Embodied Learning in Makerspace

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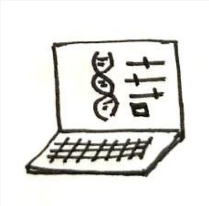

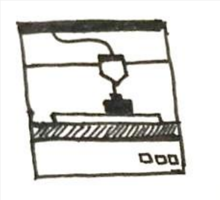

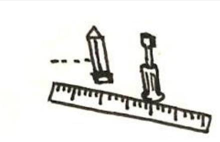

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Makerspace (MS) as a new learning practice

Gap in literature

Cognitive mechanism

Process account of MS practices

Frontier MS practices

About MS

Makerspaces (MS)

"informal sites for creative production in art, science, and engineering, where people of all ages blend digital and physical technologies, to explore ideas, learn technical skills, and create new products."

(Sheridan et al., 2014)

MS in education

Productive STEM identity

Broaden STEM participation

8000+ tinkering spaces in India

A new learning practice

Open-ended; no or flexible curriculum; interest-driven; material-based exploration; facilitation; constructive feedback; interdisciplinary; concepts recruited in context of construction

Existing Characterization of MS practices

Creative and intellectual risk taking | *(Bevan, 2017; Peppler, 2016)*

Productive STEM identity | *(Quinn & Bell, 2013; Bevan, 2017; Buechely, 2008; Kafai, 2010; Peppler, 2013)*

Personalization | *(Blikstein, 2013; Martin & Dixon, 2013)*

Productive STEM identity | *(Quinn & Bell, 2013; Bevan, 2017; Buechely, 2008; Kafai, 2010; Peppler, 2013)*

Playful experimentation | *(Regalla, 2016)*

Productive failure | *(Blikstein, 2013; Martin, 2015)*

Iterative prototyping | *(Vossoughi, Escudé, Kong, & Hooper, 2013; Tseng, 2016)*

Identifying, organize, and integrate | *(Gravel et al., 2018)*

Feedback | *(DiGiacomo et al., 2016)*

Connecting to local culture | *(Calabrese-Barton & Tan, 2018; Fields & King, 2014; Vossoughi et. al., 2013)*

Taking up leadership role | *(Buchholz et al., 2014)*

Drafts | *(Vossoughi et al., 2013; Vossoughi & Bevan, 2014; Vossoughi et al., 2016)*

Collaboration-through-air | *(Halverson et al., 2018; Litts, 2016; Kafai & Harel, 1991)*

Informal documentation | *(Peppler, 2013; Vossoughi et al., 2013)*

Conceptual learning | *(Peppler 2013; Blikstein, 2013; Wohlwend et al., 2016; Brahms & Crowley, 2016; Kafai, 2014)*

Adaptive expertise | *(Martin & Dixon, 2016; Blikstein, 2013)*

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Gap

How do the body and actions advance learning in MS?

How could this process lead to new forms of embodied learning?

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Tools for the body (schema)

Angelo Maravita[1] and Atsushi Iriki[2]

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[2]Section of Cognitive Neurobiology, Tokyo Medical and Dental University, Bunkyo-ku, Tokyo 113-8549, Japan

What happens in our brain when we use a tool to reach for a distant object? Recent neurophysiological, psychological and neuropsychological research suggests that this extended motor capability is followed by changes in specific neural networks that hold an updated map of body shape and posture (the putative 'Body Schema' of classical neurology). These changes are compatible with the notion of the inclusion of tools in the 'Body Schema', as if our own effector (e.g. the hand) were elongated to the tip of the tool. In this review we present empirical support for this intriguing idea from both single-neuron recordings in the monkey brain and behavioural performance of normal and brain-damaged humans. These relatively simple neural and behavioural aspects of tool-use shed light on more complex evolu-

centred on the body [13,15,16,21]. In this review we will refer to the widely [4,5,22–25] but perhaps ambiguously [26] used term Body Schema, or to 'body representation' to indicate such a neural system whereby space coding for action is centred on constantly updated, multisensory information about the body.

