The Development of Embodied Cognition: Six Lessons from Babies

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After: Smith, L., & Gasser, M. (2005). The development of embodied cognition: Six lessons from babies. *Artificial Life*, *11*(1–2), 13–29. https://doi.org/10.1162/1064546053278973

Embodiment hypothesis

The central idea behind the embodiment hypothesis is that intelligence emerges in the interaction of an agent with an environment and as a result of sensorimotor activity.

Lesson 1: Be Multimodal

Degeneracy → Redundancy

Reentry

The time-locked correlations create a powerful learning mechanism

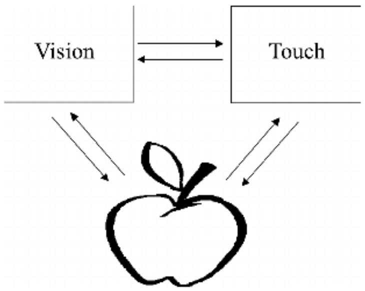


Figure 1. Illustration of the time-locked mappings of two sensory systems to the events in the world and to each other. Because visual and haptic systems actively collect information — by moving hands, by moving eyes — the arrows connecting these systems to each other also can serve as teaching signals for each other.

Lesson 1: Be Multimodal

Case study 1: Transparency in infants (babies like birds are confused by it; unusual correlation between visual and haptic cues)

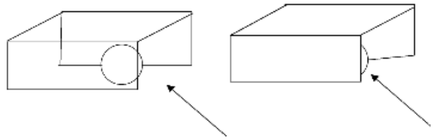


Figure 2. A toy (ball) hidden under a transparent box and an opaque box in the Diamond task. The opening is indicated by the arrow.

Diamond (1993): 9mo are better at retrieving object from opaque vs transparent box

Titzer et al. (2003): if at 8mo are allowed to play with both boxes, at 9mo they retrieve the object equally well from opaque vs transparent box

Why? What have the babies learned in the study of Titzer et al. (2003)?

Diamond, A. (1990). Developmental time course in human infants and infant monkeys, and the neural bases of, inhibitory control in reaching. *Annals of the New York Academy of Sciences*, *608*, 637–676. https://doi.org/10.1111/j.1749-6632.1990.tb48913.x
Titzer, R., Thelen, E., & Smith, L. B. (2003). Learning about transparency. Unpublished manuscript.

Lesson 1: Be Multimodal

Figure 3. Illustration of the Tucker-Ellis task. On each trial, the participant is shown one pitcher and is asked to answer as rapidly as possible the question: "Is this a pitcher?" On some trials the pitcher's handle is on the left; on some trials it is on the right. Half the participants answer "yes" by pressing a button on the right and half by pressing a button on the left. Participants are faster when the handle is on the same side as the "yes" response.

Case study 2: In visual object recognition (explicitly unimodal),

multiple modalities contribute to performance

In general, people are faster in visual recognition tasks when the response to be made is compatible with a real action on the object.

Why?

Ellis, R., & Tucker, M. (2000). Micro-affordance: The potentiation of components of action by seen objects. *British Journal of Psychology*, *91*(4), 451–471. https://doi.org/10.1348/000712600161934

Lesson 2: Be Incremental

Traditionally, both machine learning and human learning have concentrated on non-incremental learning tasks, tasks in which the entire training set is fixed at the start of learning and then is either presented in its entirety or randomly sampled.

Infants' early experiences are strongly ordered by the development of sensory systems and movement systems.

