NewWorkTech

DELIVERABLE D3.1

EXISTING RESEARCH AND REVISION OF KEY CONCEPTS

REPORT

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From the Margins to the Masses:
Standard Practices and Innovative Uses of Technology
in Augmenting Different Abilities of People in Worklife

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Abstract

This review explores theoretical and methodological approaches to human–technology interaction, with a particular emphasis on how technology is conceptualized across disciplines. The review examines the semantic scope of the concept of technology and the ways in which it is embedded – explicitly or implicitly – in scholarly frameworks. The analysis is guided by the theoretical needs of the NewWorkTech project, which prioritizes approaches that illuminate the bidirectional nature of human-technology interaction: humans shape technologies, and technologies, in turn, shape human behaviour.

One of the main focus areas is distributed cognition and the 4E cognition framework (embodied, embedded, extended, and enacted cognition). These approaches are critically examined for their treatment of technology, revealing significant variation in scope, analytical scale, and disciplinary orientation. The review also engages with affordance theory, particularly in design contexts, to assess how technologies communicate action possibilities and constraints to users.

Philosophical perspectives, including postphenomenology and actor-network theory, are reviewed to address the experiential and relational dimensions of technological mediation. These frameworks offer insights into how technologies co-constitute human subjectivity and world-disclosure, moving beyond instrumentalist and externalist views.

Finally, the review examines models of disability in relation to technology, highlighting how different paradigms – medical, social, cultural, and ecological – shape understandings of technological agency and accessibility.

1.Introduction

This review contributes to theoretical scholarship on technology by examining how technology is conceptualized within various approaches to human–technology interaction. While theoretical analysis is central, selected empirical studies are included to illustrate methodological strategies that emerge from these frameworks. Given the extensive and interdisciplinary nature of existing literature, a comprehensive survey of case studies falls outside the scope of this review. Instead, the review offers an external, non-specialist perspective on a diverse yet interconnected set of approaches. Its aim is not to evaluate the scholarly merit of individual contributions, but to identify points at which human-technology interaction becomes a salient topic and to explore how technology is understood – whether through explicit theorization or implicit assumptions.

This review also serves a specific purpose: the identification of state-of-the-art research is guided by the theoretical priorities of the NewWorkTech project. Accordingly, the focus is not necessarily on the most recent or highly specialized publications, but on approaches that have been developed to “catch the phenomenon” – to borrow a phrase from David Kirsh (2008, p. 57) – of technological mediation. As the review progressed, it became evident that the theoretical, methodological, and philosophical challenges surrounding the concept of technology are more extensive than initially anticipated. Some degree of incompleteness is therefore inevitable, though the review aims to provide a meaningful foundation for further inquiry.

In this context, “theoretical” does not imply detachment from practical concerns. Rather, it refers to the ways in which concepts, models, and systems of thought inform decision-making in academic research. Such decisions may involve methodological choices, the determination of analytical scale and scope, or the selection of appropriate tools. Although technology may not be a central concept in all the theories discussed, it is highly relevant to the thematic and empirical aims of the NewWorkTech project, particularly in shaping the direction and focus of inquiry. Much of the discussion in this review is therefore inferential analytically and synthetically: it involves identifying discussions, arguments, and frameworks in which technological elements are present but not explicitly acknowledged. In this sense, we do not expect to encounter ready-made conceptual tools, but articulate them from the outside in order to facilitate comparisons and critical insights.

Rather than compiling references to the term “technology,” this review investigates the semantic scope of the concept – specifically, the types of human activity that scholarly work has identified as involving technology. This approach allows us to uncover gaps and tensions between seemingly similar theoretical positions and to highlight potential research frontiers and methodological implications. It must be acknowledged that explicit theoretical engagement with the concept of technology is relatively rare in the literature surveyed. Instead, much of this review of approaches reveals a general vagueness in the ways technology is conceived across various theories of human-technology interaction, as well as a tendency to fall back on ideas of technology that are prevalent in the surrounding society at the given time. Therefore, it is useful to briefly introduce some established definitions of technology likely to appear in the reviewed sources. The English noun *technology* (from Hellenistic Greek *τέχνο-* + *-λογία*, via post-classical Latin *technologia*) originally referred to systematic treatises on craft or art. Over time, its meaning expanded to encompass the material artifacts, methods, and systems now commonly associated with the term (Oxford University Press, 2025). Historical lexicons trace this semantic shift from specialized, craft-oriented usage to a broad mass noun encompassing everything from hand tools to complex socio-technical platforms (Oxford University Press, 2025).