Tool-use: a clue to the plasticity of body representation and space coding

Although the length of our effectors (mainly the arms) limits our action space, we can use many different tools (from forks to pick up hot food to hyper-technological telesurgery devices) to extend our physical body structure and, consequently, our action space.

Early intuitions (e.g. [1]) suggested that manipulated

Tool Incorporation

Why Don't We Perceive Our Brain States?

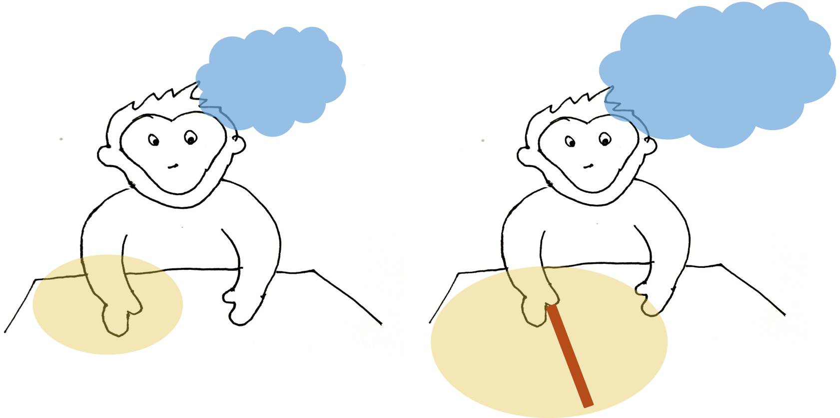
Wolfgang Prinz

Max-Planck-Institut für Psychologische Forschung and Institut für Psychologie, Universität München, München, Germany

The major part of this paper is devoted to the issue of how to bridge the gap between perception and action. First, the traditional view of the perception–action relationship is addressed. This view assumes that there are two different and incommensurate coding systems for afferent and efferent patterns (sensory and motor coding). Next, a different view is proposed that invokes the common coding of afferent and efferent patterns. One of the implications of this view is that actions can be controlled and guided by representations of distal events. There is some support for this view from two different sources: the first is nineteenth-century psychology of the will, the