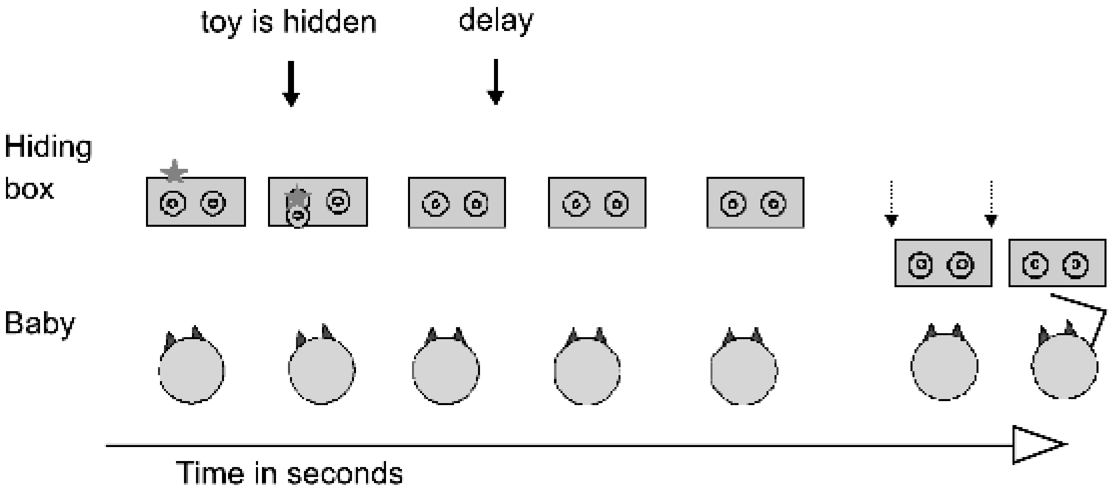
Lesson 2: Be Incremental

Example: A not B error

Error at 8-10 mo

No more error around 12 mo

Why?



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.

Lesson 2: Be Incremental

Changes in the normal development path —dramatically alter developmental outcomes.

-Opening kittens’ eyes early disrupts olfactory development and the subsequent coordination of vision and olfaction [PUT REF]. - Disrupting the developmental order of audition and vision in owls disrupts spatial localization in both modalities [PUT REF].

→One of the ingredients in building biological intelligence is ordering the training experiences in the right way.

Several attempts to model human learning [PUT REF] have shown that neural networks sometimes fail to learn the task when the entire data set is presented all at once, but succeed when the data are presented incrementally with an easy-to-difficult ordering.

PUT REFS

Lesson 3: Be Physical

Exemple 1: [Passive walker]

What does this show?

https://www.youtube.com/watch?v=wMlDT17C_Vs

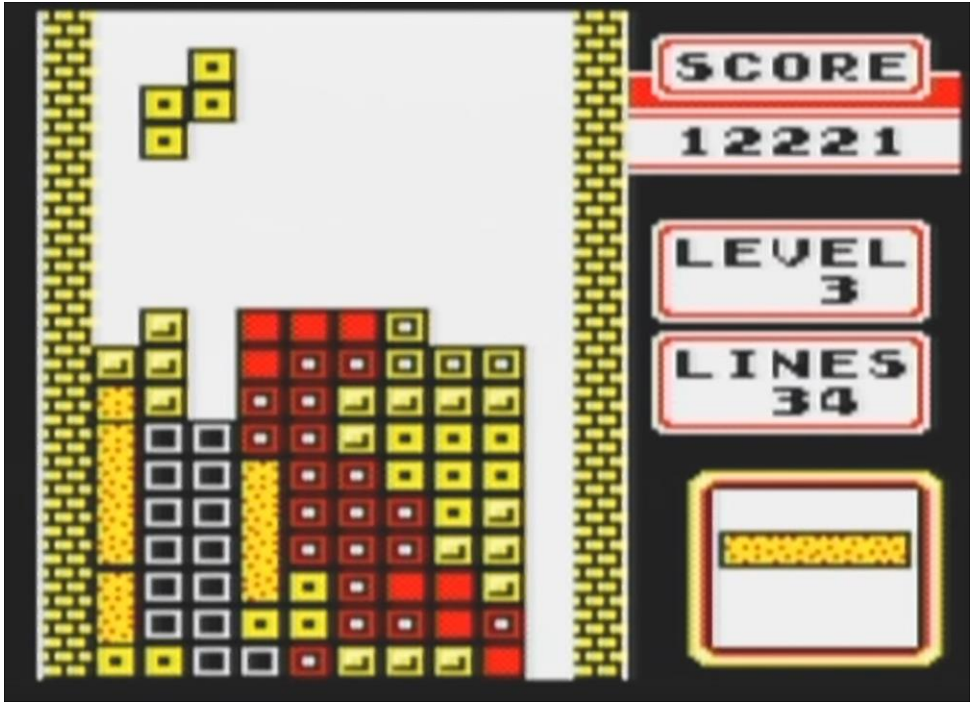
McGeer, T. (1990). Passive dynamic walking. International Journal of Robotics Research, 9(2), 62 – 82.

