
STEPS
ECOLOGY
A SITUATE
PROGRAMM
MIND

STEPS TO AN ECOLOGY OF BICYCLES FOR THE MIND

A SITUATED PROGRAMMING MANIFESTO

Robert Levy, May 2018

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Dedicated to Bristy
my partner in life
and in joint attention

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PREFACE

In the folklore of computing, the turn of phrase "bicycle for the mind"[1] characterizes the aims of intelligence amplification (IA) efforts by way of reference to the well-established scientific fact that bicycles come astonishingly close to making total use of a person's self-generated mechanical power. A bicycle is the most efficient vehicle to harness a human's own power toward locomotive objectives.[2] Can computing technology similarly be used to maximally leverage human powers of perception/action and narrative sense-making?

The metaphor raises an obvious question: why not an electric bicycle, or a self-steering sailboat, or a telepresence drone--for the mind, for that matter? Power tools of thought are ultimately what we want, but there is risk in putting them first. The bicycle model of amplifying human powers highlights the challenge of how to extend agency with technologies closely fit to core human competencies and needs. Skipping this necessary first step seems to lead down a path of not augmenting human capacities, but instead supplanting them in ways that tend to integrate poorly with the actual interests and needs of users. It leads to inscrutable oracles that trade off accountability and expertise for short-sighted convenience.

We do not yet have anything quite analogous to bicycles for the full power of the embodied human mind. But the history of human life has been punctuated by the development of new practices and tools for scaffolding and extending personhood. I suppose we could think of some of these innovations as wheelbarrows or shovels for the mind, augmenting capacities to participate in the world in specific ways. To measure up to the standards of the analogy from human mechanical power, a bicycle for the mind must extend core human competencies. What skills account for our unique cognitive ecological niche?

A clue is found in our collaborative graphical practices. The very earliest archaeological evidence of modern humans is littered with tools designed to cooperatively guide attention. In more recent human epochs, the printing press, mass media, and the internet have expanded the reach of graphical practices. Scarcity of attentional resources is a limiting factor, one historically addressed institutionally. However, we have reached a point where institutions are a bottleneck too. In order for networked individuals to viably maintain situation awareness at scale, it is necessary for software to participate in the content of information, not merely its mechanical transport and processing. Computing tools must be capable of following and augmenting our intentional processes. In other words we need bicycles for the mind.

The thesis put forward in this document, following research in ecological perception and joint attention, is that direct attending is reorganized cooperatively through use of conventions for selecting, composing, and realizing feedback loops of attending. The prescription for bicycles for the mind that follows from this is to codify the scaffolding of attending for machine followability, using immersive technology, to augment situation awareness and sense-making.

I call this work a "manifesto" because I don't consider it an idle theoretical exercise, but instead as advocacy for certain approaches and courses of action that are motivated by real problems in society, technology, and science. Alan Kay once remarked that "the best way to predict to future is to invent it". Likewise the best way to make sense of history is to excavate from it the most sound basis for the direction one is inventing toward. I survey three major trends tracing all the way back to the birth of modern human primates: attending, working, and organizing. Starting with the origins of joint attentional scaffolding and following a thread through changes that have impacted the scale of attention, work, and social organization, I draft a roadmap to an ecology of bicycles for the mind. I have kept references to authors, works, and prior art in the endnotes apart from the main text to simplify presentation.

AGENTS AND THEIR ENVIRONMENTS

Two of the oldest questions in philosophy and science are "what is life?" and "what is mind?". Only a mere 150 years ago[1] did it begin to dawn on pragmatic thinkers that these two questions are actually one question: "what is an agent?". To ask what an agent is is to ask what the difference is between inert mechanisms and living, feeling, self-steering mechanisms. So the question naturally becomes one of feedback and control mechanisms. Agents are systems that act to control parameters of environments that matter to them. To speak of an "environment of" or "mattering to" a system requires a physical explanation, and that explanation is given by natural selection. Mattering is a consequence of evolution because physico-chemical arrangements are either ephemeral or they persist through targeted manufacture, maintenance, acquisition of resources, and so on. To persist requires control of factors bearing on persistence, as biases or preferences. In other words, those things matter to the agent-- whether the agent knows it or not.