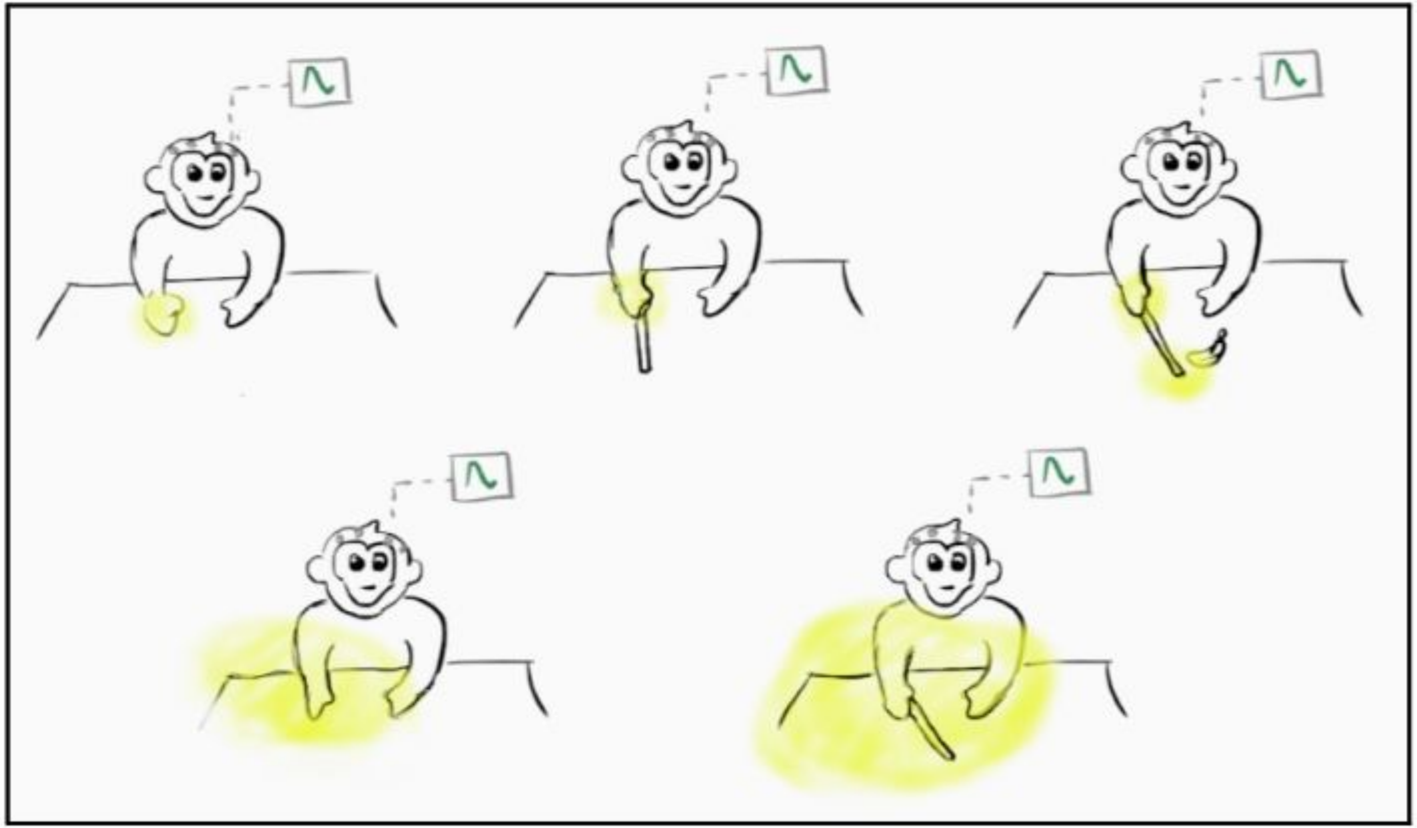
Common Coding

Tool Incorporation



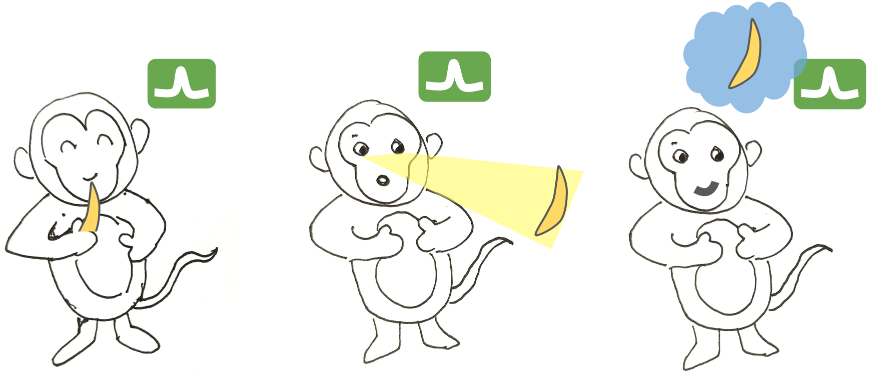
- Tool use extends body schema. Users 'incorporate' the tool into the body (Maravita and Iriki 2004).
- Incorporation extends the imagination capacities of the user.
- Incorporation of external entities (Farne et al. 2005).

action-imagination space expands on incorporating the tool



Tool use extends the body schema and the peripersonal space. (Figure based on Maravita & Iriki, 2004.)

Common Coding



- Perception and imagination of movements activates the motor system
- Execution of movements improves perception and imagination of movements
- First articulated by Prinz (1992), later supported by discovery of mirror neurons (Di Pellegrino et al., 1992)
- Body based resonance -> replicates movements it detects generating internal representation

perception, execution and imagination of movements share common representation in the brain

Forward Model

- Actions controlled and predicted by internal forward models (iFM)
- All actions involve a minimal imagination element, which seeks to predict the consequences of the action (Wolpert & Kawato, 1998)
- FM to play role in estimation of dynamic properties of manipulated objects (Davidson & Wolpert, 2005)
- FM to predict movements of inanimate objects and serial events (*Schubotz, 2007)*

