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Rich or lean? A phenomenological alternative for explaining early social cognition

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Abstract In philosophy and cognitive science, the tension between cognitivism and the 4E-Cognition approach is both deep and polarizing. A lack of serious engagement with the theoretical and empirical work generated by the opposing framework seems problematic on both sides. In this paper, we closely discuss data on early socio-cognitive development produced by an influential nativist current of thought in the cognitivist paradigm. We consider these data from the point of view of a 4E-Cognition perspective called "the pairing hypothesis", which originates in phenomenological philosophy. We show that a close examination of these cognitivist-nativist data strengthens the phenomenological 4E-Cognition perspective by significantly expanding the range of findings it can account for. By addressing the debate between rich and lean explanations in early social cognition, we corroborate the idea that careful interaction between cognitivism and the 4E-Cognition approach can lead to progress in cognitive science.
KEYWORDS: Development of Social Cognition; Cognitivist Nativism; Direct Social Perception; Phenomenology and the Cognitive Sciences; Action Production and Perception

Riassunto *Spiegazioni ricche o parsimoniose? Un'alternativa fenomenologica per lo sviluppo della prima cognizione sociale* - Un'accesa e radicale tensione nelle scienze cognitive è quella tra il cognitivismo e il cosiddetto approccio delle quattro E (*Embodied, Enactive, Embedded* e *Extended*). La mancanza di una riflessione aperta e sostanziale sul lavoro teorico ed empirico proposto dall'approccio opposto appare problematica da entrambe le parti. Il presente contributo analizza a fondo le evidenze empiriche presentate da una delle maggiori correnti innatiste del paradigma cognitivista nello studio dello sviluppo socio-cognitivo. Queste evidenze sperimentali vengono esaminate dal punto di vista della "ipotesi dell'appaiamento", ipotesi inserita nel quadro della prospettiva teorica 4E e che proviene dalla filosofia fenomenologica. Il presente contributo mostra come una considerazione approfondita dei dati generati dal cognitivismo innatista può rafforzare il potere esplicativo della prospettiva fenomenologica 4E, ampliandone in misura significativa la gamma di evidenze scientifiche che essa può contribuire a spiegare. Affrontando il dibattito sullo sviluppo della prima cognizione sociale tra spiegazioni ricche e parsimoniose, viene corroborata l'idea che un'attenta interazione tra cognitivismo e approccio 4E può essere un modo per far progredire le scienze cognitive.
PAROLE CHIAVE: Sviluppo della cognizione sociale; Innatismo cognitivo; Percezione sociale diretta; Fenomenologia e scienze cognitive; Produzione e percezione di azioni

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1 Introduction

THERE IS A DEEP AND polarizing tension in cognitive science between cognitivism, or computationalism, and the so-called 4E-Cognition approach.[1] While cognitivism is guided by the idea of the mind as a computer syntactically operating on mental representations, the 4-Cognition approach, rejecting the computer metaphor of the mind, insists on (constitutive) roles for the body and the environment, and grants greater consideration to insights from phenomenological philosophy.[2] At times, there seem to be reasons to be dissatisfied with attitudes in both camps. On the one hand, cognitivists may not realize that their assumptions are not the only viable ones and dismiss what does not fit within their familiar schemas as insufficiently rigorous. On the other hand, the supporters of 4E-Cognition may prematurely talk about paradigm shift and disdain results produced within the cognitivist framework as irremediably misguided. This lack of serious engagement with theoretical and empirical work generated within the opposite framework seems problematic.

We agree that pluralism is valuable and indispensable in cognitive science.[3] The idea that the scientificity of a discipline depends primarily on the degree of theoretical agreement between its practitioners is questionable, since procedures realized on the basis of different fundamental assumptions can be equally rigorous, intersubjectively valid, and empirically fruitful. However, pluralism does not entail independence and lack of connection between the different research frameworks. On the contrary, careful engagement with a competing framework is always to be recommended, especially when it comes to research results, since empirical data, in general, cannot be ignored.

In this paper, we draw connections between two different and at least partially alternative frameworks in relation to data on early socio-cognitive development. We engage with data produced within a nativist current of the cognitivist paradigm, that can be called "cognitivist nativism".[4] We examine these data from the point of view of a 4E Cognition perspective called "the pairing hypothesis",[5] which originates in the phenomenological philosophy of Edmund Husserl. Our goal is to show that a close examination of data produced by the cognitivist-nativist framework strengthens the phenomenological 4E Cognition perspective by significantly expanding the range of findings it can account for. At the same time, we wish to suggest that also cognitivism-inclined developmental scientists may take advantage of our interpretation of the findings and consider our recommendations for further experimental testing. We have tried to make theoretical and experimental proposals that can also be fruitfully considered from a cognitivist standpoint.

There are five main sections in this paper. After this first introductory section, the second section presents an unsettled debate in which cognitivist nativism plays a major role, i.e., the debate between rich and lean explanations in early social cognition. We identify two main trends in this debate and ask whether the pairing hypothesis can be considered a hybrid of these main trends. In the third section, we put forward a formulation of the pairing hypothesis that combines previous formulations in an original manner. Apart from a single exception – duly noted in footnote 24 – we do not repeat the empirical arguments and the outlines for empirical predictions made in previous work. Rather, we refer to empirical evidence not previously considered and focus on how the pairing hypothesis has to be formulated to account for findings produced within the cognitivist-nativist framework.

In the fourth section, we consider some methodological issues. Finally, in the fifth ans sixth sections, we engage in a close examination of two representative cognitivist-nativist studies. To the extent possible within the constraints of a single paper, this examination allows us to substantiate the plausibility of our claim that the pairing hypothesis can account for cognitivist-nativist findings.

Before we start, we must make a preliminary remark that delimits the scope of our discussion. In this paper, we focus on infants' early understanding of others' animate agency. Notwithstanding this restriction, we indicate the background of our discussion by referencing how the 4E Cognition framework can deal with related topics.[6]

2 The dispute on rich and lean explanations and why pairing is not a hybrid

The debate between lean and rich explanations of findings on early social cognition is vast and complex.[7] It is not our goal to provide an exhaustive picture of this debate. Rather, we limit ourselves to sketching out two main trends.

Generally speaking, cognitivist nativism represents the main trend in the camp of rich explanations. Cognitivist nativism is "rich" because it posits an innate, domain-specific module that makes inferences about others' mental states on the basis of innate knowledge of the abstract principles of rational agency.[8] This approach is criticized for its lack of parsimony: according to critics, cognitivist nativism postulates overly sophisticated infant capacities to infer others' mental states and a cumbersome wealth of innate abstract knowledge, in addition to hard-to-verify hypotheses about our evolutionary past.

Apart from its tendency to emphasize the function of long-standing interactions with the environment, the camp of lean explanations appears to be more differentiated. The most prominent lean approaches explain the results discussed by cognitivist nativism by resorting to options including:

domain-general associative processes, motor and perceptual experiences, basic motivations and needs, and even sophisticated reasoning abilities about "behavior", where "behavior" is taken to be bereft of mental content and infants are assumed *not* to process "what is in the head" of the target of their reasoning.[9] What unites these lean approaches is the postulate that infants are incapable of experiencing others as minded beings. Therefore, we categorize these approaches as explanatorily "mind-blind". This categorization points to the criticism often raised by opponents, who point to the seemingly overwhelming role of intersubjectivity in development. For example, Heyes' associationism[10] is criticized for its "solipsistic" nature[11] and mind-blind approaches in general are criticized with respect to the role of intersubjectivity in language acquisition.[12]

Nevertheless, these main trends of rich and lean explanations share a fundamental assumption. They both assume that infants' early cognitive access to other minds could *only* be explained through innate, domain-specific processes. In other words, both the rich cognitivist-nativist approach and the most prominent lean approaches accept the dichotomy between early access to other minds and domain-specific processes on the one hand, and domain-general processes and cognitive indifference to other minds (mind-blindness) on the other hand. There are, of course, innumerable and potentially infinite hybrids of the main trends sketched above. A hybrid, however, merely reproduces this dichotomy at the level of specific phenomena. By definition, a hybrid of these trends is a model that identifies what socio-cognitive phenomena should be explained by innate inferences to mental states and what phenomena should instead be explained by domain-general mind-blind processes: a hybrid merely *distributes* the dichotomy. What a hybrid does *not* do is to explain early infant awareness of other minds through domain-general processes.