An agent, minimally defined, is a system that exercises control over factors ultimately tied to its persistence as an autonomous entity over time. Factors that may be required for the unity of the system to endure but are less directly controllable by the agent are called the environment of an agent. It is important to note that up until here, when we speak of mattering to an agent it is meant strictly in terms of outcomes that can be observed in the functioning of the system by an outside observer. What is called "perception" is an agent's active sensitivity to ecological features called affordances that bear upon control objectives. To say affordances matter to an agent, is to say that the real outcomes matter (both in terms of learning effective habits and in terms of reproduction/survival viability), and to remark on the first-hand phenomenology of proactively leveraging ecological information.

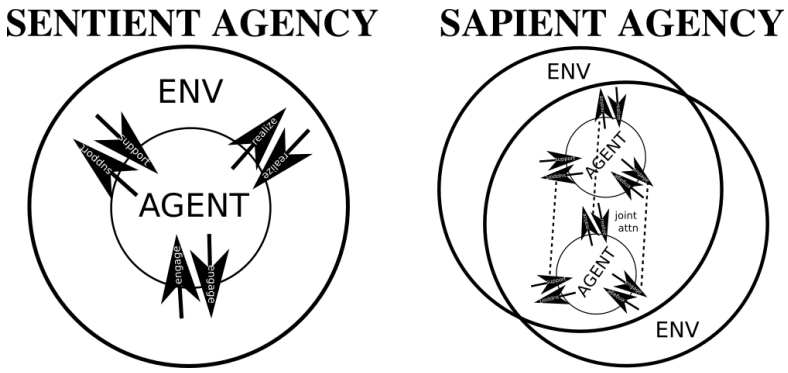
Agents' end-directed prospective control can be described in terms of three predicaments or stages in processes at which different factors bear upon action. Evidence for these predicaments derives from the pragmatics of gesture in joint attention, explored further in the next chapter.[2] Their efficacy in communication suggests they constitute the ontology of agency.[3]

1. ATTENDING: An agent is situated in environments that affords many opportunities and threats demanding awareness and readiness to potentially engage promising ends and mitigate perilous eventualities. Any engagement has opportunity costs, so an agent must budget attention[4] wisely. **The predicament of attending is that of classifying events as indicative of means to valued ends, in deciding to engage or refrain.**
2. SUPPORTING: Support, in the sense of contribution of work or effort, refers to relationships that hold between a presently engaged process and one or more potential or ongoing process. **The predicament for the agent is to what extent does the work of a secondary engagement contribute to (or hinder) the realization of the present enagement's objective, in deciding to include in scope or not.** The phenomenon of concentration or focus is also expressed by optimally excluding/including supporting or subordinate engagement. The idea of focus is that only those supporting processes that contribute to realizing valued ends should be involved, and others should be excluded.
3. REALIZING: The third predicament that agents contend with is that of organizing final causes. Final causes are those that motivate the second predicament above and indirectly, the first as well. **The predicament is that of defining ends, in deciding to continue or exit. What defines the unique character or meaning of realized ends is the specific set of options that are available to exit to.** In general, positions that offer more options (giving the agent more autonomy, rather than being at the mercy of circumstance) appear to be favorable, all other things being equal.[5]

JOINT ATTENTION: THE HUMAN NICHE

Humans are a unique case among natural agents. What distinguishes the "sapience" of humans from the more widespread "sentience" of basic agents is its narrative character. The source of our narrative abilities is the topic of this chapter. Narrative presentation or representation is not deep or intrinsic to intelligence by any means. The rich variety of sentient intelligence in nature manifests as purely pragmatic capacities of agents to steer events toward ends that matter-- solely in terms of direct bearing on positioning or readiness, often to the mutual benefit of agents.

Narrative agency is wholly due to a set of evolved capacities constituting a cooperative infrastructure of communication that began with gesture.[1] The basic gestural functions call attention to predicaments of agency: attending, supporting, and realizing processes. These skills allow us to collaboratively develop ways of seeing and knowing, by intervening to fine-tune the selection, composition, and motivation of decisions of what to attend to and why. While other species do engage in joint attention[2], only humans attend to a shared focus and coordinate motivation for directing and refining that focus.



