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Co-Ability and embodied data: blurring the lines between human and nonhuman entities in an interconnected world

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This article explores the dynamic interplay between human and non-human entities, focusing on how embodied data representation is distributed. It examines how predictive coding, which utilizes preconceived knowledge, interacts with tangible experiences to shape our understanding of the world. Emphasizing this, I propose the concept of co-Ability as a deep underlying explanatory framework for understanding adaptive behaviors within a networked world. A non-verbal dialog between humans and a data-saturated environment is analyzed through an action-oriented perspective and the predictive coding framework in cognition, utilizing digital craft and rapid prototyping. This transformative approach augments human interaction with digital landscapes through tangible prototypes, bridging physical experience with abstract information, and identifying potential ways to conceptualize data materially. The article discusses the various aspects of connectivity among network agents and the evolving nature of these connections as they adapt to real-world conditions and dynamic shifts in data, highlighting that information exchange in an interconnected network is more than bilateral; it generates ripple effects that extend beyond immediate connections. These reciprocal exchanges simultaneously alter both the digital and analog domains, with data constantly bifurcating into multiple pathways and outcomes. A significant challenge addressed in this article is the question of how to frame information materially, inviting further exploration.

KEYWORDS

co-Ability, action-oriented, tangible media, digital craft, predictive coding, data physicalization, embodiment, bifurcation

1 Introduction

In the broader field of artificial intelligence (AI), there is considerable ongoing success in machine learning (ML), particularly in the area of statistical learning from large datasets. This success has generated growing interest from academia, industry, and the public, significantly altering our perception and engagement with digital information (Holzinger et al., 2018). These transformations highlight the adoption of a digital-first strategy in data analysis and knowledge extraction, influencing the evolving landscape of data interpretation and utilization.

In our interactions with reality, shaped by the particular architectures that we evolved, the nature of information extends well beyond the confines of digitized databases. The transition from the virtual domain, where atoms and bits forge digital landscapes, to the tangible real world represents a bidirectional exchange of information crucial for comprehensive understanding. Theories of tangible computing delve into the structure of physical interfaces,

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aiming to bridge the gap between digital data and physical entities. Data sculpture studies highlight that 'embodiment describes the expression of abstract data in physical representation through the process of data mapping' (Zhao and Vande Moere, 2008). However, the primary focus remains on knowledge extraction, emphasizing the evolving landscape of data interpretation and utilization.

This discussion analyzes the properties of living organisms (humans) and non-living structures (digitally crafted objects) within a network, focusing on the operations that can be detected to make the shared ability. The process of how data structures matter over time and space is viewed not as a one-way transaction for understanding and learning but as a dynamic, reciprocal exchange that simultaneously alters both the digital and analog domains, with data constantly bifurcating into multiple pathways and outcomes (Vermeiren, 2023). This perspective spans various disciplines, emphasizing the potential for interdisciplinary methodologies and their broader application.

These dynamics occur not at the level of individuals but at the level of complex networks of biological and artificial elements. Humans are considered not as standalone centralized entities but as integral components of a vast, intricate, and ever-evolving system, where information is not static but is constantly being reshaped and redefined by the ever-changing dynamics of the network. This 'dance' of data exchange among biological and artificial entities, humans and non-humans, leads to new patterns of information with each shift in the network, highlighting the generative power of change within this complex, decentralized web. By broadening our understanding of what data represents and recognizing its integral role in both digital and physical strategies, we can appreciate the open-ended combinatorial space and the recursive properties of allowing creativity to happen.

In contemporary cognitive science, the exploration of how humans perceive and interact with their environment hinges on understanding the intricate relationship between preconceived data and evolving experiences. This dynamic interplay, crucial for self-awareness and comprehension of our surroundings, is rooted in the integration of multisensory information and the predictive coding framework. The focus of this article is not to delve into the philosophical debates of mind–body dualism but rather to highlight the importance of bodily processes in shaping cognitive functions and self-consciousness. Predictive coding, a theoretical framework extensively discussed by scholars, such as Friston and Clark, posits that our perception of the world is an active, probabilistic process where the brain continuously generates and updates models of sensory inputs. The concept suggests that our physical selves are not detached observers but integral parts of the environment, dynamically interacting and influencing one another. The embodiment of data and its physical manifestation play a pivotal role in cognitive processes. Traditional numerical representations fail to capture the action-oriented, sensory-rich experience of human cognition. On the contrary, tangible data representations offer a more immersive and interactive approach to understanding and processing information. Digital prototyping and rapid fabrication techniques have revolutionized our interaction with physical data, embedding quantitative evidence within three-dimensional contexts. These advancements enable a non-verbal dialog between humans and data, fostering a deeper engagement with the increasingly digital landscape. This article aims to explore the concept of co-Ability within adaptive behaviors, acknowledging the role of sensory exteroceptive and proprioceptive faculties enhanced by technological extensions. The decentralized, soft assembly mechanism of abilities within a network highlights the significance of distributed competencies over individual abilities. Despite lacking a common language to decode the intangible sensory information surrounding us, this article will elaborate on the 'action-oriented' human perception of data and the role of digital craftsmanship and design in supporting the dynamics of information flow in a conversational manner.