Lesson 3: Be Physical

Exemple 2: “Epistemic” actions

Kirsh & Maglio (1994)

(see also gesturing in Kirsh, 1995; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; for a review see Goldin-Meadow, 1999).



https://www.youtube.com/watch?v=RWAYTx7Mwp8&t=378s

Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science*, *18*(4), 513–549. https://doi.org/10.1016/0364-0213(94)90007-8

Lesson 3: Be Physical

Exemple 3: Change blindness (1) (2)

How could it be explained?

https://youtu.be/ERQrgb1YnoM
https://www.youtube.com/watch?v=ubNF9QNEQLA

O’Regan, J. K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences*, *24*(5), 939–973. https://doi.org/10.1017/S0140525X01000115

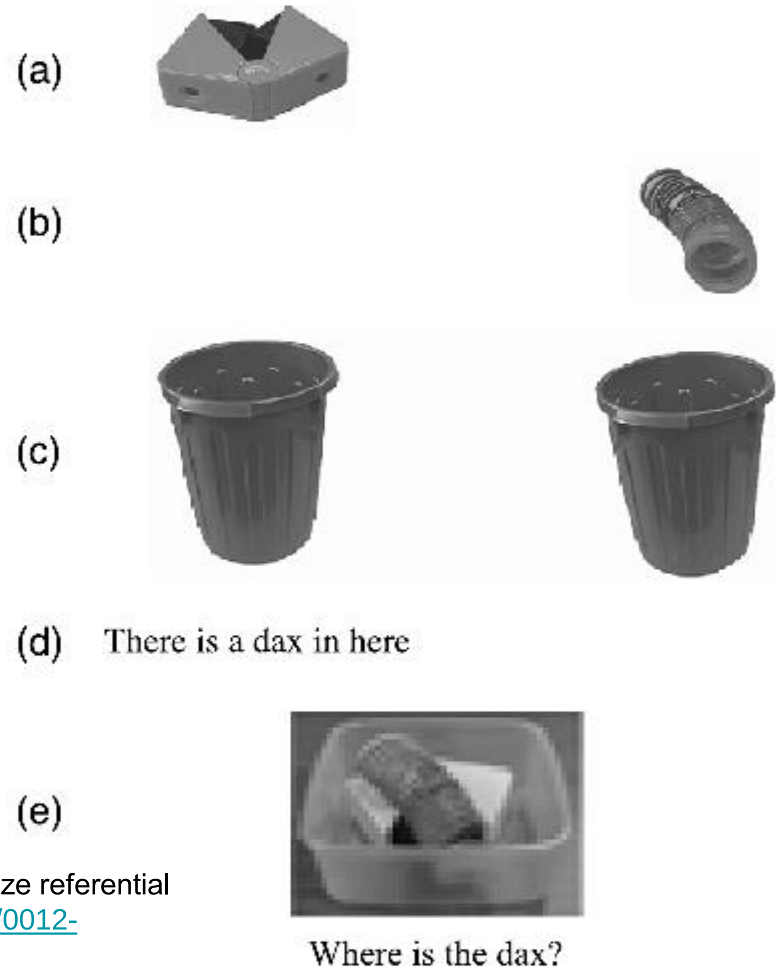
Lesson 3: Be Physical

“This offloading in the interface between body and world appears a pervasive aspect of human cognition and may be critical to the development of higher-level cognitive functions or in the binding of mental contents that are separated in time.”

1.5-2 year-olds

The name and the object were never jointly experienced.

Works even without containers and objects at (c) and (d), pointing on an empty table



Baldwin, D. A. (1993). Early referential understanding: Infants’ ability to recognize referential acts for what they are. *Developmental Psychology*. https://doi.org/10.1037/0012-1649.29.5.832