Joint attention is important for multiple reasons. One reason is that it is directly responsible for human intentionally organized tools and practices. This is because when agents externally coordinate events that bear upon attending, supporting, and realizing, they are defining and shaping shared processes of narratively reorganized agency.[3] Another reason, a consequence of the first, is the development of intersubjectivity: the practices and tools that arise in service of joint attention become a rich repository of scaffolding that constitutes tacit and explicit common ground supporting the many varieties of social interactions. The accumulation of scaffolding offers potentially endless options for agents to extend the reach of their world-involving activities in socially sharable ways. Somewhat ironically, social practices establishing content made possible the development of autonomous personal "selves" as nexuses of life narrative, identity, and "mental" contents.

The earliest stages of human societies mark the beginnings of a history of tools and practices (such as paintings, masks, signs, speaking, etc) for scaffolding joint attention. Scaffolding is still by and large a highly localized activity between small groups of people, though the coordination of local activities has been significantly broadened by technologies of writing, the printing press, mass media, and the internet. Disseminable graphical practices such as writing and diagramming exemplify how *extensive*[4] sapient agents are: the reach and influence of involvement in the world is amplified by distributed scaffolding practices. Bicycles for the mind aim to tighten or make more immediate these wide feedback loops so as to scale awareness, sense-making, and organizational practices.

THE SCALABILITY OF ATTENTION, WORK, AND SOCIAL ORGANIZATION

In the discussion above we've developed an account of narrative agents whereby intervening in other agents' attending to three basic predicaments of control (by means of gesture and scaffolding), agents establish sophisticated narrative sense-making skills and practices. The human niche in all of its cultural and psychological diversity has been built in this framework of pro-social sensitivity to other agents' states of attending to, supporting, and realizing objectives. From these control predicaments and their derived communicative motives and skills emerge corresponding cultural phenomena.

1. ATTENDING Any social unit, however temporary or time-extended, and however large or small, is confronted with the need for coordination on what merits attention. Agents develop a shared awareness or common involvement in making sense of events as bearing on shared concerns.
2. WORK (SUPPORTING) Any social unit is confronted with the need for ways of having effects on the world together. Tools and machines have greatly expanded our capacities to work toward objectives. Technologies of attention, such as diagramming and notation, serve to affect agents' processes of realizing specific ends.
3. SOCIAL ORGANIZATION (REALIZING) Any social unit is confronted with the need to coordinate on final causes that constitute "what we want to happen". This can include anything from a preference to avoid places with cold temperatures in an outing together, to political causes, legal justice rulings, or the incentive structure of a game.

Hunter gatherer/tribal society. All evidence suggests that the primary original driver of increasingly advanced cooperation amplified by joint attention in proto-human primates was the stag hunt. Big game hunting required more than one person's help, and the better they coordinated, the better results they got on average. However early human societies did not gather in groups much larger than other primates did, because of the limitations of keeping track of one another and coordinating collective efforts. Humans developed intentional tools for practical purposes (like spears), and tools and practices of attention such as gesture, drama, ritual, painting, symbols, and an explosion of cultural artifacts as they began to bootstrap their capacities further, scaffolded in this way. It was in this period that people began to tell stories and make sense of nature in the best ways they could find to influence their shared fate positively.

Agricultural/hierarchical society. The next major shift in human social organization was driven by agriculture. Permanent settlements inhabited by unprecedented numbers of people led to increasingly hierarchical social organization to manage bottlenecks of attention, work, and governance at scale. In this period the hallmarks of civilization, coins for example (out of the collectible and gift exchange practices of forager societies) arose to address limitations of personal and collective situation awareness that rendered ineffective older established ways of sharing in common resource pools. Mechanical devices and managerial hierarchies were developed to address the scale of work. Heavy-handed monarchies and religious institutions addressed problems of coordinating social values at scale.

Information/network society. In the present era we are at the beginning of another major shift in the scale of society, from a hierarchical civilization to a decentralized network society. Near the end of hierarchical civilization, the human project of industrialization culminated in a generalization of efficient work in the form of information theory, control theory, and the invention of the digital computer. Networked computers have globalized the coordination of mechanical work, enabling ad hoc, easily affordable, planetary-scale machinery. Just as old methods failed us when we formed large settlements, the new global and interplanetary scale of human interaction necessitates decentralized social organization. Beyond developing robust distributed architecture discipline, what is needed most is scaling shared situation awareness and organization.

