relations (for example, legs with locomotion, mouth and eyes with changes in internal state, hands with causal actions). If Iverson's article brings the field to a new and more mechanistic study of how the motor activities that comprise object play drive change, then it will have made a significant contribution.

LIMITATIONS

This brings us directly to limitations of Iverson's review, and this commentary: so far, all that have been put forth are ideas, intriguing but mostly conjecture and not yet on firm empirical grounds. What is needed next is rigorous experimental study. The explosion that is first language development happens in the context of another developmental explosion that is in motor skill and action. Understanding if, how and why these co-develop just might lead us to a better understanding the mechanisms of change – in both domains.

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