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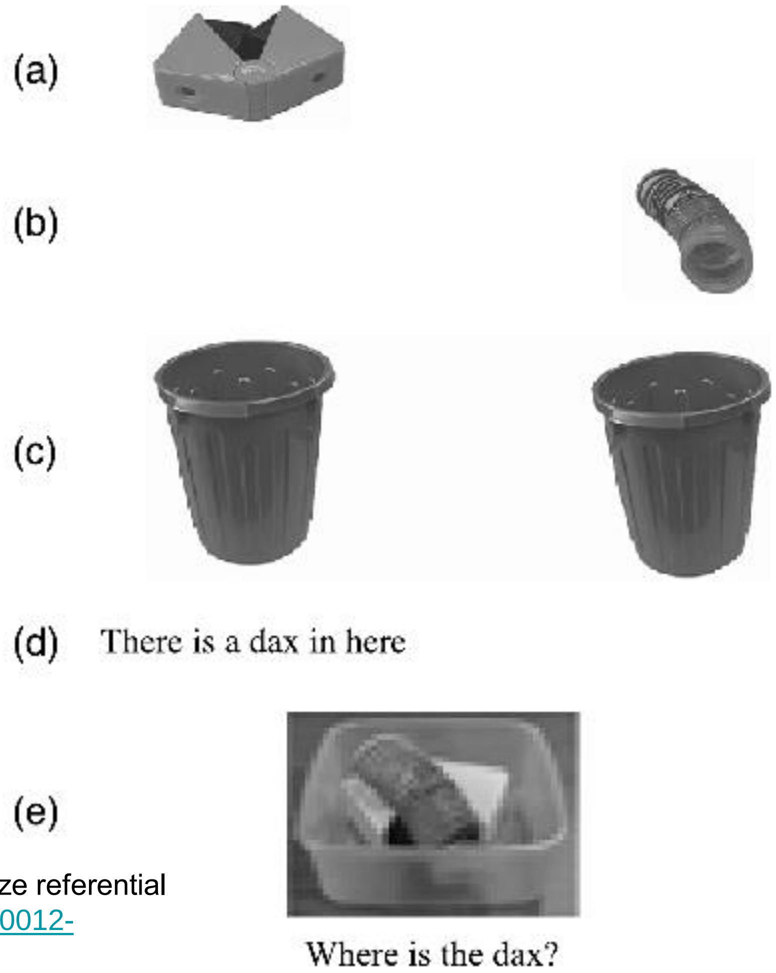


Baldwin, D. A. (1993). Early referential understanding: Infants’ ability to recognize referential acts for what they are. *Developmental Psychology*. https://doi.org/10.1037/0012-1649.29.5.832