SITUATED PROGRAMMING

At the traumatic height of the 20th century, cybernetics emerged as a bold scientific, technological, and societal program that emphasized the engineering of agent mechanisms. Cybernetics was instrumental in the invention and development of computing technology, which it cast as a tool for designing and understanding systems organized by mechanisms resembling the end-directed processes of natural agents. The first high-level programming languages reflected the machine and human sides of this project respectively, with languages like Fortran focusing on efficient use of machine resources, and languages like Lisp and Smalltalk focused on amplifying human expressive power. As time went on and resources grew more abundant, Expressively powerful languages became more practical. Parallel to these developments, user bases were expanding, but at the cost of a growing divide in power between "programmers" and "users". Ever since that trend started, there has been a tension in computing between programming being disconnected with situated use, and use lacking the expressive power of programming. Consequently there have been many efforts to make programming more accessible to wider audiences, and/or to make situated use as powerful as programming. The setbacks such efforts have faced have been both technical (fundamental challenges in interface design, knowledge representation, etc.) and cultural (respectability politics in academia and industry, economic factors).

For a few different reasons, the tide seems close to turning. Mobile and wearable computing is increasingly ubiquitous and we are only a couple of years away from affordable consumer augmented reality hardware. That means computing is more frequently applied to activities other than just those ones that are best done sitting at a desk. Some of the original cybernetics ideas, namely neural networks and agent-based learning have become wildly successful, and there is a growing interest in ways of integrating machine learning techniques with data-centric approaches to programming. Efforts in industry such as robotic process automation are aptly proposing agents as an effective user interface model to give users more expressive power. The architecture pattern of event-driven dataflow is gaining in popularity at the same time that decentralized data provenance infrastructure is maturing. Data provenance is the cornerstone of decentralized network society, because as computing scales the labor dimension of collaborative agency, it becomes necessary to scale social accountability with respect to effects and motivations of work. Having auditable records is essential to assessing and correcting faults, and for learning what works and why, in repeatable ways. Only when the systems that extend our agency and act on our behalf are sourced with reliable records, can we make sense of them, take responsibility for them, and employ them with confidence.

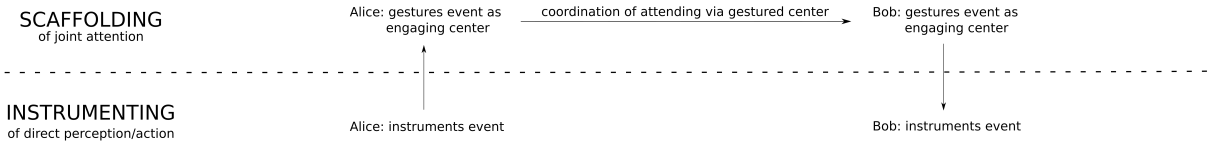
All of this points to the viability of developing a software ecosystem in which open data standards and data in the form of private and shared logs of first-class user-instrumented events replaces application-internal data silos, potentially providing a great deal of data to peers for for training agents that automate processes. Such expression and control can be directly situated in and integrated into agents' lived situations. By specifying agent-centered control as data, there is an opportunity for optimization of control, learning from past outcomes. While the term **situated programming** does not yet have much currency[1], it is a very fitting one to describe this trend of users gaining more of the power of programming and programmers gaining more situational context.

A final major question is the concern of the next chapter: what approach to information would allow software to helpfully participate meaningfully in the real situations that human participants control together. In other words how do we build bicycles for the mind? This needs to be a central concern of situated programming, I will argue. Scaling social organization requires expanding our capacities to share common ground, and common ground is established through the use of tools and and practices for coordinating attending to immediate concerns together.