Although the term *technology* was rarely used prior to the Second World War, its frequency has surged over the past 70 years (Oxford University Press, 2025), and it is increasingly employed as a synonym for *high technology* – typically referring to innovations that are novel and often disruptive to the societies into which they are introduced, rhetorically framed as emerging from outside those societies. Joseph Pitt critically examines this narrowing of the term's meaning:

> One possible reason why technology is often seen as high technology is its association with science. This is due to an epistemological misassociation, in which both are about knowledge, the former superior, theoretical, pure sort, the latter applied and inferior. The common misperception is now, with modern science and production methods, that technology is somehow originating solely from applied forms of scientific knowledge. (2000, p.1–2)

As science-based processes of technological design and production become increasingly specialized, the concept of technology appears to grow more distant from the cultural contexts in which it remains embedded. Another prevalent view that reinforces this perceived disconnection is the "tool-as-mechanical-mechanism" model (Pitt, 2000, p.9), which conceptualizes technology as a device or machine – an external "add-on" to human activity. In this framework, the human user is expected to adapt to technology, learning to operate tools that have been designed for them, except in rare cases where the technology is of their own making.

Alternative perspectives on technology do exist. As Elizabeth Keating (2006, pp. 332–333) suggests, revisiting the historical roots of the concept can help reconnect it with culture. Pitt (2000) similarly notes that much of human technological activity has historically occurred without the involvement of scientific knowledge – and continues to do so. Keating extends the category of cultural tools to include language and storytelling, thereby acknowledging the full scale and intensity of human-technology interaction. As she writes, "[t]ools shape ways of doing and ways of thinking, communicating and imagining" (Keating 2006, p.332).

Accordingly, this review seeks to move beyond an input/output model of human-technology interaction, in which technological effects are conceived as unidirectional – for example, hen deployed in transforming raw materials into finished products (see Pitt, 2000, p.13). Instead, we adopt a bidirectional perspective: humans shape technologies, and technologies, in turn, shape human behaviour. However, as previously noted, conceptualizations of technology are not always clearly articulated. For this reason, each approach reviewed will be examined through two guiding questions:

1. *How is technology acknowledged, or what constitutes technology?*

2. *What is human-technology interaction conceived to be? What is the scope and scale in which the interactions are considered.*

A third questions can be asked collectively:

3. *Where do the gaps in research emerge when the concepts of technology and models of human-technology interaction put forth in the reviewed approaches are overlaid?*

The approaches are reviewed in Sections 2. through 7., progressing from theories that focus on the finer details of human-technology interaction and applied frameworks of such theories to more philosophical views of technology in broader scale. The review begins with approaches that focus on interaction, agency and perception and how technologies have been conceptualized in relation to approaches to embodied, embedded, extended, and enacted cognition. A review of affordance theory follows as a bridge between these theories and design practice, which presents applied versions of some of the concepts in the more academic or theoretical approaches. From there, the report turns to philosophical perspectives, which deepen the conceptual analysis by addressing ambiguities in the definition of technology and introducing notions of technological mediation, intentionality, and bidirectionality through frameworks such as postphenomenology.

These theoretical foundations set the stage for the review of disability models, which examines how social, cultural, enactive, and ecological paradigms intersect with views of technology, revealing tensions between individualistic and systemic approaches and their implications for inclusion and accessibility. Finally, the discussion synthesizes insights across all sections, mapping conceptualizations of technology along a continuum from narrow, device-centered views to wide, systemic and experiential perspectives, identifying methodological gaps, and emphasizing the need for integrated frameworks that bridge micro-level interaction analysis with macro-level cultural and institutional contexts.