By examining the dynamic interplay between humans and their environment, this article contributes to a deeper understanding of the embodied nature of perception and the transformative potential of data-driven interactions. I conclude by asserting that the true strength of any physical entity in our tangible world lies in its co-Ability within the network in which it is embedded (Dezső, 2019).

2 Tangible data for human perception, the biological entity of a network

To understand the underlying issues in the complexity of the real world, it is essential to examine the link between preconceived knowledge—which forecasts potential information through predictive coding—and our evolving experiences in the tangible world. This interplay between what we know and what we experience is pivotal for our self-awareness and for our understanding of the world we inhabit. This article will not delve into the examination of mind–body dualism, a philosophical inquiry with roots in ancient Greek thought. Instead, the discussion will highlight the significance of processing information relevant to the body (Descartes, 1960; Merleau-Ponty, 1963; Varela et al., 1991; Zimmerman, 1996; Bermúdez, 2000; Gallagher, 2005; Barsalou, 2008), emphasizing the significance of bodily processes, such as the non-conceptual representations and processing of body-related information, in cognitive processes and self-consciousness (Bermúdez, 2000; Dijkerman and Lenggenhager, 2018).

The predictive coding theoretical framework (Porciello et al., 2018) highlights the role of multisensory integration mechanisms in constructing bodily self-representation, as well as in facilitating bodily self-recognition and plasticity (Srinivasan et al., 1982; Mumford, 1992; Rao and Ballard, 1999; Kilner et al., 2007; Friston, 2011; Apps and Tsakiris, 2014; Badoud and Tsakiris, 2017). Bastos et al. (2012) and Clark (2013) emphasize an 'action-oriented' perspective on how we perceive the world, aligning with Friston's (2011) notion that our sensory experiences and our self-awareness are understood through a probabilistic lens, supporting the notion of 'predictive coding' in cognition with situated environmental data modalities. Porciello et al. (2018) further propose that our physical selves are not separate from but inherently part of the environment and it is perceived through dynamic models that showcase the fluidity of how we see our bodily selves. Friston discusses the bilateral role of embodiment, asserting that we not only exist in the environment, but the environment also forms us, creating a reciprocal embodiment, where each model is modeled by the other. This perspective suggests a heuristic understanding that if an individual is a model of their environment, then they inherently model themselves as situated within that environment. This extends beyond the non-linear sensory exteroceptive/proprioceptive (visual, tactile, and motor) dialog with the surroundings; it is about the dynamic interplay between us and the environment, where both continually influence and reshape each other. Historical perspectives, like those of Schilder (1935), view the bodily self as inherently social, suggesting that an individual's perception of themselves is deeply influenced by their interactions and integration within their social environment. Friston suggests that our sense of self is an embodied entity within our environment, actively 'harvesting sensory confirmatory evidence' available. This search can either validate our sense of being or challenge it, pointing to the intricate relationship between the embodiment of environmental information (data) in self-perception and the integral role of environmental and social contexts in shaping our understanding. These theories question the notion of human-centric abilities (or disabilities), suggesting that an individual's capabilities are deeply influenced by network organization and are constructed upon the scaffolding provided by the external structure of information. Andy Clark discusses a 'variety of ways in which cognition might exploit real-world action so as to reduce computational load' and outlines the 'processes of decentralized soft assembly in which mind, body, and world act as equal partners in determining adaptive behavior'. Building upon this foundation, I propose to explore the concept of co-Ability (network-distributed abilities) further within adaptive behaviors (Dezso, 2022). This analysis acknowledges the role of sensory exteroceptive and proprioceptive faculties, enhanced by prostheses or simple tools, as extensions of our physiological systems. Within the causal network of the physical world, any alteration to a singular component causes a correspondingly adaptive response across the entirety of the network, thereby disseminating the ability for action through a decentralized, soft assembly mechanism. This extension of the self or the environment not only augments the human sensory system but also integrates into the situated environmental data modalities as an actor in its own right. Humans possess an innate tendency to engage with spatial esthetics, identifying parallels in their environments and interpreting shapes visually or verbally. In contrast, data are inherently formless while perpetually in flux. Traditional numerical representations of data do not adequately capture the human action-oriented sensory physical experience, highlighting the high relevance of body-related information in cognitive functions and self-awareness (Varela et al., 1991; Zimmerman, 1996; Bermudez, 1998; Gallagher, 2000; Gallagher, 2005; Dijkerman and Lenggenhager, 2018). In the 1960s, Mackay introduced a groundbreaking concept about our sense of touch and how we use it to explore the world around us. According to him, our senses function as exploratory tools for systematic discovery in moving from one point to another. This process is a dynamic action-oriented cycle where fragmentary perceptions guide further exploration, leading to a comprehensive experience of perceiving an object. Clark (1998) elaborates on this perspective further, suggesting that touch, characterized by its micro-detections and probing and reprobing nature, transcends mere surface sensing to foster active engagement with our surroundings for deeper comprehension. He extends this concept beyond touch to include animated vision in overall perception, proposing that our senses are deeply interactive devices that allow us to navigate and make sense of the complex world around us and ourselves in it. Theories of micro-perceptive interactions in human sensemaking highlight the necessity for the physicalization of data to enhance comprehension and engagement with complex, dynamic information. Data bound up with material reality enables human action-specific adaptive responses as information unfolds. This theory emphasizes two critical points. First, perception is driven by motor-loop-specific activity (exploratory tools of touch and animated vision), where humans exhibit micro-perceptive adaptation that influences these motor-loop-specific activities. This suggests that the most effective sensemaking comes not from visual information but from the motor activity involved in perception. This theoretical framework outlines a distinction that we are just beginning to understand "motocentric" focus in perception instead of "visuocentric" attitude (Powers, 1973; Churchland et al., 1994).