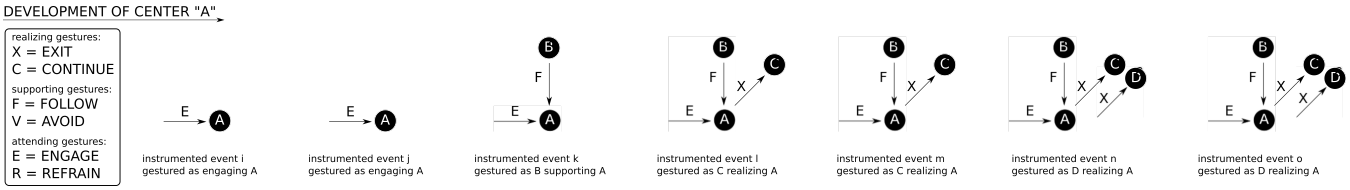
THE ART OF BICYCLE MAINTENANCE

The proverbial bicycle for the mind can be defined more precisely as the minimal instrumentation of joint attentional skills required to establish machine-followable common ground. What I propose as way of constructing bicycles for the mind within the broader context of situated programming, is an approach to specifying the coordination of joint attention, which I call **narrative process scaffolding** (NPS). I have begun work on a protocol for agent-centered coordination on joint attentional scaffolding I call **senters** (a portmanteau of "sense-making" and "center") as a way of implementing NPS. Here I will describe NPS and senters at a high level.

To review what was developed in the discussion above, there are two levels of meaning when it comes to agent-centered information. There is basic, first-order causative involvement (direct perception/action), and there is second-order convention-based (gesture/scaffolding) re-organization of first-order activity by controlling the selection, composition, and direction of activities of attending to the world. The approach of NPS is to **instrument** activities of direct world-involvement, and to **scaffold** convention-based processes of joint attentional orientation.



What are called **instruments** are typically simple functions that affect the world, including visual and haptic interactions for example. Users instrument their active involvement in environments, in an event-driven dataflow[1] style: instruments produce events when they are applied, on a feed specific to the agent's use of the instrument. Such events are in turn referred to on feeds for what are called **centers** when the instrumented events are indicated by means of **gestures** as bearing on either attending to, supporting, or realizing the processes that a center scaffolds. The six gesture types cover empirically documented classes of engage/refrain (attending), follow/avoid[2] (supporting), and continue/exit (realizing). Gestures signal the relevance of events to attending toward ends. For example given an instrumented haptic event, gesturing "engage" for a center for moving an object means that event indicates an option to attend to that process. Centers accrete information that **proxy agents** follow to extend and support users' actions.



This approach allows for moving beyond an application model to a more composable and adaptable approach. Users leverage effective crowd-sourced software behaviors custom-tailored to fit real situations. The phrase "turning the application inside out"[3] is a good description of the fact that centers (which are defined and shaped through use) replace the former role of applications, in capturing what functions are are available, how they compose, and where they get their users.

CENTERS: ROADMAPS FOR BICYCLES FOR THE MIND

The scientific hypothesis underwriting the technical proposal for narrative process scaffolding is that something we've termed a "center" describes and specifies the hard data of convention-based guidance of attention, or "scaffolding". This concept is actually quite simple, but is subtle enough to be missed without a careful presentation, so this final chapter makes that presentation its objective. The title of the chapter asserts that centers are "roadmaps for bicycles of the mind". Centers are the maps, not the territories that are mapped; the territory in this metaphor is the continuous flow of situated and embodied direct experience of participating in what happens.

In the following examples I use the descriptor "top-down" for any development/use where a center is engaged as scaffolding to direct a series of events, and "bottom-up" for development/use where occurrent events induce an appropriate center to scaffold contending with and making sense of the events. Also, a word on "development" versus "use": use of centers is technically not distinct from enacting entirely new centers, as any use of a center revisits its story of development, and the record of its process can potentially scaffold a future episode of use by someone it is shared with. There is a practical difference of degree rather than kind in leveraging (at one extreme) a well-trodden center that one's present experiences add nothing new to, and (at the other extreme) a center that has yet to be formed with respect to histories of events.

Example 1. top-down development and use of centers. Alice, Bob, and some of their friends go on a hike and pick a new kind of berries. None of them are experts at picking berries. Alice and Bob individually draw from some centers that scaffold foraging generally, including picking berries of known varieties. Together the group collaborates on the development of centers to scaffold processes of acquiring this new kind of berry, benefiting from and refining one another's findings as they progress, sharing with one another what works well.