Even if many developmental theorists may not recognize themselves in the main trends of the debate briefly sketched here,[13] it is fair to say that it is rare to find a sufficiently articulated, radical, i.e., *non-hybrid*, alternative. Nonetheless, this is precisely what the next section attempts to do: recasting the pairing hypothesis as a radical model that accounts for infants' early awareness of other minds *by exclusively relying on domain-general processes*. To be clear, the fact that the pairing hypothesis originates from and unifies numerous strands of developmental theory[14] has nothing to do with its logical location in the rich-or-lean debate. In the formulation that we are about to propose, the pairing hypothesis cannot be considered a hybrid because it rejects having to choose between domain-general explanation and early awareness of other minds – not just at the level of the general socio-cognitive picture, but also at level of each specific phenomenon.

3 The pairing hypothesis

The pairing hypothesis is a subspecies of the Direct Social Perception (DSP) hypothesis.[15] According to the DSP general hypothesis, the most fundamental access humans have to other minds is perceptual and direct: it does not require simulation or theoretical inference. Although it originates in phenomenological philosophy, the DSP hypothesis enjoys notable success in developmental science.[16]

In this section, we provide a formulation of the pairing hypothesis that combines complementary formulations that have remained disjunct until now.[17] To begin, pairing is a DSP hypothesis positing that the perception of others' embodied experiences is underpinned by the domain-general process of association by similarity. It suggests that, just as in ordinary object perception, DSP involves an *assimilation to* and *accommodation of* previous experience, but assumes that, in the case of DSP, the past experience employed in this process of assimilation-accommodation is one's own embodied experience.[18] This includes all kinds of sensorimotor experience, where proprioception plays a major role, but also essential contributions from interoception, affectivity, tactility, audition, vision, etc. The first central assumption of the pairing hypothesis is that, through their own spontaneous behavior in response to various kinds of solicitations, developing human beings acquire schemas, i.e., sensorimotor associations, of various degrees of generality that relate to their own animate behavior, goal-directed actions, emotions, and perceptions.

The behavior of others is always in many respects *different*. However, the second central assumption of the pairing hypothesis is that early DSP is made possible because many features of others' behavior are *similar* to those experienced by infants in their own behavior. This similarity, or overlap, activates the acquired sensorimotor schemas, which allow infants to recognize others' behaviors *as expressing animacy, goal-directed action, emotions, and perception*, although, obviously, all these embodied experiences present themselves in others as in many respects different from the infants' own experiences (assimilation-accommodation).

The pairing hypothesis is radically interactionist: it supposes that infant-caregiver interaction provides sufficient self-other similarities to enable DSP.[19] For example, in interaction, infants experience their own behavior as a response to the emotional reactions that the other's behavior has provoked in themselves; they also experience the other's behavior as a response to their own active calls and solicitations.[20] The response character of behavior is just one of the many (often neglected)

features that infants experience in self and others, and that enable DSP.[21]

Of course, the broader DSP framework also includes the hypothesis of domain-specific processes selected in our evolutionary past to underpin DSP. Dellantonio and colleagues, Vincini, and Vincini and Gallagher[22] acknowledge the legitimacy of this hypothesis, but provisionally put it aside for a methodological reason: in order to avoid premature nativist assumptions, one should pursue the more parsimonious pairing hypothesis until it works well; only when one finds concrete phenomena that cannot be plausibly explained by the pairing hypothesis are heavier assumptions concerning domain-specificity and our evolutionary past sufficiently motivated. This is the approach taken in the present paper too.

Vincini[23] has gathered a considerable amount of empirical evidence supporting the pairing hypothesis in the domains of animacy, action, emotion, and gaze perception. Vincini primarily pursued a "piecemeal" approach showing that the gradual expansion of the infants' own embodied experience enables the gradual development of their DSP. This dynamic has been impressively well-documented in the domain of action perception, where researchers have identified a whole series of actions – power grasp, precision grasp, containment actions (placing), tool use behaviors, pointing, etc. – that infants learn to perform themselves before they recognize them when performed by others.[24] However, Vincini[25] provisionally accepted a mind-blind explanatory approach toward a significant portion of the findings produced by cognitivist nativism. This was the portion of findings purporting to show how six-month-olds and younger infants access the goal-directedness of boxes and other geometrical figures that bear no significant visual resemblance to humans.[26] Taking Vincini's[27] formulation as final would be problematic because it would amount to accepting that a considerable portion of the data can be explained only by resorting to an auxiliary approach.

This is the reason why Vincini's formulation must be integrated with the one of Dellantonio and colleagues,[28] which comprises the claim that the pairing hypothesis can parsimoniously account for all the findings produced by cognitivist nativism. Dellantonio and colleagues postulated that the sensorimotor acquisition of very abstract schemas would allow infants to perceive a large variety of stimuli, including boxes and geometrical figures, as animate agents. This point can be taken to be substantiated with respect to self-propulsion, since even a quick look at the literature on prenatal and postnatal development indicates that infants experience their bodies as autonomously moving in space, without being necessarily contacted by other approaching bodies.[29] As Dellantonio and colleagues put it: «The child moves autonomously and therefore recognizes autonomous (self-propelled) movement as a peculiar characteristic of a creature that is similar to himself».[30]

Dellantonio and colleagues' emphasis on abstract characteristics applying to a great variety of stimuli is supported by both classical-phenomenological considerations and recent developmental studies. Classical phenomenologist Max Scheler[31] drew a certain analogy between infant and aboriginal *animism*, suggesting that socio-cognitive learning should be understood as a process of "de-animation", where – through social interactions – infants come to differentiate the beings that are really animate or "minded" from those that are not. Analogously, Quadrelli and Turati[32] have advocated a "perceptual narrowing" approach to action perception, where early sensorimotor activity provides experience of abstract behavioral features which the infant can relate to a large variety of stimuli; subsequently, infants tend to narrow down social perception to items that consistently and habitually prove to be minded agents. This idea is also confirmed by recent findings suggesting that infants are capable of employing their motor experience in visual processing very early in development.[33]

Unfortunately, there is a problem with Dellantonio and colleagues' formulation as well.[34] In addition to self-propulsion, it only refers to biomechanical motion and makes an unspecific reference to features of intentional movement. However, numerous experiments have allowed cognitivist nativism to identify *specific* indicators that make it possible for infants to discriminate goal-directed movement from non-goal-directed movement.[35] Dellantonio and colleagues do not discuss how the pairing hypothesis could explain why infants take those specific features and not others to be expressive of goal-directedness. Therefore, the claim that the pairing hypothesis can account for the findings of cognitivist nativism still needs further substantiation.

Before we approach this task, we should make a few points with respect to our combination of Dellantonio and colleagues' and Vincini's formulations.[36] The process of de-animation, or narrowing, is not alternative, but *complementary* to the piecemeal expansion of infants' embodied experience and DSP. Since DSP not only provides a general access to others as animate agents, but also to the specific meanings of their behaviors – e.g., a specific action-goal, a specific emotion, a specific (modality-qualified) perception – what infants must learn is not just a general schema for animacy or goal-directedness, but rather the specific meanings of specific behaviors. With respect to the perception of specific embodied experiences, the developmental trajectory displays a gradual expansion, as documented by the empirical literature reviewed by Vincini.[37] Hence, combining the work of Dellantonio and colleagues and Vincini[38] allows us to suggest that the pairing hypothesis may be able to ex-

plain both (i) how infants perceive a wide range of stimuli as animate agents and (ii) how infants come to perceive the specific meanings of others' embodied experiences.

Furthermore, because the pairing hypothesis supposes that infants operate with generalizable schemas, it also explains why infants' understanding of intentionality can develop in a variety of ways. For example, as Luo[39] observes, three-month-olds may already be generalizing their experience of familiar humans as animate agents to self-propelling boxes, and, as Reddy[40] argues, the experience of being the object of the caregiver's attention is a central factor in infants' developing an understanding of intentionality. However, the present paper focuses on what can be considered to be a first step in the order of scientific explanation: the discussion of sections 5 and 6 is framed in a manner that is most relevant to questions such as how an entity (be it a human, a box, or a geometrical figure) can be experienced as an animate agent *at all*, or how an infant may experience the caregiver's attention as directed to the self *in the first place*.

Finally, we note that Dellantonio and colleagues and Vincini and Gallagher have already outlined distinctive empirical predictions of the pairing hypothesis.[41] This allows us to devote sections 5-6 to the task of substantiating the pairing explanation of cognitivist-nativist findings.

