

Framing the Concept of an Action-Dependent Perceptual Invariant

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1. HOW ACTION-DEPENDENT IS PERCEPTION?

1.1 Moderate views of action/perception relations

Active perception

- Action and perception as functionally interdependent domains
- Thriving field of research in current perceptual science (Thelen & Smith, 1994; Port & Van Gelder, 1995; Hurley, 1998; Berthoz, 2000; Findlay & Gilchrist 2003)

Motor theories of perception

- Perceptual capacities depend on sensorimotor relations on top of purely sensory information
- Limited domains in which perception relies on action (e.g. perceptual skills for the control of spatial behavior, see Hurley, 2001).

Dual Vision theories

- Ventral (WHAT) pathway
- Dorsal (WHERE) pathway
- Are modulations of action in perception segregated to the dorsal system? (Milner & Goodale, 1995; Jacob & Jeannerod, 2003)

1.2 Radical views of action/perception relations

Ecological, sensorimotor and enactive theories

- Action is *pervasive* in the functioning of perceptual systems
- Perception cannot occur without action
- Perceptual information is specified through action: **action-dependent invariants**

Several criticisms of radical views (Jacob, 2006; Prinz, 2006) targeted at the most controversial issues (anti-representationalism, pervasiveness of action in perception; scarce accommodation of evidence in support of Dual Vision theories), but scarce interest for a challenging hypothesis these theories offer on the *nature of perceptual information*:

To what extent is perceptually relevant information from the senses intrinsically action-dependent?

2. ECOLOGICAL VS. SENSORIMOTOR INVARIANTS

The current debate. Ecological and sensorimotor theories are:

1. Variations on the same (enactive) theory (Pylyshyn, 2001; Stoffregen & Bardy, 2004; Stoffregen et al., 2006; Warren, 2006)
2. Mutually irreducible approaches (Varela, 1991; Hurley, 2001)

We argue that by endorsing substantially different notions of action-dependent perceptual invariants, sensorimotor and ecological theories make contrasting predictions on how action affects perception.

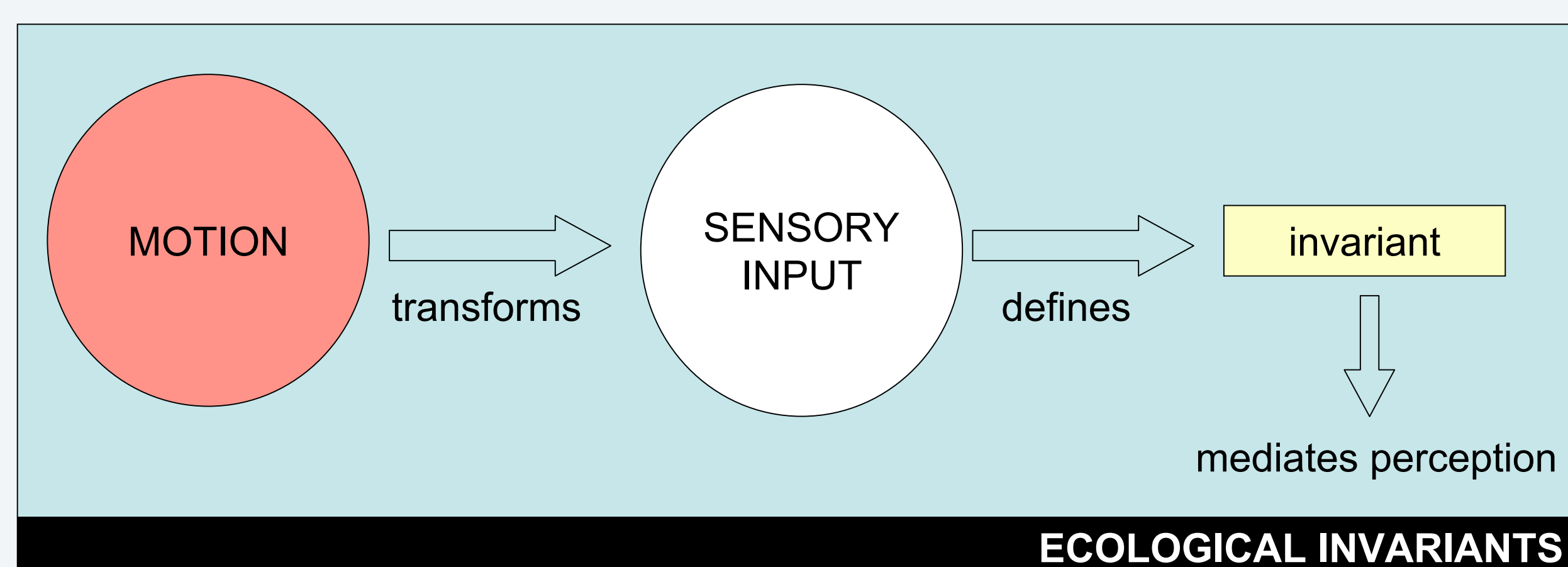
2.1 Ecological invariants

“Structures that remain invariant despite certain transformations caused by the animal and that therefore might serve to specify persisting environmental resources” (Reed, 1996)

How do ecological invariants mediate perception?