You have been hiking in the woods for days with no rations, but you have a solar charging unit for your wearables. You access the local woodland mesh network and find that many foragers have shared scaffolding on their techniques. Your reserves of agents dutifully apply these centers to direct your attention to finding berries, and other food. There are also some relatively recently sourced centers scaffolding the process of finding a new kind of berry you have never heard of, but you don't follow it, because of how few participants have contributed, and also because these pseudonymously signed strangers (Alice, Bob, and their friends) have made it difficult to link their activities to much else.

Example 2. bottom-up development and use of centers. You are sitting outside in front of your home reading a book when suddenly a car's screeching brakes break your concentration. A bicyclist flies from impact with the vehicle's windshield. After seeing to it that the bicyclist receives medical care, you and the other nearby witnesses recount what you witnessed, and develop a consistent account, pooling pieces of recorded evidence, acts of claim-making (witnesses', the artificial driver agent's, the bicyclist's) to create a content-bearing executable narrative that explains, in a process of joint attentional replay what transpired. It is accepted and applied as the basis of a "smart contract" insurance payout.

~ EPILOGUE ~

As these examples show, centers are histories of instrumented events directed by joint attentional guidance. Skillfully engaging centers means being able to use them to scaffold novel circumstances they apply to, following them through in episodes of attending toward realized outcomes. Many new ecologies of bicycles of the embodied mind can be discovered as we share, develop, and use these maps to experiencing them together.

ENDNOTES

preface: 1. To the best of my knowledge, the first documented occurrence of the turn of phrase was in a 1980 presentation by Apple Computer co-founder Steve Jobs on using computers to amplify human abilities. In so doing he paid homage to a key theme of the cybernetic movement that gave birth to computers. The title of this manifesto combines this phrase with a reference to "Steps to an Ecology of Mind" by cyberneticist Gregory Bateson, which explored the organization of individuals, societies, and ecosystems in terms feedback and adaptive self-regulation. **2.** In addition to bicycles standing for a close fit between humans and technological extension, bicycles have other fitting associations. Bicycles influence urban planning toward human-centered designs. They have historically stood for liberation and empowerment, playing a significant role in feminism. Susan B. Anthony wrote of the bicycle: "it has done more to emancipate women than anything else in the world. I stand and rejoice every time I see a woman ride by on a wheel." **3.** Spoken language, by any account a crowning achievement of our species (innateness debates aside), is supported by image schematic and metaphorical devices for coordinating construal of abstract domains (Lakoff 1993, Talmy 2000, Goldberg 2003). The use of these devices is so entrenched in cultural practice that our use presents a task of unraveling mysteries for years to come in cognitive linguistics research.

agents: 1. Roughly 150 years ago a revolution in evolutionary theory occurred, most notably punctuated by Darwin's "On the Origin of Species". In that setting, the "pragmatic turn" in philosophy and science began with Charles Sanders Peirce's project of reconstituting knowledge, meaning, and phenomenology in terms of situated agents calibrating meanings externally in networks of causative consequence. The pragmatic thread can be traced through the work of Uexkull, Vygotsky, later Wittgenstein, Heidegger, Merleau-Ponty and many others. Crucially it led to the 1st and 2nd cybernetics movements, the latter of which in conjunction with James and Eleanor Gibson's pioneering work in ecological psychology has developed into the "e-turn" or "4E" (embodied, ecological, enactive, and extensive) cognitive sciences. The underlying theoretical basis of semiotics (Peircean, not Sassurian), cybernetics, and radical embodied cognitive science is that meaning happens in the world, relative to the predicaments of agents, and as such must be understood in terms of processes of agents' involvement in the world over time. **2.** The assertion that agents are necessarily and sufficiently defined on three dimensions of situated bearing is mainly based on the work of Michael Tomasello, Adele Goldberg, and other related work in their usage-based program of communication research. This research has identified three ways in which humans learn (around nine months of age) to intervene in others' processes of attending: sharing, following into, and directing processes of attending. These three skills of attention are directly related to three identified communicative motives of sharing, informing (supporting), and requesting (directing) process. These appear to be constitutive factors of the human semantic niche of specifying shared intention. In this manifesto I have taken the speculative liberty of extrapolating the historical themes of attention, work, and organization from these communicative skills or motives, as it seems to carry its explanatory weight. **3.** Turvey 1992 also supports this account of prospective awareness, supporting subacts, and afforded ends. **4.** Eleanor Gibson and Nancy Rader in "Attention: The Perceiver as Performer" (1979) explain that it would be misleading to regard attention as a special mechanism to be studied, and is more appropriately understood to be the activities of the perceiver-actor. Attending is simply the conduct of world-involving, end-directed activity. The word is however useful in pointing out that an agent must prioritize what to engage in, at the cost of engaging in some other activity. The word becomes more of a reference to a distinctive phenomenon in the discussion of joint attention, the phenomenon of agents' states of attending being made targets of attention in their own right, to be influenced and organized. **5.** A case for maximizing potential next options as a default utility function for intrinsic motivation was first made by Klyubin, Polani, and Nehaniv 2005, which they term "empowerment", quantifying it in information-theoretic terms as the channel capacity of an agent's actuation channel terminating at the sensor.