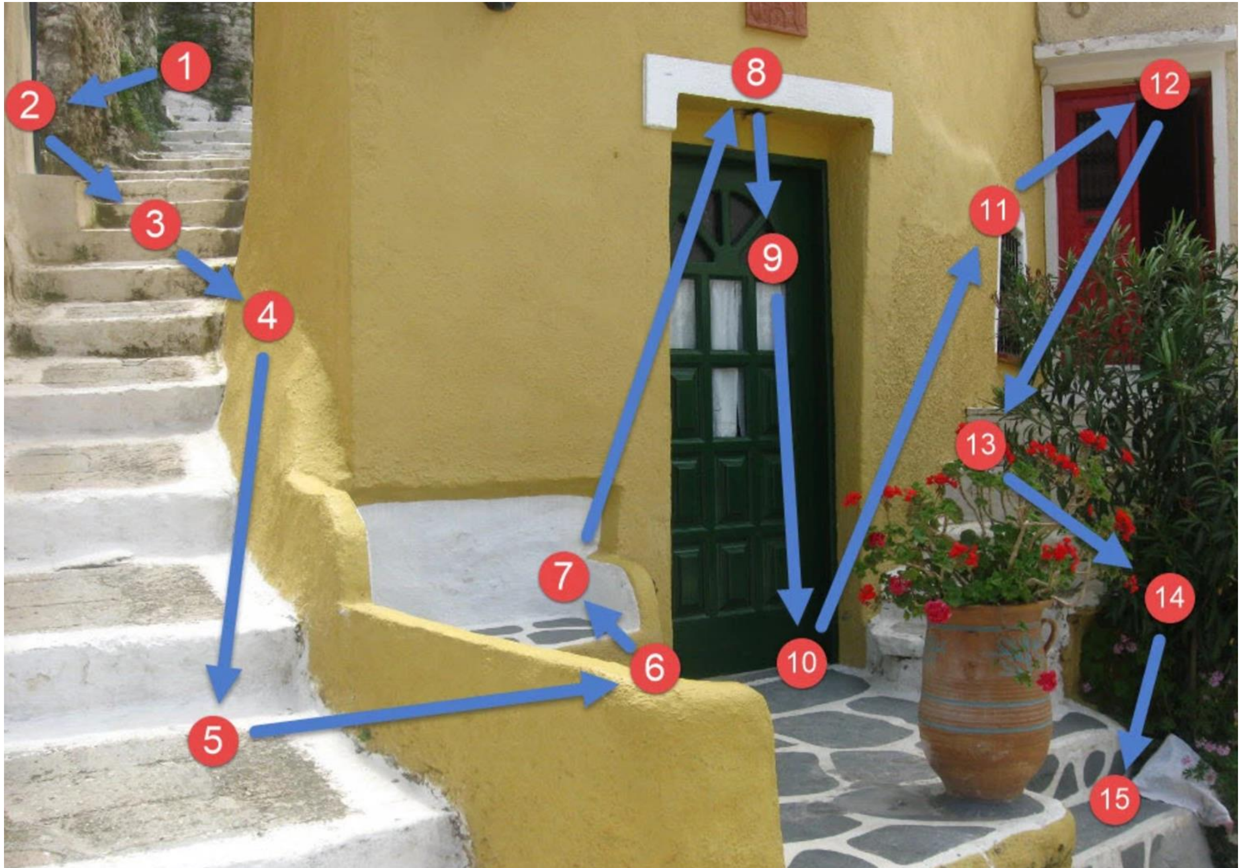
Lesson 3: Be Physical

Method of loci

What is it?

How does it work?

Why does it work?



Lesson 4: Explore

How can a learner who does not know what there is to learn manage to learn anyway?
Do one needs to prespecify the learning tasks and the learning goals: whether the agent or its designer has to know what needs to be learned in order to learn?

Evidence from human development shows that babies can discover both the tasks to be learned and the solution to those tasks **through exploration, or non-goal-directed action. In babies, spontaneous movement creates both tasks and opportunities for learning**. One elegant demonstration concerns the study of reaching (Corbetta & Thelen, 1996).

4 babies observed over 3 months →4 different patterns
The presentation of an enticing toy is arousing and elicits all sorts of nonproductive actions, and very different individual actions in different babies.
These actions are first, quite literally, all over the place with no clear coherence in form or direction.
But by acting, by movements that explore the whole range of the movement space, each baby, in its own unique fashion, sooner or later makes contact
with the toy— banging into or brushing against it or swiping it.

Corbetta, D., & Thelen, E. (1996). The developmental origins of bimanual coordination.
Journal of Experimental Psychology: Human Perception and Performance, 22, 502 – 522.

Lesson 4: Explore

[Conjugate reinforcement with mobile paradigm](https://www.youtube.com/watch?v=ZgOu_Uc00ao&t=4s)

From ~ 3mo
Exploration, discovery and selection of one optimal pattern.
Without spontaneous move-ment, without exploration, there is nothing to learn from the mobile.

https://www.youtube.com/watch?v=ZgOu_Uc00ao&t=4s

Rovee-Collier, C., & Hayne, H. (1987). Reactivation of infant memory: Implications for cognitive development. In H. Reese (Ed.), Advances in child development and behavior, Vol. 20, (pp. 185 – 238). San Diego, CA: Academic Press.

Lesson 5: Be Social

Mother-infant face-to-face interactions look like conjugate reinforcement as in mobile paradigm. Crucially, the social partner in these interactions offers much more than a mobile, and this changes everything.

Turn taking

Imitation: infants learn to imitate parent vocalizations, parents imitate infants ⇒ Cyclical pattern of vocal and facial gestures to match adult model

Mature social partners provide multimodal inputs to support early language learning, e.g. naming object, waving it, altering the intonation

Cohn, J. F., & Tronick, E. Z. (1988). Mother-infant face-to-face interaction: Influence is bidirectional and unrelated to periodic cycles in either partner's behavior. *Developmental Psychology*, *24*, 386–392. https://doi.org/10.1037/0012-1649.24.3.386

Masur, E., & Rodemaker, J. (1999). Mothers' and Infants' Spontaneous Vocal, Verbal, and Action Imitation During the Second Year. *Merrill-Palmer Quarterly*, *45*.

Yoshida, H., & Smith, L. B. (2003). Sound Symbolism and Early Word Learning in Two Languages. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 25. Retrieved from https://escholarship.org/uc/item/0x80838r