In a concluding discussion, models of disability will be examined in correlation to the reviewed notions of technology. The problematic that can already be articulated emerges from the relation between models of disability and those of technology:

1. *How do views of technology connect with those of disability, or the diversity of people in general?*
2. *What are the gaps in research related to how views of technology coincide with the diversity in human abilities?*

Before moving on to the review, it needs to be stated that the aim of this review is not to endorse any of the approaches discussed but aims to chart the diverse ways in which technology has been conceptualized across disciplines. Having said this, some of the approaches are more closely aligned to this purpose, but this does not reduce the relevance of others in providing critical opposition to a wide view of technology, for example. While some frameworks – such as representational and computational views – imply a separation between mind and body, for example, the position taken here rejects such dualisms. Cognition is understood as inseparable from embodied, situated, and technologically mediated conditions of human life. Technologies are not external add-ons but constitutive elements of cognitive systems, shaping and being shaped by human perception, action, and experience. Where earlier paradigms suggest boundaries between mental and physical domains, this report affirms a holistic view: affordances, agency, and sense-making emerge through dynamic coupling of bodies, environments, and technologies rather than through isolated mental processes. Finally, it must be noted that this document is the first step in an ongoing endeavour and will be met with substantial amendments in later iterations.

Having now introduced some of the fault lines within conceptualizations of technology and its role in shaping human experience, the next step is to identify theoretical frameworks that can be used to further elaborate on this complexity. Distributed cognition offers such a waypoint: it reconceives cognition not as an isolated process within the individual mind, but as an activity distributed across people, artifacts, and environments. This perspective is particularly relevant for understanding technological mediation because it foregrounds the systemic and relational nature of interaction, that is, how tools, representations, and socio-material structures co-organize cognitive processes. By starting with distributed cognition, the review situates technology within a broader ecology of action and meaning, providing a conceptual bridge to subsequent discussions on affordances, design, and disability.

2.Approaches to Distributed Cognition

This review devotes substantial attention to approaches within the research on distributed cognition, as well as to related concepts such as distributed agency and perception. This emphasis reflects two key factors: first, much of the work conducted within the NewWorkTech project is closely aligned with some version of distributed cognition (Due, 2021; Korhonen & Hirvonen, 2021; Hirvonen, 2025); second, these frameworks occupy a prominent position in the broader field of human-technology interaction.

2.1.Distributed cognition

Numerous reviews of the scholarship on distributed cognition already exist (see, for example, Alexander, 2025; Windhager and Mayr, 2024; Anderson et al., 2019; Newen et al., 2018; Michaelian and Sutton, 2013; Moore and Rocklin, 1998), and there is no need to reiterate their findings, particularly as they do not focus on the theme of technology. In reviews that group multiple related approaches under the umbrella of “distributeds” – including distributed cognition, 4E cognition, situated action, and embodied action – two key features consistently emerge. First, there is a shared emphasis on the environment in which an organism (typically an individual or a group of humans) is embedded. Second, the concept of distribution is articulated through a variety of definitions, reflecting both the theoretical and disciplinary diversity of the field, as well as practical considerations that shape its application.

Accordingly, the way technology is viewed varies considerably, sometimes along the lines of theoretical and disciplinary divergencies, sometimes due to the more individual interests of the scholars working with them. The theoretical roots of the distributed cognition approaches partly explain why the conceptual space in the field has become so nebulous:

> In the 1990s, Varela, Thompson, and Rosch’s (1991) *The Embodied Mind*, drawing on phenomenological and neurobiological resources, proposed an enactivist account of cognition that emphasized the role of the dynamical coupling of brain–body– environment. Around the same time, a paper by Flor und Hutchins (1991) introduced distributed cognition as a “new branch of cognitive science” for which the unit of analysis includes external structures, collectives, and artifacts organized as a system to perform a task. Hutchins’s (1995) *Cognition in the Wild* was a direct influence on Clark and Chalmers’s (1998) now-classic philosophical essay, “The Extended Mind.” Throughout this time period, additional work inspired by Gibson’s ecological approach to psychology