3 Digital prototyping with data, the artificial entity of a network

Within the context of an action-oriented perspective and the predictive coding framework in cognition, the application of digital craft and rapid prototyping introduces a new layer of depth to the integration of situated environmental data into the design process. Digital fabrication techniques have revolutionized how we interact with physical data, enhancing action-oriented interactions and embedding quantitative evidentiary records within a three-dimensional context. This advancement enables documentation and analysis in unprecedented ways. This approach transcends merely providing visual or tangible access to data; it integrates esthetic and material qualities into the very fabric of the objects, thus fostering a non-verbal dialog between humans and the data-saturated world around them. Digital prototyping offers that each piece has a unique feature, marked by distinct shapes, elements, and proportions, each embodying diverse numeric data expanded across three dimensions. These characteristics endow them with a dual capacity: they act as both a visual and tactile manifestation of numeric information and as a medium for somaesthetic appreciation (Shusterman, 2012; Höök et al., 2016). Therefore, physical prototypes, crafted through the meticulous application of data, establish a foundational platform for a non-verbal dialog between humans and data, enhancing our engagement with the increasingly digital landscape that envelops us. The ethos of digital crafting embodies a particular mindset, a way of engaging with the world that revolves around iterative, non-verbal, and action-oriented interactions between humans and data (Sennett, 2009). The fabrication of objects via rapid prototyping is predominantly exploratory, driven by curiosity, and aimed at uncovering areas of interest. However, unlike traditional craftsmanship, this process is distinguished by its capacity for recall, repetition, and examination—foundational aspects that support the scientific inquiry into these creations. Manzini notes, "There is no information without a medium, there is no information processing without single crystal silicon (or, in the future, other materials)" (Manzini, 1989). The tangible media of prototypes can facilitate understanding between the "physical" realm (living organisms and biological systems and artificial human-made objects or systems) and the "nonphysical" domain (information data, ideas and concepts, and cultural and social constructs). This investigation draws on the physical agents of the design process, where each agent in a close network echoes social and cultural narratives and brings to the table a variety of ways to engage with the world. In my doctoral research project, the 3D-printed real-world prototypes were identified as the best-structured information source for theory development in exploring the phenomena of co-Ability (Dezso, 2022). The data of the artifacts construct the evidentiary values of the research and enable an exploration of philosophical and strategic approaches to co-Ability. The term 'co-Ability' is rooted in the critical approach of posthuman disability studies. It serves as a broad umbrella term under which we can reconsider the potentials of various entities (biological and artificial) that enhance the shared competencies of those entities rather than dwell on the oppressive nature of human-centered norms (Dezso, 2023). I imply that the principles of co-Ability can be universally applied to both living and non-living entities. This unified perspective approach helps quantify the number of elements required to create a complex network, whether they are biological organisms or artificial objects, and supports understanding the emergence and evolution of complexity in a network that interacts. The aim of co-Ability is to develop a new understanding of the mechanism of complex matter in terms of what contributions are physically necessary in constructing an effect.