Process Account of MS Constructs

Iterative Prototyping

Creating multiple drafts of the product and revising them iteratively

(Vossoughi, Escudé, Kong, & Hooper, 2013; Tseng, 2016)

Playful Experimentation

Exploring different aspects of the prototypes without predefined goals or procedure

(Regalla, 2016)

Feedback

Repair-friendly feedback; further experimentation and intellectual risk-taking

(DiGiacomo et al., 2016)

Collaboration through air

Ideas, tools, techniques "picked up" unpredictably, without "explicitly coordinated goals"

(Halverson et al., 2018; Litts, 2016; Kafai & Harel, 1991)

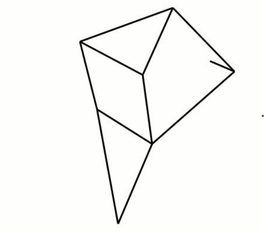
Iterative Prototyping

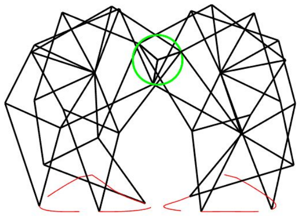
Tool use → Action Space

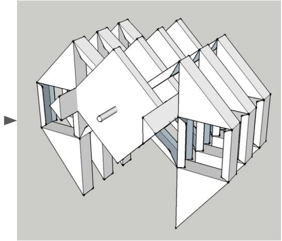
Imagination Space

Thinking with tools

Incorporation and Forward Model







Building Prototypes (P) → Mutates the action space

Imagination Space also mutates

Thinking with prototypes

Chain of embodied learning and imagination

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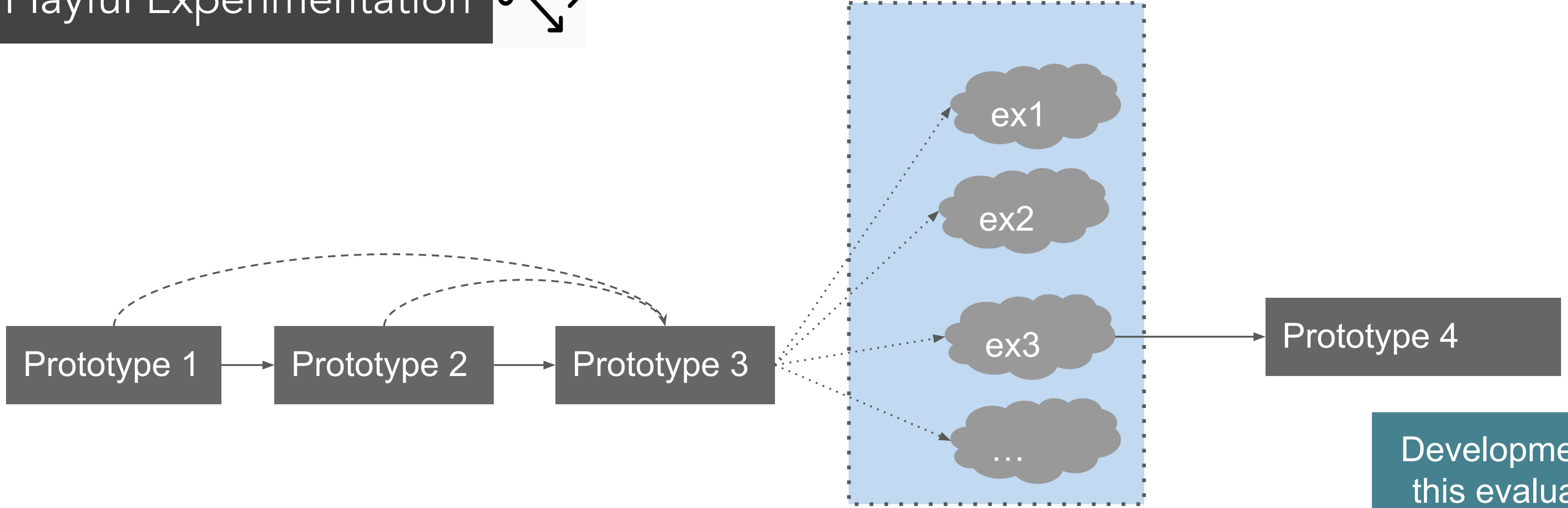
Single Leg Mechanism MichaelFrey, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons
6 Leg mechanism MichaelFrey, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons
Paper Prototype
https://www.instructables.com/Papercraft-Theo-Jansen-Walking-Machine-Making-Pape/

Playful Experimentation



Seeded by incorporation of previous prototypes (P1 - P2 - …)

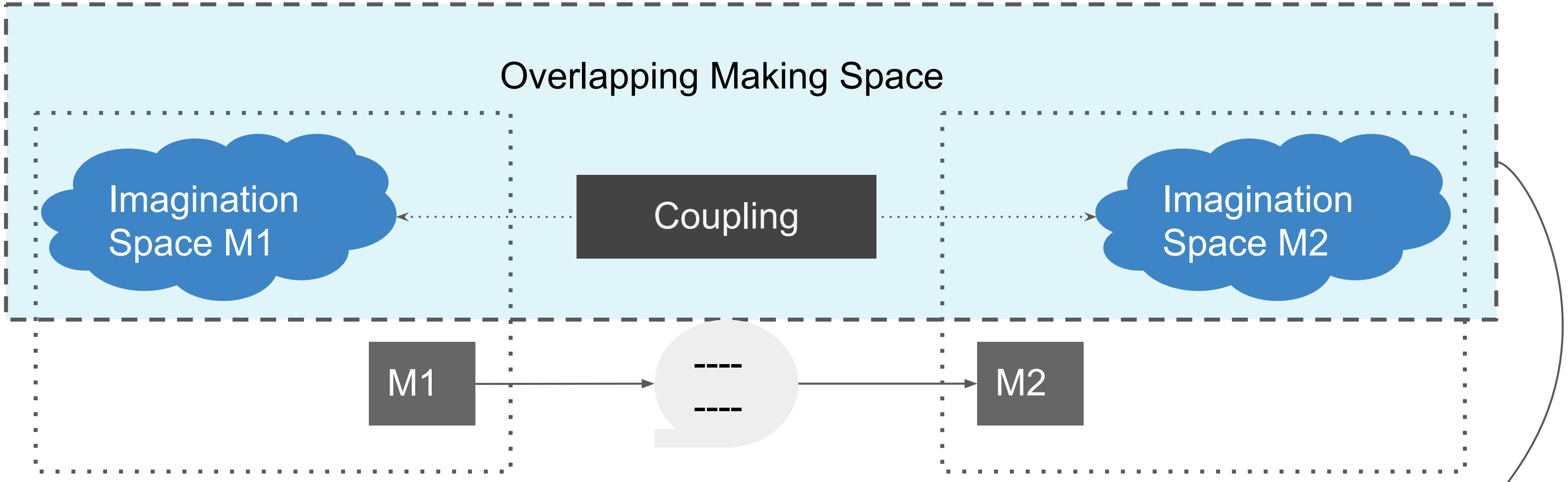
Branching into several possible prototype ideas

Emergence of evaluative neural network

Selection of productive ones by the maker

Development of this evaluative module is a key embodied learning effect of MS, which is not possible without prototypes and playful experimentation

Feedback on Prototypes



Such 'recombinant enactions' generate new making spaces, and thus embodied learning (Rahaman et. al., 2017)