joint attention: 1. Michael Tomasello's research over several decades shows that directing the flow and focus of others' attention in service of cooperative organization is the reason we direct the flow, focus, and organization our own world-involving activities. Basic ecological dynamics cannot be equivocated with the reflective reorganizational process of developing the what, how, and why of activity developed from from skills of joint attention. Some related work that builds this case for a duplex account of sapient intelligence are Hutto and Myin's "Radicalizing Enactivism" and "Evolving Enactivism", Chapman and Agre's "Abstract Reasoning as Emergent from Concrete Activity", Alva Noe's "Strange Tools", Nancy Salay's "Representation: Problems and Solutions", and Sabrina Golonka's "Laws and conventions in language−related behaviors". Importantly, all of this work acknowledges that this duplex account is usage-based, at the level of embodied agents situated in the world together. Representational content is achieved by agents by means of the tools and practices they use to scaffold jointly attending. **2.** Ape gestures include "intention movements" (abbreviated actions that have effects within social contexts) and "attention getters" (actions that call attention, such as slapping the ground). Perhaps surprisingly, dogs (having had some time to adapt to our cognitive niche) have experimentally shown far better understanding of human pro-social intentions and gestures such as pointing than other animals (Kirchhofer, et al). **3.** The use of the term "narratively reorganized agency" refers to what is discussed in the first endnote of this section. Narrative process is a kind of feedback process concerned specifically with the selection, composition, and direction of what is attended to. As such, it is a second-order mode of end-directed feedback that is convention-based rather than law-based in its relation to ecological information. **4.** As Tracy Harms puts it, "mind, as cognitive scientists and philosophers focused on human flexibility are most interested, is characterized by an expanse of reorganizational fluidity." Hutto et al (2014), on the limits of this extent write "limits can be revealed by empirical experiment. Even if one were able to see for miles one might not be able to see for leagues."

situated programming: 1. William Clancey explored "situated action" in the context of computing in his influential 1997 book "Situated Cognition: On Human Knowledge and Computer Representation". In 2002, Mills and Scholtz published "Situated Computing: The Next Frontier for HCI Research", exploring the reorientation to a data-first, agent-centered approach to computing brought about by mobile and wearable devices. They write, "a future where people will interact with information through a continuously varying array of devices that combine to form ad hoc portals suitable to particular situations. In such a future, people and information will be emancipated." The term "situated programming" was used by Rich Hickey in his keynote lecture at Clojure Conj 2017, emphasizing effective programs, the importance of developing meaning at the systems level rather than fixating on machine-level program abstraction, and the agent-centered design of systems.

bicycle maintenance: 1. Dominic Tarr's secure scuttlebutt protocol (ssb) is an example of the sort of approach I have in mind. It applies the kappa architecture or event-driven dataflow programming at the user level, and for that reason it is a good fit for NPS. Further implementation-level concerns are explored in the senters RFC. **2.** "Avoid" might also be substituted with "voice" in reference to the notion of "voice and exit". In the context of the support predicament of a narrative process, some other process can either be followed as supporting, or voiced as not supporting. In the realization predicament of a narrative process, "continue" and "exit" apply. **3.** To paraphrase Martin Kleppman's (2014) "turning the database inside out" in reference to event sourcing. More broadly speaking this approach is in the spirit of Licklider's (1960) vision of designing systems that "cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs".