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Cognitive probatonics: Towards an ecological psychology of cognitive particulars

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Abstract

This article takes an ecological approach to the functioning of self-organised cognitive systems. The dynamics of such systems are traced to how they are animated by agents through interactivity, or sense-saturated agent-environment coordination. These dynamics give rise to cognitive events, the nature of which is revealed with detailed micro level qualitative analyses which, in turn, unveil unique cognitive trajectories in a problem landscape. The article presents and exemplifies a method for doing so, the Cognitive Event Analysis. This method is based on a "probatonic principle" that prompts cognitive scientists to pay close attention to fine-grained particulars in human behaviour. Based on the methodological approach and two case studies, the article discusses how affordances and language function in a cognitive ecology.

1. Introduction

In early 2014, 50 participants were given a problem-solving task in the Systemic Cognition Lab at Kingston University (Steffensen, Vallée-Tourangeau, & Vallée-Tourangeau, submitted; Vallée-Tourangeau, Steffensen, Vallée-Tourangeau, & Makri, 2015). The participants were given the so-called 17 Animals problem in one of two conditions (using pen and paper, or using a physical model), just as they underwent a series of psychometric measures. The experiment was designed to determine how differences in the physical layout of the problem presentation affects behavioural outcomes and success rates. The statistical results suggested that a physical model does in fact facilitate a successful outcome (Vallée-Tourangeau et al., 2015), which is not surprising if one takes recent work on cueing into account (e.g. Ball & Litchfield, 2013; Kirsh, 2009). By determining whether a participant had reached a solution or not within the time limit, it was shown that participants in the “physical model” condition perform far better than chance performance, while subjects in the “pen and paper” condition perform much worse. So far, so good. But here comes a surprising insight: the 50 participants were all video-recorded during their performance, and even a first glance at the videos revealed that the uniform group of “successful solvers” in fact covered a substantial variability in the way that they used the physical model. This surprising variability was undetected in the initial measurement and would thus never have reached the surface without the additional analysis of the video-recordings. Obviously, one’s measurement methods constrain what one can find, but one may wonder, how many experiments would have exhibited similar variability, had the measurement methods allowed for it.

Variability can be utterly trivial. For instance, whether a subject solves the Tower of Hanoi problem using his/her left or right hand (or whether the disks are red, blue, or green) hardly matters; such questions are hardly worth any scientific investigation. But how does one a priori distinguish between cognitively relevant and irrelevant variability? Given the usual methodological assumptions of cognitive science, the obvious way forward is to advance a set of experimentally testable hypotheses. However, while cognitive science has developed robust methods for testing hypotheses, the field is surprisingly silent when it comes to its methods for generating hypotheses.1 In the absence of explicit procedures for...
generating hypotheses, the field must rely on anecdotal hypotheses, or hypotheses derived from theoretical arguments.

In this paper, I argue, that what is missing is an inductive method for observing cognitive performance and behavioral particulars, both in real-life and in the lab. On the one hand, such a method complements the standard inventory of methods in cognitive science, as it generates hypotheses on a principled basis and with a starting point in empirical work. On the other, slightly more radical hand, such a method goes one step further by complementing the nomothetic enterprise with an idiographic framework. In both variants, the argument builds on a methodological principle called the Probatonic Principle; this principle is introduced in section 2. In section 3, the method, Cognitive Event Analysis, is introduced, and section 4 demonstrates the kind of insights yielded by such a fine-grained qualitative method to human behavior by showcasing two examples. In section 5 I use the two case studies to discuss how affordances are best conceptualised in an ecological framework. Finally, in the discussion in section 6, I discuss the role of language in human behavior and the perennial topic of the validity of idiographic approaches.

2. The probatonic principle

The approach presented in this paper builds on a methodological principle that I call the probatonic principle, borrowing a term from Luke 15.4–6:

Which one of you, having a hundred sheep and losing one of them, does not leave the ninety-nine in the wilderness and go after the one that is lost until he finds it? [ ... ] And when he comes home, he calls together his friends and neighbors, saying to them, ‘Rejoice with me, for I have found my sheep [ἐρωταύτον μου] that was lost.’ (Luke 15:4–6; New Revised Standard Version; my italics and insertion of the Greek original)

The probatonic principle is named after the single sheep (probaton in Greek) that has our full attention and which is not reducible to being just a member of the herd — or of the dataset, as it were. It acknowledges each participant as following his or her own “microecological orbit” (Goffman, 1964), and thus takes a starting point in a specific cognitive ecosystem (Valcke-Tourangeau et al., 2015). As a research principle it states that much can be gained from scrutinising single, particular instances in detail. The probatonic principle urges us to study instances, either in their own right or as part of a hypothesis-generating procedure. The principle’s importance lies in the fact that it forces us to attend to small, nonlinear (and at times one-off) phenomena that (also) impact on behavior.

The argument for this line of thought is as follows. If we accept the view that cognition is embodied, we must reject the assumption that there is an inner bodily core that does the cognition: the body is a systemic whole, and not a layered non-cognitive. This view parallels Thelen and Smith’s (1994:337) comment that “we, like the symbolic computational theorist, view cognition as all one kind; but in our view, it is all embodied, all distributed, all activity, all a complex event in time.” At the very least, we must acknowledge that if there is a cognitive core somewhere in a cognitive system, it is sensitive to input from all other parts of the system. Following this argument, there is no principled way of determining what is, or can become, part of the cognitive system. Cognition regulates the agent-environment relation, and all ingredients in the agent-environment system potentially partake in this regulation. Therefore, we have no a priori ways of determining what parts of the system we should attend to. In contrast, experimental methods rely on isolating and measuring variables. By necessity, a measurement requires that the parameter to be measured is determined a priori. Likewise, experimental methods require that the variables are predetermined.

Given the probatonic principle, how do we study cognitive particulars? The ecosystemic emphasis entails that, while the uniqueness of particulars may appear as differences in peripheral details, it is not reducible to such details. Thus, it makes little sense to study specific details in isolation, without considering how they contribute to a specific cognitive system. How this system is defined depends on the specific research question being asked. Obviously, any investigation depends on some sort of delineation, but the probatonic principle urges us to rely on inductive delineation where a given cognitive system is documented in as much detail as possible, so that the delineation can be an a posteriori procedure based on data, rather than an a priori procedure.

On a naturalised viewpoint, a cognitive system is ecological, and as such it has an irreducible and irreproducible historical trajectory. Studying cognitive particulars, thus, amounts to studying the unique trajectory of a dynamical cognitive system. Evoking Dynamical Systems Theory in this context is not incidental. Thus, the emphasis on cognitive trajectories parallels Esther Thelen’s mountain stream metaphor for describing cognitive development:

I suggest another metaphor for human behavior: a mountain stream. This is an apt comparison to keep in mind, because a stream is moving all the time in continuous flow and continuous change. Development is continuous—whatever has happened in the past influences what happens in the future. But the stream also has patterns. We can see whirlpools, eddies, and waterfalls, places where the water is moving rapidly and places where it is still. [ ... ] The patterns reflect not just the immediate conditions of the stream, however; they also reflect the history of the whole system, including the snowfall on the mountain last winter, the conditions on the mountain last summer, and indeed the entire geological history of the region, which determined the incline of the stream and its path through the mountain. (Thelen, 2005:259)

Thelen focuses on the temporal scale of child development, but the metaphor also supports the probatonic principle because it urges us to study particulars in real-time behavior. Just like development is non-linear, so are real-life, on-line, cognitive action—perception cycles non-linear.

In the current context, the principal explanans for how the ecological agent-environment relation is upheld and modified is interactivity, here defined as sense-saturated coordination that yields functional results. Coordination takes place whenever a living agent interacts with (conspecific, living, or non-living) entities in its environment. In the words of Kirsh (2006:250), “coordination is the glue of distributed cognition”: embodied agents are physical-material structures, and their actions are directed towards physical-material structures in their ecology. However, it is a peculiar fact about the human ecology that it is permeated by (historically generated) symbolic and organisational structures that extend our perceptual and actional domain. The human ecology is an extended ecology (Steffensen, 2011), because sociocultural resources (above all language) extend our range of action and perception, not unlike how a spider’s web functions as “a huge extension of the effective catchment area of her predatory organs” (Dawkins, 1982:192; quoted in Waters, 2012:505). The human ecology extends by exploiting sense-making capacities: when we

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2 This definition differs slightly from the one given in Steffensen (2013:196): “sense-saturated coordination that contributes to human action.”
avoid a bench because of a ‘Wet Paint’ sign, we use the (linguistically mediated) experiences of others to constrain our own behaviour. Likewise, all human cultures exploit sense-making processes to extend our biologically grounded distinction between edible and inedible (e.g. by dubbing certain food items ‘halal’, ‘kosher’, ‘delicious’, etc.), as well as our biological categorisation of whom we may mate with and whom not. Since sense-making occurs everywhere in the human ecology, our ecology is sense-saturated, not unlike how blood, iron, and fluid can be saturated with oxygen, magneticity, and thermal energy. On the one hand, sense-saturation implies that we need to take linguistic and sociocultural dynamics into account when we investigate (living in) the human ecology. On the other hand, the opposite also holds true: we cannot study language and human socioculture without considering how it impacts on the bio-ecological dynamics in specific socioculturally extended ecologies. Accordingly, our object of study is the sense-saturated human interactivity that unfolds in an extended ecology permeated with symbolic structures. The aim of such a study is to determine how sense-saturated coordination enables human beings to achieve results (or cognitive outcomes) in a complex socioculturally laden ecology. Given how interactivity maintains the agent and the environment as a coupled system, cognitive outcomes can neither be traced to the organism-environment interface, it is a fallacy to ascribe it to an individual organism. Rather, when it comes to determining whether the agent or the environment, or any subsystem of either, has causal priority in determining behaviour: “it is not possible to say what directly causes what, because the whole system is so mutually embedded and interdependent” (Thelen, 2005:259). Hence, to identify stable patterns, one has to investigate (the trajectory of) the cognitive probatonics of individual agent-environment system.

3. Cognitive Event Analysis

Cognitive Event Analysis (CEA) is a method that complies with the probatonic principle and which can be used in its own right, as well as a hypothesis-generating procedure. Building on fine-grained scrutiny of video recordings of human behaviour in natural or experimental settings, CEA seeks to answer two foundational questions: How are cognitive results achieved by cognitive systems? And how do human agents animate such cognitive systems? In the context of this special issue, one can add a third question: how does language contribute to generating results within a wider (non-symbolic) ecological context?

While space limitations prohibit a full explication of the method, CEA takes a starting point in the ecological claim that all living systems must make “their way in the world” (Reed, 1996:11) as a continual behavioural and metabolical process of interactivity. Accordingly, cognition is what enables organisms to regulate the organism-environment relation in a flexible and adaptive way that serves the purpose of staying alive (and reproduce). Since cognition can be traced to the organism-environment interface, it is a fallacy to ascribe it to an individual organism. Rather, when it comes to human cognising, one should start from a distributed cognitive system (Hollan, Hutchins, & Kirsh, 2000), that is “a self-organising entity that arises as human beings co-engage through interactivity, and connect up brains, bodies and aspects of the environment” (Steffensen, 2013:199–200). Human cognition, therefore, is a collective achievement grounded in interactivity. Like organisms, distributed cognitive systems “make their way in the world,” and by so doing they define a cognitive trajectory. Such trajectories, however, cannot per se be the object of study for a science of cognitive probatonics. The reason is that they are open-ended and thus unanalysable: all parts of a cognitive system have their own unique trajectories, and what happens in a given moment is the result of these multiple trajectories meshing in a single point in time (Steffensen & Pedersen, 2014). To elaborate on Thelen’s mountain stream metaphor, a distributed cognitive system flows as a unification of tributaries. The solution to this methodological problem is to segment a cognitive trajectory into delineated cognitive events that can be investigated.

This segmentation procedure is observer-dependent and can be based on purely functional criteria, because a cognitive system “is a constellation of structures [...] involved in the performance of some invariant task” (Hutchins, 1995:281). Thus, having defined or identified the task of the system, one can identify points in time where the system accomplishes the task, fails to accomplish the task, breaks down before having accomplished the task, etc. Thus, the key to segment a cognitive trajectory is the identification of the cognitive result, defined in relation to the task that in the first place defined the cognitive system. Thus, as Giere (2004:771) makes clear, “a distributed cognitive system is a system that produces cognitive outputs, just as an agricultural system yields agricultural products.” Paraphrasing Reed, we can say that just as cognition is all about organisms finding their way in the world, so is the cognitive result the way found by the organisms.