> contributed to a growing realization that cognition was not limited to processes in the head, but was embodied, embedded, extended, and enactive. (Newen et al. 2018)

In some cases, the relations between the approaches are vague resemblances, in others, higher degrees of theoretical and practical compatibility, but the relatively brief period during which they appeared may suggest a greater degree of similarity than can actually be found. Furthermore, the multiple starting points and the give and take that has occurred between the approaches over the years has resulted in a multitude of reconceptualizations of cognition-body-environment models. Anderson et al. (2017) describe the diversity of views that makes the search for a "state of the art" a difficult pursuit:

> We have seen that distributed cognition can roughly be split into 4 Es (embodied, embedded, extended and enactive) with each 'E' admitting of further, sometimes competing, articulations in the hands of different philosophers and cognitive scientists […]. Philosophers and cognitive scientists who work in this area often adopt what might appear to be a mix-and-match approach: they accept some 'distributed' claims but reject others. Moreover, they may accept a different combination of distributed (or non-distributed) claims about different parts of human mental life: some aspects of our mental life (perhaps our feelings of joy and pain) may be treated as purely internal while others (perhaps some of our memories and decision-making) are distributed. A further complication is that, even if attention is restricted to a single aspect of human mental life, a distributed theorist may give a different distributed/non-distributed answer for different human subjects in different environmental contexts at different times (some humans are more inclined than others to distribute their memory on to external devices). (p. 9)

It should also be noted that significant theoretical disagreements exist at the root of the approaches mentioned above. Edwin Hutchins' early work was influenced by Lev Vygotsky's work as well as by cognitive anthropology and systems theory, whereas most of the 4Es are indebted to phenomenology of Maurice Merleau-Ponty, John Dewey's pragmatism, and the early enactivism of Francisco Varela, Evan Thompson and Eleanor Rosch. By taking some of the basic assumptions of the different approaches as denominators, a simplified chart can be drawn of the variables that often inform how, in general terms, the distribution of cognition is thought to take place.

	Representational view	**Computational view**	**4E Approaches**
View of Mind	Representation manipulator	Symbol processor	Embodied agent
Role of Environment	Means for external representation	External memory	Integral to cognition
Distribution	Across media/representations	Across systems/tools	Across body, world, and action

Figure 1. Basic assumptions in mainstream accounts of distributed cognition

Figure 1. gives some initial clues as to the role of technologies in different views; while the representational view suggests a mediation between essentially, or at least constitutionally different systems (mind and external representations), the 4E approaches have a more diffused and integrated view of not only distribution of cognition, but the relations between an organism and the environment, which also points towards a more intertwined notions of human-technology

interactions. In practice, however, the differences are not always viewed as mutually exclusive, but as Hutchins has proposed in later work, the approaches of "distributed cognition and extended mind imply related, but different (hopefully complementary), perspectives on cognition" (2013, p.35). Hutchins' work exemplifies this attitude, as it started as a combination of representational and computational views of the mind, later to include elements from 4E.

Moreover, the emphasis in all the distributed cognition approaches is the importance of tools, manner of interaction and the context of activity. Furthermore, it is apparent that the theoretical discussion on distributed cognition is informed by the changing interests in the field of practice, as the theories are being reformulated and rearticulated for different kinds of case studies, data and materials and combinations with other theories. Indeed, distributed cognition approaches are currently being applied in so many different disciplinary contexts – including psychology, memory research, human-computer interaction, design, IT, activity research, learning, history, and literary studies – that it is safe to assume that the practical applications introduce a further layer of methodological diversity.