1. Invariants in sensory stimulation produced by motor transformations
2. In virtue of the **laws of ecological optics**, these invariants specify structures or changes in the physical environment
3. Pickup of ecological invariants mediates perception of the structure of the environment

Ecological invariants are **action-dependent** insofar as they can only be revealed through transformations produced by motor action.



2.2 Sensorimotor invariants

Systematic coupling between sensory (S) and motor (M) patterns:

“The structure of the rules governing the sensory changes produced by various motor actions, that is, what we call the sensorimotor contingencies governing visual exploration” (O'Regan & Noë, 2001)

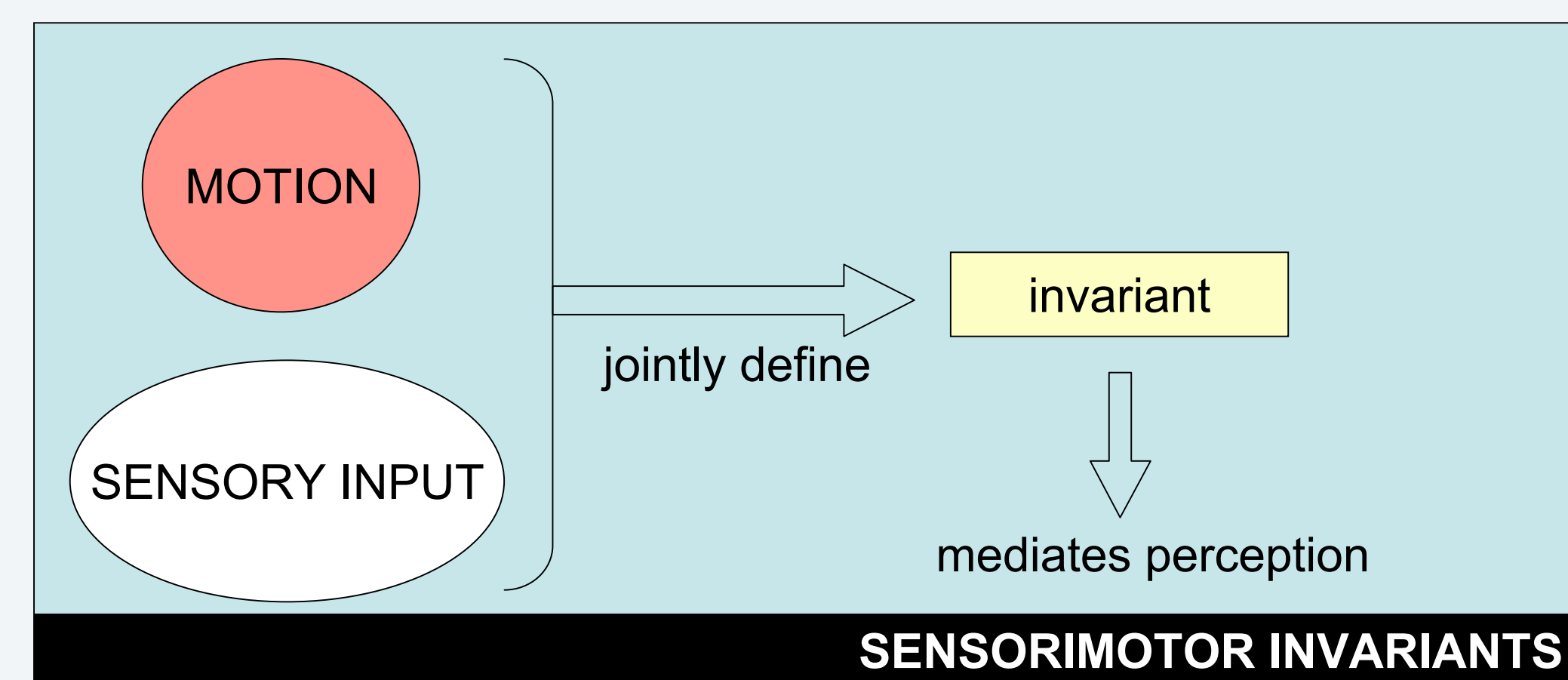
How do sensorimotor invariants mediate perception?

1. Invariants produced when motor and sensory patterns co-occur in a lawful way
2. The way in which motor and sensory patterns systematically co-vary is constrained by **sensorimotor laws**
3. Learning of invariant sensorimotor correlations governed by sensorimotor laws inform us on the structure of the environment.

How to characterize sensorimotor laws? (Philipona et al., 2004):

- Given the configuration of the body (P) and of the environment (E)
- P and M are linked through a function φ_a : $P = \varphi_a(M)$
- S is linked to E and P in virtue of a function φ_b : $S = \varphi_b(P, E)$, then $S = \varphi_b(\varphi_a(M), E)$
- If $\varphi(M, E) = \varphi_b(\varphi_a(M), E)$ then: $S = \varphi(M, E)$ (sensorimotor law)

Sensorimotor invariants are **action-dependent** insofar as they are jointly specified by sensory *and* motor regularities.



3. TWO CONCEPTS OF ACTION DEPENDENCE

Ecological theories:

Invariants: properties of sensory patterns invariant across transformations
Instrumental role of motor patterns in the specification of invariants

Sensorimotor theories:

Invariants: invariant properties of co-occurring sensory and motor patterns.
Constitutive role of motion in the specification of invariants

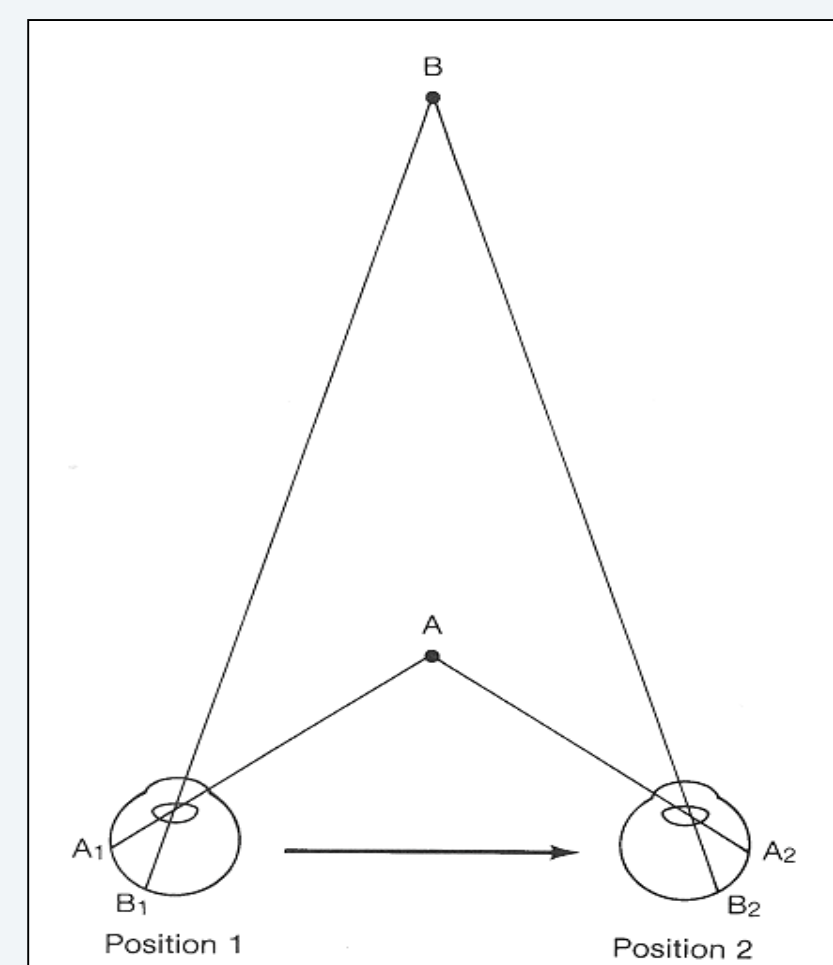
4. CONTRASTING EMPIRICAL PREDICTIONS

4.1 Ecological invariants and motor equivalence

- Invariants are defined by an appropriate transformations of sensory pattern
- Observer's motion is only required to produce the transformation
- In terms of ecological laws, multiple movements could result in identical proximal transformations (**motor equivalence hypothesis**)
- *Hence*: the specific nature of the motion patterns responsible for transforming sensory patterns is merely *instrumental*

Example: in *motion parallax*, equivalence between:

- Observer's active movement
- Observer's passive movement
- Object's movement in the environment



4.2 Sensorimotor invariants and motor specificity

- Invariants are properties of sensorimotor couplings, invariant under transformations affecting sensory and motor variables.
- Motion variables are a *component* of the invariant
- *Hence*: motion is constitutive of sensorimotor invariants

Example: spatial perception from motion parallax **changes** depending on whether the observer is allowed to move or not (Wexler et al., 2001a; Wexler et al., 2001b; van Boxtel et al., 2003)

4.3 Loose convergence

The sensorimotor and ecological approaches share the assumption that information is action-dependent in a *loose sense*:

“Enactive knowledge depends upon an action-perception cycle. Action reveals information, which guides further action, which reveals additional information, and so on” (Stoffregen & Bardy, 2004).

But they critically diverge on how they characterize *action-dependent perceptual information*.

5. TAKE-HOME MESSAGE

- According to radical views of action/perception relations, action modulates perception in the very definition of perceptually relevant information.
- There are at least two conceptually distinct hypotheses on how perceptually relevant information can be action-dependent (motor-dependent vs. transformation-dependent).
- These hypotheses lead to contrasting empirical predictions on how perception is penetrable or refractory to action.

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