4 Methodological remarks

In sections 5-6 we closely examine single studies. The main reason for this methodological choice is that examinations of a general character do not seem to promote enduring progress. At a general level, opposing explanations all seem to be equally possible and it is not clear whether one is really more plausible than the other. In contrast, when a rich and detailed picture of an experiment is provided, one gets a much better sense of what these different hypotheses concretely entail.

Our methodological choice has a consequence for our discussion of "agency indicators," i.e., the specific features of a stimulus that cognitivist nativism has identified as signaling to infants the presence of goal-directedness. We decided to introduce these indicators in the order in which they present themselves in the cognitivist-nativist studies selected for our consideration. In this manner, across sections 5-6, we will discuss five primary indicators of agency according to cognitivist nativism. If we add self-propulsion – already discussed by Dellantonio and colleagues – our examination will reveal a total of six primary agency indicators that can be readily explained by the pairing hypothesis. Although the claim that pairing can account for cognitivist-nativist findings can be substantiated only partially in a single paper, we hope that our discussion will succeed in showing that – at least *prima facie* – there is no reason why the pairing explanation should not be extended to analogous results hinging on the same indicators. Indeed, Baillargeon and colleagues' influential and comprehensive review suggests that the other studies on how infants six-month-old and younger understand animated boxes and figures are analogous to those considered in this paper.[42]

A close examination of the findings entails taking seriously the question of whether they can be explained by a mind-blind approach. There are at least three reasons to take mind-blind explanations seriously:

1) The debate between rich and lean explanations is still unsettled and the mind-blind approach needs to be given its fair dues.
2) Identifying mind-blind explanations is the first step towards testing and empirically excluding them. Thus, it encourages empirical research and may end up strengthening mind-aware explanations – we use the term "mind-aware" for explanations, like cognitivist nativism and the pairing hypothesis, that rely on the idea of infant early awareness of other minds. We note that the mind-blind explanations identified in sections 5-6 have not been discussed in the literature until now and are an additional contribution of the present paper.
3) Some elements of a mind-blind explanation might actually be correct and should therefore be integrated within a final mind-aware explanation. Section 6 presents an example of this.

Both sections 5 and 6 proceed as follows. We start by presenting the experimental design of the study under consideration, its results, and the cognitivist-nativist explanation it advocates. Then we identify a mind-blind alternative and a way to test this alternative. Finally, in each case, we argue for a pairing explanation of the findings.

5 Straightness of path and behavioral variability

In Csibra's study, four groups of 6.5-month-olds were habituated to different conditions consisting in videos of a box that moved from one side of a 3D room to another box in another location of the room (each infant watched the same video about 7 times).[43] In all conditions the box started its movement on the same side of the room and ended up next to the other box (*Figure 1*).

In the Single Route Condition, infants watched the first box reach the second box by making a detour to the right (from the viewer's perspective) to move around an obstacle. The obstacle was a third box. The Variable Route Condition presented the same obstacle in the same position, but the first box reached the second by going around the obstacle at

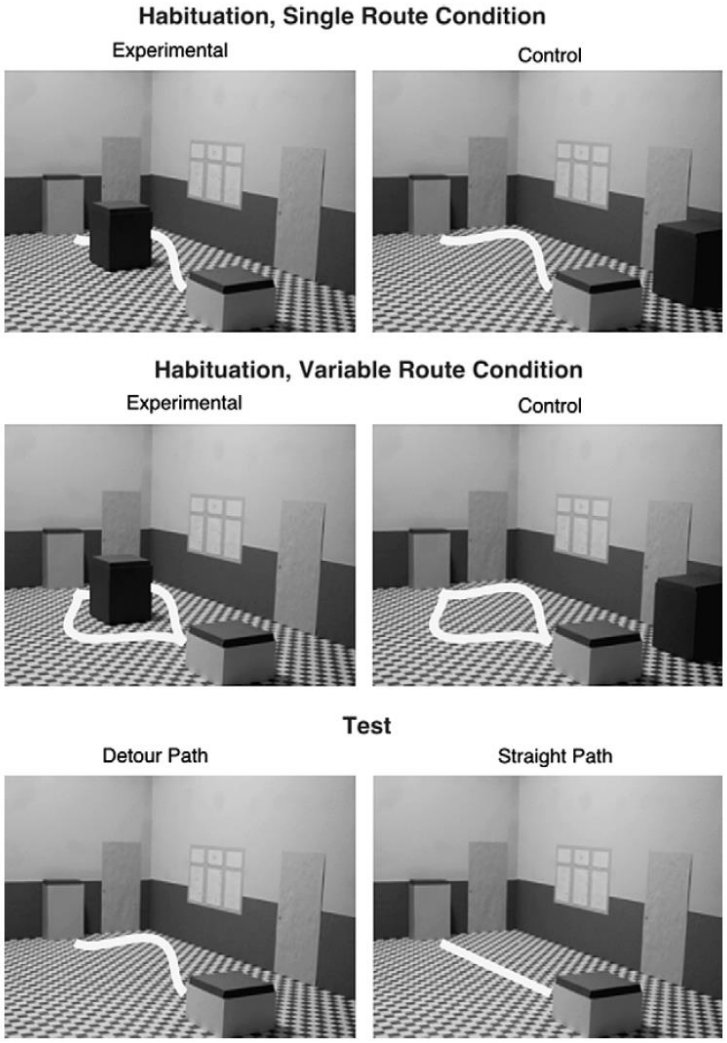

Figure 1. *Figure 1* in this paper is *Figure 2* in G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*, p. 710. We thank the original author and the publisher for permission to reproduce this figure. The figure represents the different habituation conditions and test events. Each picture shows the first frame of the video clip watched by infants. The white lines represent the path of the box from the wall in the background to the box in the foreground.

times toward the right, at times toward the left. These conditions had their respective controls, in which infants watched the box moving along the same paths without any obstacle in the middle (the obstacle appeared in a background position).

After habituation, all infants were presented with two test videos in which the obstacle had completely disappeared. In the Detour Path video, the first box reached the second box making a detour to the right as if it had to go around the obstacle. In the Straight Path video, the first box moved to the second box along a straight path. The result was that only infants from the Variable Route condition looked significantly longer at the Detour Path than the Straight Path. This result indicates that only these infants expected the first box to take the Straight Path and thus were "surprised" by seeing it take the Detour Path – a conflict with their expectation led to increased attention. According to a mind-aware explanation, only the infants from the Variable Route condition expected the box to take the Straight Path because only this group of infants considered the box to have the goal of reaching the second box.

Now, in Csibra's cognitivist-nativist version of the mind-aware approach, the reason why only the Variable Route condition group took the box to be goal-directed is that only this group was presented with two agency indicators in addition to self-propulsion. The first agency indicator was "straightness of the path". Only boxes that take the straightest path during habituation can be ascribed goal-directedness in light of the efficiency principle ("agents minimize costs"): infants have innate knowledge of abstract principle of rationality. The second agency indicator is the "most important":[44] only boxes that display behavioral variability – in this case, path variability – can be interpreted as goal-directed.

A problem with the cognitivist-nativist perspective is that, while it is clear how the first indicator can be derived from a rationality principle – the straightest path minimizes costs – this is not clear for the most important indicator. Sometimes, it can be more

convenient for an agent to vary its course of behavior to achieve the same goal; at other times, it is more convenient to maintain it. For example, it is often safer and less demanding for an agent to reuse the path she is accustomed to taking. Hence, the derivability of the variability indicator from rationality principles does not seem to be direct.

Let's now move to an alternative mind-blind interpretation according to which infants do not ascribe any goal to the box, but simply see *an inanimate box vary its position in space and end up next to another box*. Csibra's findings would merely attest to the infants' ability to track perceptual regularities and detect deviations. This is a basic adaptive ability, since actions must not only respond to the regular movements things make but also to variations in such movements. For example, the organism must adjust its grasp if an object takes an unexpected trajectory. Below, we examine what happens in each condition according to the mind-blind explanation.

In the control conditions, infants are presented with an empty space between two boxes; then one of the boxes moves toward the other by making detours with respect to an imaginary straight line, and, at least on a few occasions, these detours are to the right. Thus, when they are presented with the same scene in the Detour Path video, they don't see anything unexpected. The situation is different in the Variable Route Condition. Here infants are habituated to a box moving toward a second box, taking a detour around a box in the middle. The direction of the detour varies, so infants form no expectation about the specific direction it will take. However, infants do form an expectation about the box reaching the second box. This expectation is stronger in this condition than in any of the other conditions because (a) in contrast to the control conditions, the first box appears to reach the second box in the shortest possible way (considering that the presence of the third box in the middle requires a deviation), and (b) in contrast to the Single Route Condition, the final contact between the two boxes remains the same despite a variable path – the variation highlights what remains the same. Furthermore, during habituation, infants learn that deviations from the straight line occur around an interposed object. Therefore, while there is nothing surprising about seeing the box moving toward the other box along the straight direct path (this is how things normally move or fall) infants experience a conflict with their expectations when they see the Detour Path. In this test video, the detour presents itself as a deviation *away* from the second box, which contradicts infants' relatively strong expectation that the first box will move toward the second. Moreover, the detour occurs around an empty space, which contradicts what infants have just learned, i.e., that detours occur around an interposed object.

In the Single Route Condition, infants develop a strong expectation that the box will move to the right because this is what they see during the entire habituation procedure. Thus, although the Detour Path test presents the detour as being around an empty space for the first time, any surprise this may induce is quashed by the fact that their expectation about the direction of the box's movement is fully met: the detour to the right does not look new. Moreover, one can suppose that in the Single Route Condition infants do not really learn that detours occur around objects and may see the detour from the start simply as a movement to the right. In contrast, in the Variable Route condition, infants could appreciate that the detour was a movement around an object precisely because it kept presenting itself as a movement around an object despite changes in its direction. Hence infants in the Variable Route Condition were more surprised than the others when they saw a detour but no object.

Though surely less intuitive, this mind-blind explanation can account for the findings reported in Csibra.[45] This mind-blind explanation could be undermined by testing how infants in the Single Route Condition would react to a detour to the left of the empty space in the test phase. The mind-blind explanation would predict that the Single Route Condition would also give rise to a renewal of attention because infants in this condition would expect the box to move to the right. In other words, if the adaptive capacities identified by the mind-blind explanation are really at work, this variation would also be a perceptual novelty capable of renewing attention.

Finally, the pairing hypothesis generates a mind-aware interpretation that relies exclusively on the infants' own sensorimotor experience and domain-general perceptual processes. The literature on prenatal and early post-natal behavior shows that, before and after birth, humans learn to move along the straightest path to achieve their goals.[46] Before birth, for example, after a phase of relatively chaotic movements where the hand somehow ends up on the mouth or the eyes, fetuses learn to reach the mouth and the eyes along a straight path; they even learn to reach the eyes – the more delicate target – more slowly than the mouth.[47] In general, fetuses display a gradually increasing capacity to efficiently reach their targets in order to provoke pleasurable or desirable sensations.[48] After birth, infants have to learn how to move in a new environment where they experience the effects of gravity. Infants gradually learn how to reach and grasp their clothes or different objects in the environment. This process involves learning to reach and grasp along a straight path.[49] Hence, movements made by an external stimulus along the straightest path are most readily assimilable to the goal-directedness infants embody in their own behaviors.

In general, straightness of path as an indicator of agency is directly derivable from an approach based on domain-general assimilation-accommodation. Infants experience their own intentional actions as characterized by a «quality of expectation or "incompleteness"».[50] Husserl would describe it as a certain "emptiness", which is only completed or "fulfilled" when the goal is achieved. Thus, an unmotivated detour from the straightest path is an unnatural prolongation of such incompleteness and unfulfillment: perceived in an external stimulus, it would indicate a failure to express comprehensible behavior. This is even more true if – as in the Variable Route Condition – the self-propelled entity has been repeatedly perceived to reach its goal by the straightest path.

The literature on prenatal and early development also teaches us that infant behavior is characterized by continuous variability – a variability connected with infants' own need to explore their motor potentialities.[51] Consequently, the experience of animate agency that infants embody in themselves is inextricable from an experience of variability. According to the pairing hypothesis, it is on the basis of this experience that infants soon learn to perceive their caregivers as animate agents. Caregivers also display high behavioral variability and this contributes to making behavioral variability a typical feature of agency. It follows that the second, "most important" indicator of agency that grounds a mind-aware interpretation of Csibra's findings is also directly derivable from the pairing hypothesis.[52] The monotony of a movement such as that presented in the Single Route Condition – the same (reatively uninteresting) movement presented 7 times – is precisely the kind of stimulus that cannot be assimilated to infants' previous experience of agency.

Accordingly, the main point we wish to highlight from this section is that, while both straightness of path and behavioral variability are indicators of agency that can be directly derived from core assumptions of the pairing hypothesis, it is not immediately clear how behavioral variability could be derived from a rationality principle.

6 New goal, richness of context, and contingent interaction

Luo[53] familiarized three groups of 3-month-olds with different stimulus conditions. Each condition was preceded by the presentation of a self-propelling box moving back and forth across the scene (the so-called "orientation event"; cf. *Figure 2* and *Figure 3*).

The first familiarization condition presented two objects, each of which stayed on one side of the scene ("two-object condition"). The object on the right side (from the observer's viewpoint) was a white cone decorated with pastel dots; the object on the left was a yellow cylinder decorated with blue stripes. The box appeared in the middle of the scene between the two objects. Then, the box moved until it stopped next to the cone and and paused in this position. Infants watched this sequence of movement toward the cone and pause next to it five consecutive times.

The second ("one-object") condition was exactly like the first – infants observed the box moving toward and resting next to the cone on the right, five times – except that, in this condition, there was no cylinder on the left. Finally, the third condition also presented only one object, the cone, but in the first, second, and fifth iterations, the cone appeared on the right side of the scene, whereas, on the second and fourth iterations, it appeared on the left ("different-positions condition"). Accordingly, in this last condition, the box – always starting from the center – moved in different directions to come into contact with the cone and rest next to it.

After seeing the respective familiarization condition, each group was presented with the same novel display and then with two fixed test-events. The display consisted in a scene with the cone on the left and the cylinder on the right, but no box in the middle: the positions of cone and cylinder were inverted with respect to the two-object condition. One of the test-events consisted in the box moving from the center to rest next to the cone on the left. The other test-event showed the box moving from the center to the cylinder on the right (the order of test-events was counterbalanced across infants in each group). The result was that only the infants from the two-object and the different-positions conditions watched the box moving toward the cylinder significantly longer than the box moving toward the cone, whereas the infants from the one-object condition looked about equally at both test-events. This means that only infants from two-object and the different-positions conditions expected the box to move toward the cone and hence experienced "surprise", renewing their attention when it instead moved toward the cylinder. A mind-aware interpretation explains this result by positing that only infants from those conditions considered the box had the goal of reaching the cone and argues that they did so on the basis of agency indicators. According to Luo's cognitivist-nativist version of the mind-aware explanation, the agency indicators activated an «innate psychological-reasoning system».[54] The first agency indicator identified by Luo is, once again, self-propulsion, which was presented at the beginning of the experiment in the "orientation event". The second is a special kind of behavioral variability: changing behavior in order to achieve a new potential goal. This second indicator was presented in the shift from the orientation event to the familiarization condition, since the box changed its behavior from moving back and forth to moving

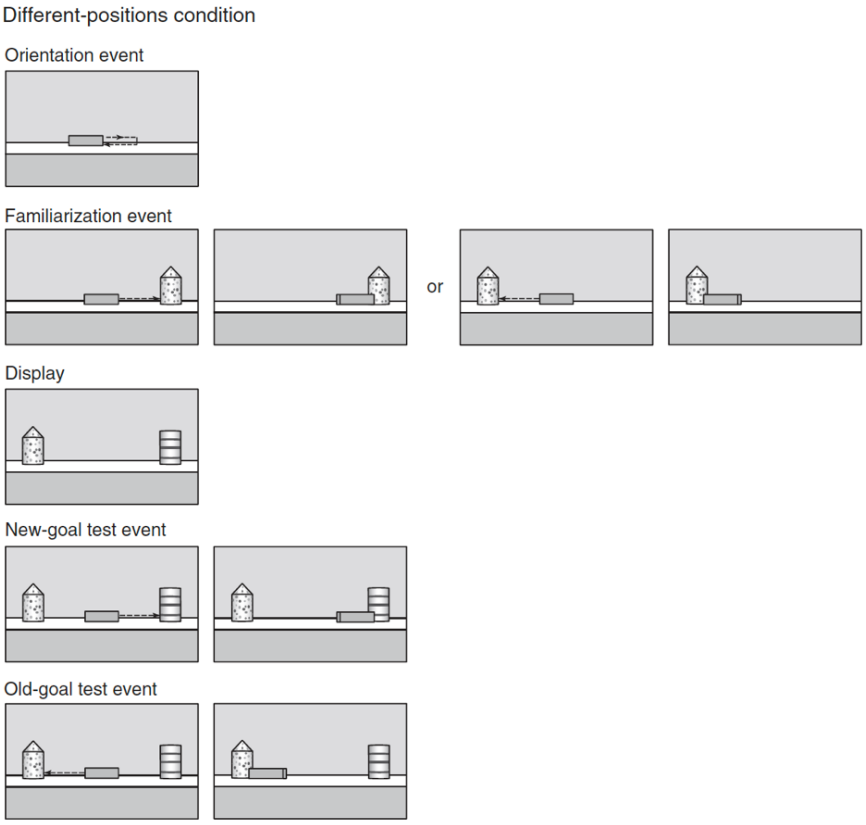

Figure 2. *Figure 2* and *Figure 3* in this paper are *Figure 1* and *Figure 3* in Y. Luo, *Three-month-old infants attribute goals to a non-human agent*, p. 455 and p. 458, respectively. We thank the original author and the publisher for permission to reproduce these figures. *Figure 2* consists in a schematic drawing of the experimental events in the two-object and the one-object conditions

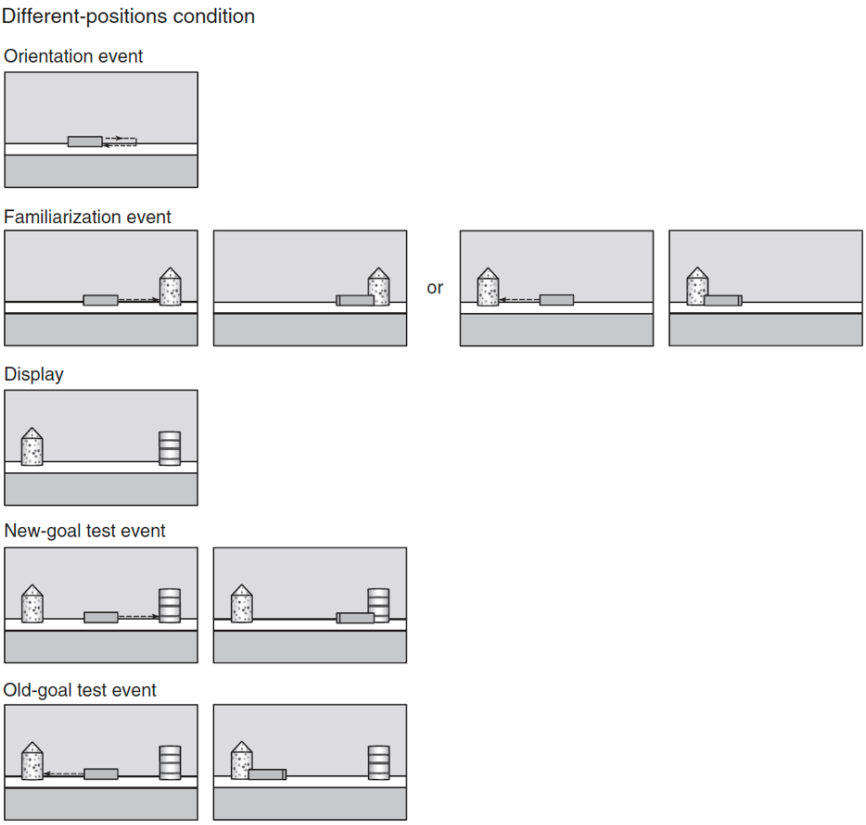

Figure 3. Schematic drawing of the experimental events in the different-positions condition

towards and then resting next to a cone. These two cues were present in the one-object condition as well, but, according to Luo, they were not sufficient to motivate any inference about the presence of a goal in this condition, not even an unspecific goal of a higher-level generality. [55]

The decisive indicator present in the two-object condition was the richer context: the box appears to move in the context of two objects.

According to Luo,[56] infants interpreted the two objects as options between which the box could make a "choice". This concept of "choice" has been specified in detail in the cognitivist-nativist literature: a choice is the expression of a "*preference* for A over B".[57] An entity has a preference for A over B if it deems A better than B, which necessarily entails that the entity must be aware of both A and B.[58] Finally, Luo[59] identified behavioral variability, i.e., variation of behavior to achieve the same goal on different occasions as the decisive indicator of agency in the different-positions condition (as in Csibra).[60] In the different-positions condition, the box sometimes moved to the right, sometimes to the left, in order to reach the cone.

Unfortunately, however, Luo[61] seems to dismiss "low-level interpretations" somewhat prematurely. As in the previous section, we shall now revisit the stimuli from the point of view of a viable mind-blind explanation. The mind-blind explanation relies on the assumption that the distinctive features of an object are highlighted when (i) it is presented alongside a different object (ii) it must be identified in different circumstances. In the two-object condition, having both objects in the scene allowed infants to differentiate between these two objects, and they got used to the fact that the box ended up being next to the white object with pastel dots and a conical top (the cone), while the slightly more voluminous, yellow object with blue stripes (the cylinder) remained distant and did not participate in any contact event. Seeing the box ending up next to the cylinder contradicted what they were used to and thus caused the observed renewal of attention.

In the one-object condition, infants habituated to the box moving toward a taller object on the right. Then a new two-object configuration appeared, likely weakening the memory of the least global features of the familiarization event (e.g., the details of the object) – this is the phenomenon known as "retroactive interference" emphasized by Heyes.[62] Accordingly, when infants saw the box moving again toward a taller object on the right, no expectations were violated, even though the object was not the same as before. Indeed, if anything, infants precisely expected that the box would contact the taller object on the right – as possibly suggested by a closer look at the test data for this condition – because that was all they could remember from familiarization (or all that they could perceive in the familiarization event).

In the different-positions condition, infants were familiarized with the box contacting a taller object in whichever position it appeared (on the right or left of the scene). Therefore, they were habituated to seeing the box moving in different directions and to seeing the object in different positions, which might have diminished retroactive interference in the test phase. Furthermore, a repetition of an event in different circumstances highlights the features of the event that remains constant.[63] While infants in the one-object condition may have identified the cone simply as "the taller object on the right," infants in the different-positions condition could identify the cone as *the same object despite its different positions* only by relying on its distinctive features (white, pastel dots, conical top).Thus, the infants in the different-positions condition, but not those in the one-object condition, formed the expectation "box moves toward white object with pastel dots and conical top," which was contradicted in the test phase. This mind-blind explanation also suggests that it might have been easier for the infants from the different-positions condition to identify the cone in the display and test phases, since they had already identified it in different positions during familiarization.

As in the previous section, we now suggest a test for this mind-blind explanation. In substance, the mind-blind explanation assumes that infants in the one-object condition had difficulty differentiating the cone and the cylinder. This, however, might simply be due to the fact that these objects were relatively similar to each other. If so, the problem could be fixed by using two more obviously different objects like the little pyramid and the voluminous pumpkin used in Choi et al.[64] The mind-blind explanation would predict that, using an obviously different pair of objects would lead to renewal of attention in the one-object condition too, because infants would, for example, recognize a big pumpkin from familiarization in the display and test phases, and thus expect the box to move toward it.

Lastly, let's consider the mind-aware explanation generated by the pairing hypothesis. In Sections 3 and 5, we have already argued that the pairing hypothesis coherently explains three of the agency indicators that play a role in Luo's paper: self-propulsion, straightness of path, and variability of behavior when preserving the identity of the goal.[65] We add here that the special kind of variability Luo identified as an agency indicator – change of behavior to achieve a new goal – can be readily accounted for by the pairing hypothesis. In fact, changing goals and corresponding behaviors is a very common feature of infants' experience of their own embodiment: e.g., a fetus may vary her behavior from touching her eyes to sucking her finger[66] and a two-month-old may vary hers from touching her clothes to stretching her legs.[67]

The question, then, seems to be how the pairing hypothesis can account for the last agency indicator in Luo, i.e., richness of context. In this regard, the emphasis on infants' own embodied experience leads to the consideration that, at three months, infants rarely engage in the process of rational choice described by the cognitivist-nativist approach.[68] Recall that this process requires considering at least two options and evaluating which is better.[69] At three months, babies rarely do this and even if we (somewhat artificially) put them in front of different options, they simply tend to select whatever option is attractive enough to first solicit the first response. Therefore, if the pairing hypothesis can account for the richness-of-context indicator in a way that (i) does not require considering two options and rationally choosing between them, and that (ii) relies exclusively on domain-general perceptual processes, it seems fair to conclude that the pairing hypothesis can also explain the richness-of-context indicator in a sufficiently direct and coherent manner.

To examine this issue, we should note that, in all accounts – including the mind-blind account, infants in the two-object condition differentiate the cone from the cylinder. Hence, for simplicity's sake, let's call them A and B, respectively. Moreover, watching a familiarization condition is an activity that unfolds over time, in which infants gradually make sense of the events they see, e.g., at any point in time perceiving them in light of what happened before. Now, the pairing hypothesis does suggest that infants in the two-object condition perceive that the box has goal A and not goal B. However, according to the pairing hypothesis, infants do not need to assume that the box *has chosen* A over B, nor, indeed, that the box is in any way considering option B. We can clarify this distinction between "having a specific goal" and "considering and choosing between options" by means of an example.

Imagine observing an academic in her office. She has just come up with a solution for how to address a problem in a paper that blocked her from writing for a while. You observe the academic absorbed by the process of writing for a few minutes. Surely, the office environment presents many possible action goals – drinking from a bottle of water, texting from the smart phone, reading a book located on the desk, looking out of the window, etc. – but you do not observe the academic choosing between these possible goals and the goal she is actually realizing. In fact, you see that she is not considering the other goals at all. You are simply in a position to see that, during that entire time you watch, she pursues a specific goal, i.e., writing something on her laptop, rather than doing anything else in her office. This presumably applies to infants as well. For example, the scene presented in Csibra (*Figure 1*)[70] shows a number of possible goals that the moving box could reach – a window, two doors, a third box, etc. – but it is unnatural to construe the scene in terms of the box choosing one goal over the others. Indeed, Csibra did not describe it in these terms and the other goals usually go unnoticed when considering his study. *The simple fact that an environment presents a plurality of possible action goals for an agent does not entail that the agent is considering them.*[71]

Consequently, the pairing explanations of Luo's first two conditions go as follows. In the two-object condition, infants see that there is a possible other goal for the box, that is, goal B, and this is why they appreciate that having goal A excludes goal B, but *they do not have to assume that the box is considering goal B*. In the one-object condition, the box is perceived to have the unspecific goal of reaching an object. Because the box reaches an object in the test events too, there is no renewal of attention in this case.

This explanation can be generalized to numerous experimental settings discussed by cognitivist-nativists. These settings often imply a rich context, which entails displaying the repeated pursuit of A over B.[72] According to the pairing hypothesis, this kind of richness-of-context represents the stimulus to which a general sensorimotor schema of animate agency (including self-propulsion, straightness of path, and the different kinds of behavioral variability) must be accommodated. Although it derives from previous experiences, the general schema of animate agency is unspecific with respect to the goal pursued by an agent in a particular case. The goal of the agent is specified by the perceptual scene on the basis of the elements present in the scene – think about how, in Csibra,[73] the goal is specified as "move to that particular box" as opposed to a generic "move to another object in the room". From the domain-generality of this process of assimilation-accommodation, it follows that the pairing hypothesis has a rather direct and coherent manner of explaining the richness-of-context indicator. The pairing explanation points out that *richness-of-context determines the specificity of the goal ascribed to the agent* and that this is sufficient to explain the findings.[74]

The cognitivist-nativist explanation suggests that «since infants in the one-object condition were not given information to predict the box's choice between the two objects when the cylinder was added during test, they should not differentiate between the two [test] events»[75] – but why should this not apply to the different-positions condition too? The same principle of rationality that keeps infants from predicting a specific choice after the one-object condition, should keep them from making a specific prediction after the different-positions condition, because *no information about a preference* is given in this case either.[76]

The pairing hypothesis does not have this problem. It explains the different-positions condition by

emphasizing the behavioral variability that infants experience in themselves and in the caregivers they soon become familiar with. Infants rarely achieve *the same goal* in precisely *the same manner*. For example, if they want to scratch a part of their head, the hand can initiate this movement from many different locations: the belly, a stretched open arm, a contact position with the other hand, etc. Therefore, the behavioral variability of the different-positions condition is readily assimilable to infants' general schema for goal-directed agency. Indeed, this variability is not just a strong indicator of intentionality,[77] but also an indicator of *strong intentionality*: since the box moves in different directions to reach the cone, the box displays a consistency, an insistence, a commitment, an "effort", that it does not display in the one-object condition.[78] Furthermore, in this condition, infants have to identify the object across different positions, which obliges them to rely on its distinctive features (white, pastel dots, conical top) and allows them to identify it in a more specific manner – as the mind-blind explanation for this experiment suggests. Therefore, infants form the expectation that the box will continue to reach this specific object and the contradiction of this expectation causes the renewal of attention in the test phase.

Finally, we should consider the last agency indicator mentioned by Luo[79] and extensively emphasized by Baillargeon and colleagues: the entity's contingent interaction with a human, which is more effective if it occurs «as when participating in a conversation or a playful interaction».[80] This indicator is clearly derivable in a more direct manner from the pairing account than from the idea of innate inferences based on rationality principles. Most likely, infants assimilate the vision of a contingently interacting and playful entity to the first-person interactions they have had with their own caregivers.[81] In this regard, the characteristic prediction of the pairing hypothesis – that social interaction promotes early action perception[82] – has already been verified.[83]

7 Conclusion

The goal of this paper was to show that a close examination of data produced by the cognitivist-nativist framework strengthens the pairing hypothesis by significantly expanding the range of findings it can account for. Vincini's previous formulation of the pairing hypothesis gathered a considerable amount of empirical evidence in the domains of animacy, action, emotion, and gaze perception. However, Vincini[84] provisionally took a mind-blind approach toward a significant portion of cognitivist-nativist findings on how six-month-olds and younger infants access the goal-directedness of boxes and other geometrical figures that bear no visual resemblance to humans.[85] Dellantonio and colleagues made the claim that the pairing hypothesis could account for cognitivist-nativist findings, but only substantiated this claim with respect to self-propulsion as an agency indicator. What was missing in both Vincini and Dellantonio and colleagues was a close engagement with cognitivist-nativist findings.[86]

Here, we examined six primary indicators of agency identified by cognitivist-nativists in two representative studies by Csibra and Luo.[87] In addition to (1) self-propulsion, we considered (2) straightness of path, (3) richness-of-context, (4) change of behavior to achieve a new goal, (5) variation of behavior preserving goal identity, and (6) contingent-playful interaction. We have argued that the pairing hypothesis can directly derive all of these, displaying even more explanatory coherence than cognitivist-nativism in the case of (5) and (6). These agency indicators explain findings – analogous to those of Csibra and Luo – concerning early access to the goal-directedness of boxes and geometrical figures.[88] Therefore, by arguing that the agency indicators can be coherently derived from the pairing hypothesis, we have shown that the pairing hypothesis can account for this significant portion of the findings. Of course, Dellantonio and colleagues' general claim that the pairing hypothesis can account for cognitivist-nativist findings can be substantiated only partially in a single paper.[89] Future work should examine a number of other studies in detail and pursue the lines of argument put forward in this paper at different levels of analysis.[90]

Overall, our discussion has strengthened the pairing hypothesis. We combined Vincini's discussion of gradual expansion with Dellantonio and colleagues' perspective,[91] which emphasizes perceptual narrowing/de-animation. In our formulation, the pairing hypothesis includes two complementary processes:

(a) sensorimotor experience provides infants with a general schema of animate agency with which they can perceive a great variety of stimuli as animate and then, through social interaction, come to understand what entities are or are not actually agents;
(b) through gradual development of their behavioral repertoire, infants expand the range of others' behaviors which they perceive as having specific meanings.

Apart from an exception in section 3 – duly noted in footnote 24 – across the entire paper we have referenced empirical studies that were not employed in previous work on the pairing hypothesis, thus adding to the evidence that supports it. Fortunately, we could rely on the fact that Dellantonio and colleagues and Gallagher and Vincini have already outlined distinctive empirical predic-

tions of the pairing hypothesis.[92]

The pairing hypothesis is more parsimonious than cognitivist-nativism because it explains early social understanding solely by means of domain-general processes that are accepted by practically everyone in the field, including cognitivist nativists.[93] However, the pairing hypothesis also differs radically from a central trend in lean explanations, which posits that infants are unable to access other minds. We identified two "mind-blind" explanations that have not been discussed in previous literature. The mind-blind explanation for Csibra's study relied on infants' ability to track patterns of movements, whereas the mind-blind explanation for Luo's study relied on lack of specification in object identification. As has often been pointed out,[94] these examples confirm that mind-blind explanations tend to vary for each particular study and thus are not widely applicable explanations. In contrast, our argument that the pairing hypothesis coherently explains six primary agency indicators shows that it may constitute a unitary hypothesis for the entire set of findings produced by the cognitivist-nativist framework.

Our critique of cognitivist-nativism is meant to be constructive. We hope that cognitivism-inclined developmental scientists will find it stimulating to consider a more parsimonious "mind-aware" alternative. In particular, we hope that the pairing hypothesis – as a constructive challenge – may give new impulse to empirical research. Our suggestions on how to test the mind-blind explanations for Csibra and Luo take a small step in this direction. In general, in this paper we promote interaction between cognitivism and the 4E Cognition approach and corroborate the idea that this interaction could lead to renewed progress in cognitive science.

Author contributions

Stefano Vincini is the lead author and wrote the Introduction and Section 2-Section 6 (pp. 109-119). Valentina Fantasia wrote the Conclusion (pp. 119-120). Both authors reviewed and accepted all sections of the paper.

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Notes

[1] Cf. M. MARRAFFA, A. PATERNOSTER, *Functions, levels, and mechanisms: Explanation in cognitive science and its problems*; A. NEWEN, L. DE BRUIN, S. GALLAGHER (eds.), *The Oxford handbook of 4E cognition*.

[2] As a reviewer correctly pointed out, the 4E-cognition approach is not a monolithic whole. Rather, it includes positions as diverse as those of J.J. GIBSON, *The ecological approach to visual perception*; F.J. VARELA, E. THOMPSON, E. ROSCH, *The embodied mind. Cognitive science and human experience*; R.A. BROOKS, *Intelligence without representation*; E. HUTCHINS, *Cognition in the wild*; E. THELEN, G. SCHÖNER, C. SCHEIER, L.B. SMITH, *The dynamics of embodiment: A field theory of infant preservative reaching*; A. NOË, *Action in perception*; A. CHEMERO, *Radical embodied cognitive science*; A. CLARK, *Supersizing the mind: Embodiment, action, and cognitve extension*; D. HUTTO, E. MYIN, *Radicalizing enactivism. Basic minds without content*; V. GALLESE, C. SINIGAGLIA, *Embodied resonance*; S. GALLAGHER, *Action and interaction*. Thus, it also comprises positions that are friendlier to the computer metaphor and the notion of mental representation.

[3] Cf. R. DALE, E. DIETRICH, A. CHEMERO, *Explanatory pluralism in cognitive science*; D. GENTNER, *Cognitive science is and should be pluralistic*.

[4] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*.

[5] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*; S. VINCINI, *The pairing account of infant social perception*; S. VINCINI, *Pairing and sharing: The birth of the sense of us;* S. VINCINI, S. GALLAGHER, *Developmental phenomenology: Examples from social cognition*.

[6] Cf. V. REDDY, *How infants know minds*; S. VINCINI, *Pairing and sharing: The birth of the sense of us*; S. GALLAGHER, *Action and interaction*; S. GALLAGHER, D. ZAHAVI, *The phenomenological mind*; V. FANTASIA, J. DELAFIELD-BUTT, *Time and prospectivity in development* (submitted).

[7] Cf. M. BEISERT, N. ZMYJ, M. DAUM, *Turning the tide: A plea for cognitively lean interpretations of infant behavior*; L. SURIAN, A. LESLIE, *"The Scylla of nativism..."*.

[8] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*; Y. CHOI, Y. MOU, Y. LUO, *How do three-month-old infants attribute preferences to a human agent?*; J.K. HAMLIN, *The case for social evaluation in preverbal infants: Gazing toward one's goal drives infants' preferences for helpers over hinderers in the hill paradigm*.

[9] Cf. C. HEYES, *False belief in infancy: A fresh look*; C. HEYES, *Cognitive gadgets: The cultural evolution of thinking*; D.C. PENN, D.J. POVINELLI, *On the lack of evidence that non-human animals possess anything remotely resembling a "theory of mind"*; J. PERNER, *Who took the cog out of cognitive science? Mentalism in an era of anti-cognitivism*; T. RUFFMAN, *To belief or not belief: Children's theory of mind*.

[10] Cf. C. HEYES, *Cognitive gadgets: The cultural evolution of thinking*.

[11] Cf. R. NICHOLS, H. MOLL, J.L. MACKEY, *Rethinking cultural evolutionary psychology*.

[12] Cf. M. MARRAFFA, *Mindreading and introspection*.

[13] E.g., situating Tomasello in this debate would require a separate discussion; cf. M. TOMASELLO, *Becoming human: A theory of ontogeny*.

[14] Here are a few of the many sources indicated in previous versions of the pairing hypothesis: S.A. GERSON, A.L. WOODWARD, *Building intentional action knowledge with one's hands*; V. REDDY, *How infants know minds*; V. REDDY, *Joining intentions in infancy*; C. TREVARTHEN, *From*

the intrinsic motive pulse of infant actions, to the life time of cultural meanings; D. STERN, *Forms of vitality*; A.N. MELTZOFF, *Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli*; S. OOSTERWIJK, L.F. BARRETT, *Embodiment in the construction of emotion experience and emotion understanding*; M.W. SULLIVAN, N.J. MINAR, *Developmental perspectives on "How emotions are made"*. It goes without saying that the pairing hypothesis owes the possibility of its contemporary revival to the Direct Matching Hypothesis (G. RIZZOLATTI, L. CRAIGHERO, *The mirror-neuron system*; cf. S. VINCINI, *The pairing account of infant social perception*).

[15] Cf. T. FROESE, D.A. LEAVENS, *The direct perception hypothesis: Perceiving the intention of another's action hinders its precise imitation*; S. GALLAGHER, D. ZAHAVI, *The phenomenological mind*.

[16] Cf. J.W. ASTINGTON, C. HUGHES, *Theory of mind: Self-reflection and social understanding*; P. HOBSON, *The cradle of thought*; V. REDDY, *How infants know minds*.

[17] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*; S. VINCINI, *The pairing account of infant social perception*; S. VINCINI, *Pairing and sharing: The birth of the sense of us*; S. VINCINI, S. GALLAGHER, *Developmental phenomenology: Examples from social cognition*.

[18] For the embodied-enactive interpretation of Piagetian ideas cf. E.A. DI PAOLO, *Process and individuation: The development of sensorimotor agency*; D. CORBETTA, R.F. WIENER, S.L. THURMAN, E. MCMAHON, *The embodied origins of infant reaching: Implications for the emergence of eye-hand coordination*.

[19] S. VINCINI, *The pairing account of infant social perception*, pp. 189-197.

[20] Cf. D. STERN, *Diary of a baby*, pp. 66-67; J. TAIPALE, *Empathy and the melodic unity of the other*.

[21] S. VINCINI, *Pairing and sharing: The birth of the sense of us*, p. 17-20.

[22] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*; S. VINCINI, *The pairing account of infant social perception*; S. VINCINI, S. GALLAGHER, *Developmental phenomenology: Examples from social cognition*.

[23] Cf. S. VINCINI, *The pairing account of infant social perception*; S. VINCINI, *Pairing and sharing: The birth of the sense of us*.

[24] This is the only empirical argument that this paper takes from previous work on the pairing hypothesis. Cf. M. BAKKER, M.M. DAUM, A. HANDL, G. GREDEBÄCK, *Neural correlates of action perception at the onset of functional grasping*; E.N. CANNON, A.L. WOODWARD, G. GREDEBÄCK, C. VON HOFSTEN, C. TUREK, *Action production influences 12-month-old infants' attention to others' actions*; J.A. SOMMERVILLE, E.A. HILDEBRAND, C.C. CRANE, *Experience matters: The impact of doing versus watching on infants' subsequent perception of tool use events*; A.L. WOODWARD, J.J. GUAJARDO, *Infants' understanding of the point gesture as an object-directed action*.

[25] Cf. S. VINCINI, *The pairing account of infant social perception*.

[26] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*.

[27] Cf. S. VINCINI, *The pairing account of infant social perception*.

[28] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*.

[29] Cf. D. CORBETTA, R.F. WIENER, S.L. THURMAN, E. MCMAHON, *The embodied origins of infant reaching: Implications for the emergence of eye-hand coordination*; J. FAGARD, R. ESSEILY, L. JACQUEY, K. O'REGAN, E. SOMOGYI, *Fetal origin of sensorimotor behavior*; M. HADDERS-ALGRA, *Early human motor development: From variation to the ability to vary and adapt*.

[30] S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*, p. 185.

[31] Cf. M. SCHELER, *The nature of sympathy*, pp. 239-240.

[32] Cf. E. QUADRELLI, C. TURATI, *Origins and development of mirroring mechanisms: A neuroconstructivist framework*.

[33] Cf. L. CRAIGHERO, V. GHIRARDI, M. LUNGHI, F. PANIN, F. SIMION, *Two-day-old newborns learn to discriminate accelerated-decelerated biological kinematics from constant velocity motion*; V.M. REID, K. KADUK, J. LUNN, *Links between action perception and action production in 10-week-old infants*; G.A. SAUCIUC, J. ZLAKOWSKA, T. PERSSON, S. LENNINGER, E. ALENKAER MADSEN, *Imitation recognition and its prosocial effects in 6-month-old infants*.

[34] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*, p. 177 and 185.

[35] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*; G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*; Y. LUO, *Three-month-old infants attribute goals to a non-human agent*.

[36] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*; S. VINCINI, *The pairing account of infant social perception*.

[37] Cf. S. VINCINI, *The pairing account of infant social perception*; S. VINCINI, *Pairing and sharing: The birth of the sense of us*.

[38] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*; S. VINCINI, *The pairing account of infant social perception*.

[39] Y. LUO, *Three-month-old infants attribute goals to a non-human agent*, p. 459.

[40] Cf. V. REDDY, *How infants know minds*.

[41] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*; S. VINCINI, S. GALLAGHER, *Developmental phenomenology: Examples from social cognition*.

[42] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*.

[43] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*.

[44] G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*, p. 705.

[45] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*.

[46] Cf. D. CORBETTA, R.F. WIENER, S.L. THURMAN, E. MCMAHON, *The embodied origins of infant reaching: Implications for the emergence of eye-hand coordination*; J. FAGARD, R. ESSEILY, L. JACQUEY, K. O'REGAN, E. SOMOGYI, *Fetal origin of sensorimotor behavior*; M. HADDERS-ALGRA, *Early human motor development: From variation to the ability to vary and adapt*.

[47] Cf. S. ZOIA, L. BLASON, G. D'OTTAVIO, M.

BULGHERONI, E. PEZZETTA, A. SCABAR, U. CASTIELLO, *Evidence of early development of action planning in the human fetus: A kinematic study*.

[48] Cf. J. FAGARD, R. ESSEILY, L. JACQUEY, K. O'REGAN, E. SOMOGYI, *Fetal origin of sensorimotor behavior*; U. CASTIELLO, C. BECCHIO, S. ZOIA, C. NELINI, L. SARTORI, L. BLASON, G. D'OTTAVIO, M. BULGHERONI, V. GALLESE, *Wired to be social: The ontogeny of human interaction*.

[49] Cf. D. CORBETTA, R.F. WIENER, S.L. THURMAN, E. MCMAHON, *The embodied origins of infant reaching: Implications for the emergence of eye-hand coordination*.

[50] V. REDDY, *Joining intentions in infancy*, p. 25. This quality is also present in early routines wherein goal-directed sequential actions integrate affective, cognitive, communicative, and kinetic aspects. The repeated experience of their own direct movements in concert with those of others makes infant capable of expecting the "goals" of early routines (cf. V. FANTASIA, G. MARKOVA, A. FASULO, A. COSTALL, V. REDDY, *Not just being lifted: Infants are sensitive to delay during a pick-up routine*).

[51] Cf. D. CORBETTA, R.F. WIENER, S.L. THURMAN, E. MCMAHON, *The embodied origins of infant reaching: Implications for the emergence of eye-hand coordination*; J. FAGARD, R. ESSEILY, L. JACQUEY, K. O'REGAN, E. SOMOGYI, *Fetal origin of sensorimotor behavior*; M. HADDERS-ALGRA, *Early human motor development*; L.B. SMITH, E. THELEN, *Development as a dynamic system*.

[52] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*.

[53] Cf. Y. LUO, *Three-month-old infants attribute goals to a non-human agent*.

[54] *Ibid*., p. 459.

[55] *Ibid*., p. 456.

[56] Cf. *ibid*., p. 455.

[57] Y. CHOI, Y. MOU, Y. LUO, *How do three-month-old infants attribute preferences to a human agent?*, p. 97.

[58] R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*, p. 171.

[59] Y. LUO, *Three-month-old infants attribute goals to a non-human agent*, pp. 457-458.

[60] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*.

[61] Y. LUO, *Three-month-old infants attribute goals to a non-human agent*, p. 458.

[62] Cf. C. HEYES, *False belief in infancy: A fresh look*.

[63] Cf. R.W. RIEBER, *Wilhelm Wundt and the making of a scientific psychology*, p. 221.

[64] Cf. Y. CHOI, Y. MOU, Y. LUO, *How do three-month-old infants attribute preferences to a human agent?*.

[65] Cf. Y. LUO, *Three-month-old infants attribute goals to a non-human agent*.

[66] Cf. J. FAGARD, R. ESSEILY, L. JACQUEY, K. O'REGAN, E. SOMOGYI, *Fetal origin of sensorimotor behavior*.

[67] Cf. D. CORBETTA, R.F. WIENER, S.L. THURMAN, E. MCMAHON, *The embodied origins of infant reaching*.

[68] Y. LUO, *Three-month-old infants attribute goals to a non-human agent*.

[69] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*, pp. 162-171; Y. CHOI, Y. MOU, Y. LUO, *How do three-month-old infants attribute preferences to a human agent?*, p. 97; Y. LUO, *Three-month-old infants attribute goals to a non-human agent*, p. 455.

[70] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*, figure1.

[71] It is not irrelevant to observe that a human organism that had to consider all the action possibilities provided by the environment in each situation would have a rather hard life. Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*.

[72] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*.

[73] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*.

[74] We should also note that it is a domain-general process of perception that the meanings of the elements of a perceptual scene depend on each other and the global configuration (T. FARRONI, E. VALENZA, F. SIMION, C. UMILTÀ, *Configural processing at birth: Evidence for perceptual organization*; S. VINCINI, *The pairing account of infant social perception*; S. VINCINI, *Pairing and sharing: The birth of the sense of us*; S. VINCINI, S. GALLAGHER, *Developmental phenomenology: Examples from social cognition*).

[75] Y. LUO, *Three-month-old infants attribute goals to a non-human agent*, p. 455.

[76] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*, p. 171.

[77] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*.

[78] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*, p. 167.

[79] Cf. Y. LUO, *Three-month-old infants attribute goals to a non-human agent*, p 459.

[80] R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*, p. 163.

[81] Cf. V. FANTASIA, G. MARKOVA, A. FASULO, A. COSTALL, V. REDDY, *Not just being lifted: Infants are sensitive to delay during a pick-up routine*; V. FANTASIA, A. FASULO, A. COSTALL, B. LÓPEZ, *Changing the game: exploring infants' participation in early play routines*.

[82] Cf. S. VINCINI, S. GALLAGHER, *Developmental phenomenology: Examples from social cognition*.

[83] Cf. M. LICATA, M. PAULUS, C. THOERMER, S. KRISTEN, A.L. WOODWARD, B. SODIAN, *Mother-infant interaction and infants' goal encoding*.

[84] Cf. S. VINCINI, *The pairing account of infant social perception*.

[85] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*.

[86] S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*; S. VINCINI, *The pairing account of infant social perception*.

[87] Cf. G. CSIBRA, *Goal attribution to inanimate agents by 6.5-month-old infants*; Y. LUO, *Three-month-old infants attribute goals to a non-human agent*.

[88] Cf. R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*.

[89] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*.

[90] In our recent research, we have conducted a close examination of a number of other studies cited by R. BAILLARGEON, R.M. SCOTT, L. BIAN, *Psychological reasoning in infancy*. We plan to include this currently unpublished work in future publications.

[91] Cf. S. VINCINI, *The pairing account of infant social perception*; S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the categories "animate" and "inanimate"*.

[92] Cf. S. DELLANTONIO, M. INNAMORATI, L. PASTORE, *Sensing aliveness: A hypothesis on the constitution of the*

categories "animate" and "inanimate"; S. VINCINI, S. GALLAGHER, *Developmental phenomenology: Examples from social cognition*.

[93] E.g., Luo admits without reservation that the experience that infants have of their own actions and of other human agents is a factor enabling their general understanding of goal-directed agency and that it might have played a role in her study too (Y. LUO, *Three-month-old infants attribute goals to a non-human agent*, p. 459).

[94] Cf., e.g., L. SURIAN, A. LESLIE, *"The Scylla of nativism..."*.

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