Collaboration-through-air

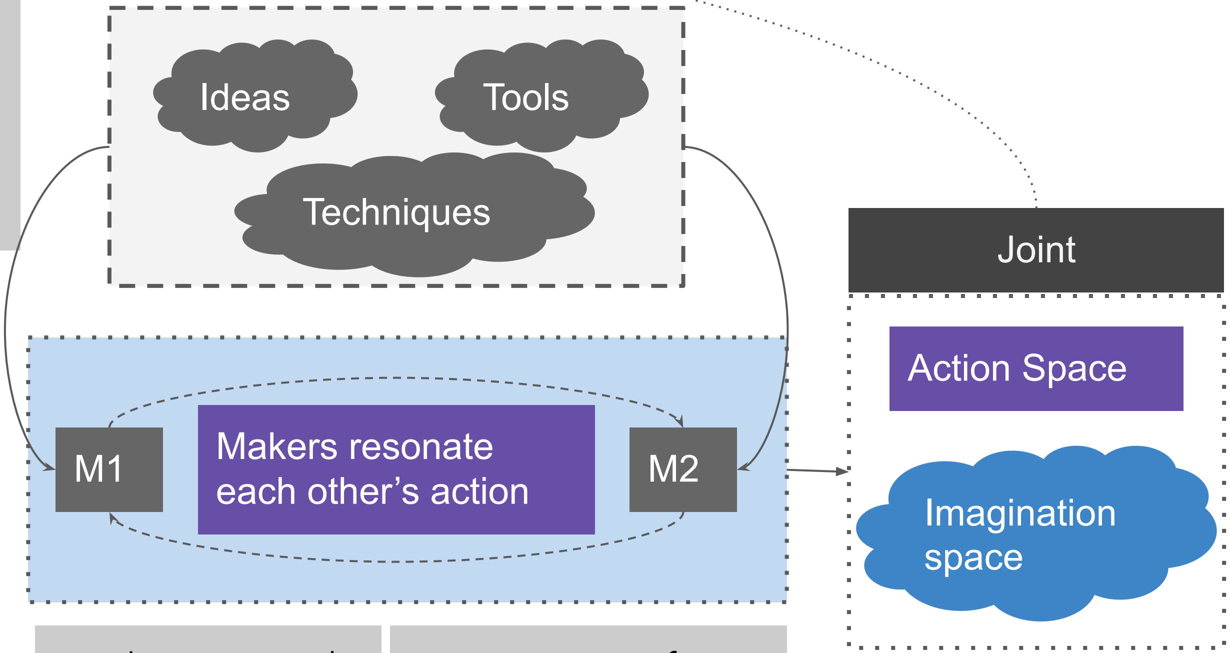
Ideas, tools , techniques "picked up" unpredictably, without "explicitly coordinated goals"

(Halverson et al., 2018; Litts, 2016; Kafai & Harel, 1991)

Resonance Effect

Common Coding

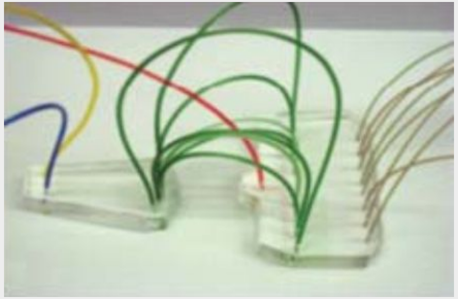
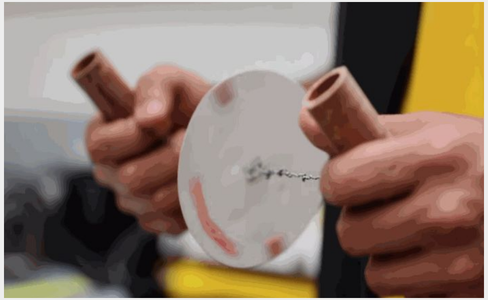
Forward Model



Leads to minimal ability to replicate others' use of tools and prototype

Incorporation of prototype, resonance generates new and extends action-imagination spaces

Making at the Frontiers

Techno-scientifically driven	Socio-technically driven	Eco-socio-technically driven
Microfluidic lab-on-a-chip	Paper-fuge	Danish Wind Technology
		
(Aurigemma et al., 2013)	(Bhamla et al., 2017)	(Date et al., 2019)

Such frontier practices are not supported by MS

How can MS change to support such practices?

Developing EC models of frontier practices and MS practices could give direction to redesign MS to support frontier practices.

- formal (equation, simulation) models
- socio-political contexts
- collaboration across multiple stakeholders

Embodied cognition analyses could help navigate these design question

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Thank You

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