Accordingly, CEA adopts Timo Jarvilehto’s sound methodological principle for studying cognition: “the research should start from the determination of the results of behaviour and lead to the necessary constituents of the living system determining the achievement of these results” (Jarvilehto, 2009:118). Hence, a cognitive event is a sequence of flexible, adaptive behaviour that constitutes the cognitive results identified by the observer. Again, Thelen’s mountain stream metaphor is helpful. Waterfalls and standstills segment the stream into distinct phases, not unlike how development and evolution take the shape of punctuated equilibria (Gould, 1989). Along the cognitive trajectory, small-scale, idiosyncratic changes and variations are picked up by the system, amplified through processes of positive feedback, turned into affordances for solving the problem, and exploited in the current cognitive activity. In CEA, such a point along the trajectory is a transition point where the system undergoes a phase transition, for instance a recalibration (where the system recruits or expels one or more parts), a behavioural change (where the system for instance neutralises its previous attempts and starts all over), or a perturbation (where the system reacts to—or fails to react to—external influences). Such transition points are central in CEA, but some are more central than others. Such central or decisive transition points are called event pivots in CEA. An event pivot is a phase transition that is necessary for the event to take place. For instance, in problem-solving psychology — as will be elaborated in the following section — cognitive systems are often operating under one or more false constraints, which lead them to an impasse where they cannot solve the problem. In such examples, two transition points are crucial: first, the cognitive system must overcome an impasse (the primary event pivot), and second it must reach a solution based on the insight (the secondary event pivot). While the latter is rather trivial, the former is challenging: how does a cognitive system move beyond a point where it is functionally fixated on a wrong premise?

To sum up, CEA is a method of cognitive probatonics: it studies cognitive trajectories by segmenting them into delineated cognitive conclu-
events that are brought forth through a sequence of cognitive phase transitions. Some of these transitions are pivotal for the achievement of a cognitive result, and these are accordingly called event pivots. The trajectory is modelled as in the (generic) Fig. 1, which visualises the trajectory, the event, the phase transitions, and the event pivots.

Although CEA accords with the probatonic principle and thus promotes a single-case approach, it can still generate valid generalisations. Thus, with CEA it is possible to develop a typology of cognitive events, based on the configuration of transition points and event pivots within and across cases. For instance, the problem-solving examples discussed here and elsewhere (e.g. Steffensen & Pedersen, 2014) seem consistently to be constituted by a cognitive trajectory where an extended period of multiple cycles of repetitive behaviour (each demarcated by a transition point) is interrupted by a sudden behavioural shift (a primary event pivot) which shortly after leads to another sudden shift (a secondary event pivot) at which point in time the problem-solving behaviour ceases. Such a generalised description further suggests that the pre-pivot cycles contain small behavioural modifications that in a nonlinear fashion bring about the large-scale behavioural change that most problem-solving psychologists identify as an aha moment.

4. Two cognitive ecosystems

In the remainder of this article, I discuss two case studies of cognitive ecosystems engaged in problem-solving. The two cognitive systems follow cognitive trajectories that exhibit cyclicity and phase transitions, toward a cognitive event which is defined as the achievement of a cognitive result, namely the solution of the problem. In both cases the solution is preceded by unsuccessful attempts at solving it, and the solution manifestly depends on overcoming an impasse.

The first case (from Steffensen, 2013) comes from a real-life setting in a Danish company. Two office workers – known as Black and White – struggle to figure out why the company’s invoice system does not add the required Company Identification Number (called “the CVR number”) to the printed invoices. In their first attempts to solve the problem, they assume an implicit constraint namely that the missing number is caused by a malfunction in the computer software; hence, apart from blaming the software programmers, they try to solve the problem by feeding the number into the computer. But suddenly it dawns upon them that the CVR number is in fact pre-printed on the company’s logo paper; hence, simply choosing another printer tray in the computer’s printer setup menu solves their problem. But how did they come to this realisation?

The second case is Cowley and Nash (2013) semi-naturalistic study of a young air cadet (“Billy”). As part of his military training, Billy is given the river-crossing task (a.k.a “the missionaries and cannibals problem”), cf. Metcalfe and Wiebe (1987) and Guthrie, Vallée-Tourangeau, Vallée-Tourangeau, and Howard (2015). In this version, the problem is tailored to Billy’s military training: his task is to transport three “good guys” (“air cadets” (A) in this military setting) and three “bad guys” (“pongos” (P) in the setting) across a river in 5 min, using a raft that carries two persons, and which cannot move across the river on its own. A further constraint is that the pongos may not outnumber the air cadets on any bank (in this setting, those on the raft are not counted). Billy is solving the problem using a physical model. His officer is present in the room, which incidentally prompts him to speak aloud about his reasoning. The tricky point emerges when Billy has moved 1 A and 1 P to the far bank. Logically, Billy can make six different moves at this stage:

$$\begin{align*}
\text{P} & \text{AP} & \text{AP} & \text{P} & \text{PP} & \text{PP} \\
\end{align*}$$

Two of these moves, [AA] and [PP], obviously violate the outnumbering constraint. Of the four remaining moves, one sticks out, namely [AA], as this is the only move where the raft is driven back to the home bank by a figure not driving it to the far bank. Nearly all solvers, Billy included, initially constructs a false “ferryman constraint” which requires that one figure acts as a ferryman that takes one passenger (A or P) to the other bank and returns, either to take another passenger or to be replaced by another ferryman. Under this constraint, the problem cannot be solved; it has to be relaxed in order to allow for the felicitous move [AA] where the ferryman A is replaced by P on the far bank. Only few solvers manage to do so, and Billy is one of them. But how did he do it?