A dichotomy exists between the physical realm of human experience and the intangible nature of data, presenting challenges in mutual understanding and interaction within a complex physical network. The process of making the transition from a prototype's visual form in 3D modeling to its physical existence involves transforming informational data into code that dictates the movements of a 3D printer. This code transforms the model, represented in CAD format, into a tangible prototype, effectively mediating the perpetual flux of information, making it comprehensible to humans by rendering it physical. This serves as a crucial mechanism to bridge the communicative gap between humans (embodied entities) and data (abstract information). To understand the data of our environment, digital craft and fast prototyping can support this kind of discourse with the data in action-oriented predictive processing. Navigating the intricate dynamics of data exchange within the interconnected fabric of the real world presents substantial challenges. However, the domains of digital craftsmanship and prototyping stand out as powerful allies in this exploratory path. This significance extends beyond mere comprehension of the mechanisms of embodied data in design research to potentially encompass a wide array of applied sciences engaged with data prototypes, such as robotics or virtual reality, architecture and urban planning, and biomedical engineering and healthcare. These approaches transcend the given form of ideas and concepts; they foster dynamic conversation with data, facilitated by action-oriented predictive processing. Industrial design theorist Ezio Manzini posits a transformative view of matter—not as mere tangible entities like wood or stone requiring manipulation but as abstract models defined by their characteristics (properties) and the interplay among those characteristics.

4 Discussion

In this discussion, I argue that the fundamental strength of any type of physical entity in our tangible world is derived from its co-Ability within the network it is embedded in, despite the absence of a universal language for interpreting the dynamic, intangible information that surrounds us. This perspective article builds on understanding co-perception related to the co-Ability phenomenon through the synergistic interplay within networks comprising both biological and artificial elements. It focuses on the significance of distributed competencies over individual abilities or disabilities.

In the debate surrounding disability politics, Longmore posits that the obstacles faced by individuals with disabilities are more attributable to societal attitudes and structures than to the disabilities themselves or underlying biological factors (Longmore, 2003). This investigation outlines the varying aspects of connectivity among network agents and how the nature of these conjunctures evolves dynamically in adaptation to real-world situations and dynamic shifts in data. This perspective article offers a state-of-the-art overview of data representations that influence the design process and networked interactions in the co-design process with discursive prototypes. I propose that various forms of data and their physical manifestations enhance tangible interaction modalities through digitally crafted objects embedded with specific data. This exploration considers data as material for subjective inquiry, incorporating insights from a blend of fields such as cognitive and social neuroscience, embodied cognition, design studies, and robotics to demonstrate how the abilities of any element depend on the network's distributed relationships. The dynamics of information flow highlight the interoceptive and exteroceptive signals, as well as stored representations of the body (body memory) in interactions and their reciprocal impact on network behavior (Riva, 2018). When an agent (biological-artificial or human–non-human) within a network connects, whether, at first, second, or third degree, they become integral parts of the network, influencing each other's situated living bodies and distributing their sensory data within this network. As Friston discussed, "not only does the agent embody the environment but the environment embodies the agent" (Friston, 2011). The exchange of data between any agents in a connected network is more than bilateral, it creates ripple effects that reach far beyond immediate connections, impacting not only directly involved agents but also reaching further connections to influence the structure of embodied experience. A critical aspect of this discourse is the transmission of information between directly linked (first-degree) network elements, characterized by varied types of traits for processing the information data. These transmissions, distinguished by their bilateral directionality—encompassing both input and output—along with interpretative and perceptive capacities conveyed through data-based physical artifacts, significantly influence subsequent lines of action and potential disruptions within the network. At the heart of these interactions lies the physical data exchange, covering a wide range of subjects, with the format of bidirectional communication reflecting the nature of first-degree connections.

In conclusion, this discussion emphasizes the essential notion that the potency and functionality of any entity within a network are not solely inherent to its individual abilities but are significantly amplified through the distributed co-Ability phenomenon. In this deep underlying explanatory framework, with the construction of new possibilities, data structures are viewed as dynamic, reciprocal exchanges that simultaneously alter both digital and analog domains, with data constantly bifurcating into multiple pathways. This intricate interdependence within networks, bridging the biological and artificial, highlights the transformative power of distributed competencies and the pivotal role of data-driven interactions in shaping the dynamics of connectivity.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RD: Writing – original draft, Writing – review & editing.

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