4.1. Black and White’s cognitive trajectory

The main insight in this section is that cognitive results depend on patterns of interactivity, patterns that are as unique as the agent’s fingerprint. Interactivity, or sense-saturated coordination, flows as action–perception cycles between cognitive agents and their environment, and it allows agents to engage in, not reconstructive problem-solving, but in performative solution-probing. Reconstructive problem-solving applies when participants in problem-solving analyse the emergence of the problem by making a step-by-step reconstruction of how to solve a task. Such a reconstruction would have taken Black and White to the print menu, including the printer tray selection, and thus they would have

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4 Square brackets indicate a roundtrip move. Those travelling to the far bank are indicated before the vertical line; after the line, those sailing back to the home bank is indicated.

5 As pointed out by an anonymous reviewer, an alternative formulation of this constraint is that a figure that has already been brought across cannot be returned to the original side, as this is, literally, a counterintuitive drawback in the problem-solving. Other versions of the river crossing problem do in fact require that the ferryman takes one passenger back to the original side, and certainly this alternative formulation of the implicit constraint applies to this scenario. In Cowley and Nash’s version, however, no move that requires two figures to travel back is needed. Hence, there is no way of determining which of the two constraint formulations applies to Billy.
have been confronted with the difference between their actual choice of paper and the correct choice of paper for sending out the invoice to a customer. In contrast, performative solution-probing emerge when cognitive agents engage in action—perception cycles in a way where affordances for problem-solving are procured. The agents probe the environment in order to detect felicitous solutions. To demonstrate how interactive solution-probing works for Black and White, let us first turn to their cognitive trajectory (cf. Fig. 2).

The solution-probing shows in a cyclical interactivity pattern where Black repetitively states what the problem is. He informs White three times that the current invoice cannot be paid; in the first two cycles he even opens with the same formulation: *men jeg kan fortælle dig* … (eng. *But I can tell you* …), uttered at \(-45,000\) and \(-18,625\) in the cognitive trajectory (Fig. 3). But in the third cycle, Black's wordings have changed, although content-wise he “says the same:”

1. *Hvis det var mig så røg den bare hen i stakken.* (0.7)
2. *Den kan jeg ikke betale.* (0.4)
3. *Hvorfor kan jeg ikke det?* (0.8)
4. *Der er ikke noget CVR nummer på.* (0.9)
5. *Du må ikke sende en faktura uden CVR nummer* (0.4)

As argued in Steffensen (2013), Black creates a counterfactual narrative by using the formulation *hvis det var mig* … *(if it were me*...
Within the scope of the narrative, Black (and by implication also White) sees the situation from the point of view of a virtual agent, namely the receiver of the invoice. The force of the narrative is so strong that it recalibrates the deictic system, as jeg (I) in line 2 and 3 does not refer to the speaker, but to the virtual, narrated receiver of the invoice. Thus, Black and White probe for solutions by seeing the problem from another relevant point of view: that of the invoice receiver. Crucially, what the receiver receives is an invoice printed on logo paper.

However, Black not only narrates the receiver, he also enacts him. Thus, as illustrated in Fig. 3, and documented in detail in Fig. 4, when Black says the unstressed syllables hvis det var (if it were), he lifts the invoice (Fig. 3a) and drops it (Fig. 3b). Further, when he utters the stressed syllable mig (‘maɪ, me), he catches the invoice again (Fig. 3c) and throws it into a pile on table (Fig. 3d). His narrative is thus complemented by a drop-catch-throw movement through which Black embodies the virtual invoice receiver, as s/he receives the invoice and throws it into a hypothetical pile of unpayable invoices. Black thus narrates and embodies the invoice receiver in a 1500 ms whole-bodied sequence. It is a crucial part of this embodied narrative that Black uses the three stressed syllables in line 1 to organise the manual enactment of the receiver’s handling of the invoice. Thus, as shown in Fig. 4, the receiving of the invoice is synchronised with uttering the stressed syllable mig (‘maɪ, me); on the stressed syllable bare (‘baː, just), Black starts his throw movement; and on the stressed syllable stakken (‘stagn, the pile), he lets go of the paper that continues into a pile on his own table. Through this solution-probing sequence, Black-as-sender passes the invoice on to the virtual-invoice-receiver-embodied-by-Black. Furthermore, by throwing the invoice away, Black effectively dissolves the fixation bias prompted by the printed paper. In turn, this reframing of the problem prompts White to come up with the solution right after Black’s five consecutive utterances: nå nej, men det er der jo hvis vi printer ud på logo papir (well no, but it [the number] is there if we print on logo paper).

In summary, the cognitive result was achieved through Black’s repetitive framing of the problem, combined with his changing the perspective to that of the invoice receiver. This change of perspective was prompted by the narrative structure where Black told how he would handle the blank paper invoice if he were the one who received it. Crucially, this narrative was embodied by enacting the receiver’s handling of the invoice. In conclusion, neither mental models nor linguistic reasoning, but the messy reality of interactivity brought forth the cognitive event of solving the invoice problem.

4.2. Billy’s cognitive trajectory

In the meantime, Billy is still struggling to get his air cadets across the river, as shown in the cognitive trajectory in Fig. 5.
moved one A and one P to the far bank, using an A as ferryman. For the first time along the cognitive trajectory, Billy has run into what Cowley and Nash (2013) call the reality point where the decisive move is [AA/P], which requires that the ferryman constraint is relaxed. Billy has not realized this yet, so for the next minute he engages in reasoning. First, he launches a 20 s sequence of conditional reasoning: If I take \( \ldots \) this guy over there \( \ldots \) I’m going to be attacked \( \ldots \). Second, he tries another strategy, namely to draw on his military training: Should I divide my forces or attacked?

Billy sequentially goes through the logically possible moves, as shown in Fig. 6 (step 1–2): first [xA|x] (i.e. [AA/A] or [PA/P]), then [xP|x] (i.e. [AP/A]).

Billy slows down. Unknowingly, by doing so he redeems a move to be one trip over the river, rather than a roundtrip with the same ferryman. This change allows Billy to focus on the home bank, and in step 3 he realizes that [-A] is illegal when there are two Ps on the home bank. This realization is repeated in step 4. This is crucial, because Billy has now honed in on the problem: it emerges when an A is brought back — hence, a P must be brought back (step 5). While it looks like an exercise in disembodied, conditional reasoning, it is far from the case. Rather, Billy relies on his gaze moving back and forth between the two banks and on his fingers pointing to, and touching, the figures. A remarkable change appears in step 4: while logically Billy repeats the conditional in step 3, his embodiment is different, as he now accompanies the move with a manual gesture from bank to bank. Effectively, this embodiment individuates the move to the home bank, and hence dissolves the implicit ferryman constraint. As his hand makes the move back, Billy’s gaze stays at the far bank: he thus integrates a manual move back and a gaze selection of one of the figures on the far bank. This embodied constellation leads Billy right to the event pivot, as he in step 5 utters pongo come back.

The ungrammatical construction indicates how he in fact integrates the two movements (i.e. pointing out the pongo and making a move back). Thus, the wording in step 5 is accompanied by a composite left hand movement: on pongo, he points to (the pongo on) the far bank, and on come back, he makes a sweeping hand movement towards the home bank. While this is indeed the solution to the problem, it takes Billy a moment to realize that this is the case, and having done so, he summarises the solution: So I take my two air cadets over and I change them \( \ldots \). This guy for a pongo \( \ldots \) move him back.

In summary, Billy reached a solution through his embodied interactivity with the physical model. His interactivity includes verbal patterns that endow his movement with a layer of conditional reasoning. Crucially, slowing down the action—perception cycles that constitute his interactivity led him to individuate the moves, and thus he dissolved the implicit ferryman constraint.

**5. Affordances as thick relations: or how cognitive systems are animated**

Information computational processing models often build on the assumption that cognition is a stepwise process from an initial state to an end goal. While such models may be compatible with observed behaviour, they certainly do not explain it. Amongst other problems, they fail prey to the computationalist fallacy that a path automatically creates a journey. They thus ignore what prompts a cognitive agent to take the next step in the model. In particular, computationalist models fail to explain how cognitive agents move beyond impasses. If there is no obvious next step in the
computational model, we should expect the system to come to an apathetic halt. However, when faced with the impasse, Billy, Black, and White all keep going.

In comparison, classical ecological psychology (Gibson, 1979; Hodges, 2014; Reed, 1996) traces progress along the cognitive trajectory to the affordances of environment: “affordances and only the relative availability (or nonavailability) of affordances create selection pressure on the behaviour of individual organisms; hence behaviour is regulated with respect to the affordances of the environment for a given animal” (Reed, 1996:18). However, Billy, Black and White all reside in a stable environment with nearly no changes in the layout of affordances. According to Reed’s classic formulation, a stable layout of affordances entails a stable set of selection pressures, which in turn, ceteris paribus, should mean that the behaviour is stable too. But in the two case studies, behaviour is far from stable, so behaviour must be regulated with respect to something else than affordances. This classic ecological model lacks an explanation of how an agent exerts adaptive, flexible behaviour in a stable layout of affordances. To solve this problem, the relational turn in ecological psychology (Chemero, 2003, 2011) has contributed with an alternative understanding of affordances as “relations between particular aspects of animals and particular aspects of situations” (Chemero, 2003:184). According to this model, changes in the layout of affordances need not emerge in the environment:

Most changes in relations between the abilities of animals and environmental situations will be changes in environmental situations. [...] But there can also be changes in affordances without changes in the features of the environment. The very same stair no longer affords climbing to an individual whose stepping abilities have decayed because of old age. (Chemero, 2003:192f.)

However, Chemero’s model is in itself insufficient for giving an ecological explanation of the data presented here, because the two examples play out on a timescale that is too fast (or too short) to allow for substantial changes in the agents’ abilities (or effectiveness). To remedy this shortcoming, I suggest that the probatonic principle is a key to understand the dynamics described.

By taking micro-ecological variability into account, the probatonic principle implies that the affordance relation between the agent and the environment is a “thick relation,” similar to Geertz’ (1973) “thick description.” A thick relation implies, first, that it is not the relation per se that constitutes the affordance, but rather the iterative interactivity through which the agent upholds the relation, perceives environmental structures, and acts in the world. Second, given its relational thickness, an affordance is nonlinear, dynamical and inherently unstable: stretches of interactivity may bring forth affordances that were hitherto unnoticed. Such small changes in the layout of affordances may, even on timescales as short as those investigated in this article, create a large-scale restructuring of the layout of affordances that in turn bring about observable changes in behaviour. Third, the thick relation also gives space for sense-saturation to play out in interactivity. Thus, as summarised by Casasanto and Dijkstra (2010), there is “a growing body of evidence that links bodily action with meaning, memory, and emotion.” Without delving into the details of this work, it allows us to hypothesise that emotional and autobiographical dynamics cause affordance, qua thick relations, to change on a relatively short timescale — not unlike how an optometrist can make light refract in different ways by twisting and turning a prism.

Both cases discussed in this paper illustrate how emotional, sense-saturated interactivity affects the layout of affordances and thus behaviour. In agent-environment systems, frustration and similar emotions are an order parameter that indicates the instability of the layout of affordances: the more frustration (or “emotional energy”) there is in the system, the more unstable is the layout of affordances, and the more sensitive is it to small-scale perturbations that may cascade into observable changes in the layout of affordances, and thus in behaviour. Frustration thus functions as an impetus for the agents to keep trying and keep acting, rather than to sink into apathy. Interestingly, the frustration can be traced to different sources: Black and White’s frustration increases as their problem keeps preventing them from carrying out their duties. In contrast, Billy’s problem is trivial. His frustration can be traced to a much slower trajectory: his decision to go for a military career. As Cowley and Nash (2013:196) observe, Billy “places himself in history; he acts as a Royal Air Force cadet, uses artifacts and institutions — and, in so doing, lives these roles and relationships.” In a similar study, Steffensen et al. (submitted) show how a participant in a lab experiment uses aesthetic inclinations to twist and turn the thick relation, so as to change the layout of affordances on a short timescale.

In conclusion, while emotions have not been a matter of high concern for ecological psychologists, they seem to function as an impetus for performing unplanned and unmethodical changes that reveal unnoticed affordances for reaching a solution: cognitive agents in the wild engage less in problem-solving, and more in solution-probing.

6. Discussion

This article has aimed to show the potential of cognitive proto-batonics. It has argued that self-organising cognitive systems are functional systems that achieve results through interactivity, i.e. microscale action—perception cycles between agents and affordances in their environment. Following this line of thought, it has argued for the potential of scrutinising particulars on a very fine-grained level, using the method of Cognitive Event Analysis (CEA). It has thus prioritised a qualitative, idiographic research strategy that, in line with the probatonic principle, complements quantitative research methods.

To complement the picture, we must also consider how language contributes to the functioning of cognitive systems. Crucially, the examples presented here undermine the idea that language primarily functions as a means for externalising and exchanging thoughts. Rather, the examples above have shown that the verbal aspects of Black’s and Billy’s utterances become significant when they mesh with other bodily dynamics on a fine-grained timescale. Unlike models that endow language with a privileged status vis-à-vis cognition, as if language was a golden path to understand the inner machinery of the mind, cognitive proto-batonics rejects the view that language is a separate modality (or module) for meaning-making. Rather, language depends on the whole-bodied meshwork of manual, gestural, and vocal activity — or interactivity, rather, as behaviour depends on the capacity of agent-environment systems. As illustrated in Black’s drop-catch-throw movement on the stressed syllable mig (’I’mai, me) and in Billy’s pointing-sweeping hand movement on pongo come back, timing is the key to understanding the cognitive trajectory: it is the real-time, self-organised interlocking of parts that make a multi-faceted cognitive system function. Language partakes in this interlocking by providing an economic way of establishing and stabilising perspectives and hypotheses. For instance, verbal if-then conditionals allowed Billy to keep track of multiple possibilities by transforming them into a series of sequential hypotheses (cf. Fig. 6), and the counterfactual if it were me-narrative allowed Black to reframe the problem in ways that would be extremely cumbersome or costly without the resource of linguistic patterns. Such patterns suggest
that coordination in cognitive systems become sense-saturated as they integrate non-local resources (Steffensen, 2015; Steffensen & Cowley, 2010). Theoretically, this is what motivates the concept of interactivity, defined as sense-saturated coordination: human cognition takes place neither in a disembodied mental realm, nor in a purely situated flow of flesh.

I finalise this discussion by addressing a concern that was brought up in the review process, namely regarding the status of qualitative methods: is there a place for cognitive probatonics in cognitive science? Or should the approach be rejected because it equips the researcher with vast freedom to interpret at will? To exemplify, one may argue that the analysis above falls prey to the post hoc ergo propter hoc fallacy: indeed Black’s becoming the invoice receiver occurred, and indeed their coming up with a solution occurred, but there is no way to prove that Black’s change in perspective is what led to the solution.

This objection can be met in two ways: first, while one may follow a Popperian line and argue that “non-reproducible single occurrences are of no significance to science” (Popper, 2002:66), it is worthwhile pointing out that none of the causal relations that have been experimentally identified comes on its own “in real life,” but always in a noisy environment, intertwined with a good deal of other causal and non-causal relations. One cannot a priori eschew the study of such complexes, even if the price is lack of certainty: other criteria than reproducibility may be possible and relevant in science.

Second, practitioners of qualitative studies could accept a Dual Compatibility Test (DCT): the first part of the DCT dictates that an interpretation must be internally compatible with all observable facts about the cognitive system under scrutiny. The second part of the DCT evaluates a qualitative analysis of cognitive probatonics by measuring it against the knowledge about cognition that the scientific community has accumulated. Thus, if a qualitative interpretation is compatible with the best of our knowledge of cognition, then it is sufficiently constrained to be plausible. It may not be the only plausible interpretation, but such under-determination is also the case in quantitative work. Interestingly, the same DIT applies to quantitative methods. For instance, Bert Hodges’ reanalysis of the Asch experiment (Hodges, 2007; Hodges & Geyer, 2006) relies on the same data as Asch and followers did when they interpreted the experiment. But Hodges’ interpretation of these results is more compatible with the full dataset, and not just the subset that caused most social psychologists to assume that conformist behaviour is widespread in social groups.

While the traditional battlefield in psychology has been defined by the disagreements between direct and indirect realists, and between mentalists and ecologists, the parties have been surprisingly eye to eye when it comes to the choice of weapon to use at the front: experimental designs, statistics and (to some extent) dynamical modelling. In such a situation, one easily forgets that there are other voices that present new ideas in psychology that may contribute to our understanding of the complexities of human behaviour and cognition. Cognitive probatonics is one such voice. By building on ecological models of cognition, it attempts to establish a descriptive and, in time, explanatory frame for capturing the real-life dynamics of human behaviour on a fine-grained timescale. It makes no claim to replace nomenclaturally inclined approaches, but more modestly it suggests that it complements these approaches by providing a method for studying the messy, real-life manifestation of cognition and behaviour. Time will show if this modesty is reciprocated by the theoretical superpowers in cognitive science.

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