Hutchins' ecology of tools: computations and representations

Some scholars trace the core ideas of distributed cognition to the 1960s and 70s[1], but here, the review will take Hutchins' work as a starting point for the kind of conceptual and methodological frameworks that are recognizably in the same tradition. Hutchins' initial concept of technology emerges in his study of maritime navigation techniques, through which he presents a "computational ecology of navigation tools" (1995, p.112). In this study, technology is seen not as a collection of tools for different purposes, but – in Heideggerian fashion – as a system in which "mutual dependencies among the various instruments and techniques is clearly visible" (Hutchins 1995, p.114) – in the activity of navigation in Hutchins' case study. Hutchins' seminal work in distributed cognition focused on technological interactions through a concept that not only included formalized organizational duties as technological systems (1995, p.38-41), but also deployed a detailed charting of the technological environment as part of his methodological toolkit, as is exemplified by his description of the procedures of navigation such as position fixing (Hutchins 1995, p.29-38), which explicates the use and functional principles of navigation tools, formalized crew duties the organization of work stations. In later work, Hutchins has reiterated this holistic inclusion of the environment in cognitive events as central to distributed cognition:

> Distributed cognition begins with the assumption that all instances of cognition can be seen as emerging from distributed processes. For any process there is always a way to see it as distributed. In practice this implies that wherever we find cognition, it will be possible to investigate how a process we call cognitive emerges from the interactions among elements in some system. (2013, p.36)

However, as will be shown in the course of this review, a wide view of the consequentiality of the environment (the technological included) in this vein has not become a standard among approaches to distributed cognition, nor has the method of wide-ranging, detailed charting of technologies that accompanied Hutchins' empirical work in *Cognition in the Wild* (1995). The interest in Hutchins' seminal work is thus not only historical; the wide lens with which Hutchins

[1] For example, to John Milton Roberts' *The Self-Management of Cultures* (1964).

approached his subject of study looks particularly intriguing in hindsight, but it has also enabled significant changes in direction and revision in theoretical grounds. The scope in Hutchins' analytical method includes devices of navigation (instruments and charts) and the practices or "techniques" (1995, p.12) that enable their coordinated use both for individual crewmembers and groups. Furthermore, Hutchins includes in his analyses the spatial as well as social organization of the environment, arguing, for instance, that "[m]ilitary ranks and the ways in which military identities are formed are presented […] because these things affect individual's relationship to their work" (1995). The resulting assemblage is what Hutchins calls the "cognitive system" (1995, p.128), which he deems "directly observable" to the extent that the cognitive activity is distributed across a social network and thus "remaining agnostic on the issue of "representations in the head"" (1995, p.128–129).

For NewWorkTech, Hutchins' way of charting the workplace milieu and organization is of central interest, as these, Hutchins argues, are the means by which it is communicated what actions are allowed or what resources are available to whom, and how the tasks, duties, responsibilities are divided and attributed (1995, p. 15–17). Zourou has described Hutchin's unit of analysis as consisting of "small socio-technical systems (or functional systems in Hutchins' terminology) and especially the functional relationships between system elements" (2008, p.161). Yet, while it may appear on the surface that the solutions for navigation on a ship comprise a small-scale socio-technical system, the holistic approach to the various agentive elements that are involved in the activity of navigation reveals a systemic complexity that extends far beyond the confines of the specific situation. In this way, Hutchins' work seeks to lays bare the multitude of things that make up a "socio-technical system", the functional interdependencies within such systems and the way in which the situatedness of the system and activity within it are historically effected. Hutchins' description of the *ecology of tools* clarifies the complexities of systemic interdependencies:

> In the ecology of tools, based on the flow of computational products, each tool creates the environment for others. This is easy to see in the history of the physical tools, but the same is certainly true of the mental tools that navigators bring to their tasks. Frake's compass is there for all to see, but it becomes a tide computer only in interaction with the establishment of the port and with a particular way of seeing the circle of directions as a representation of the temporal relationships of the periodic cycles of the sun and the moon. Every argument showing why a particular tool is easy to use is also an argument showing why both internal and external tools are part of the very same cognitive ecology. It is a truism that we cannot know what the task is until we know what the tools are. Not only is this true of both internal and external tools, it is also true of the relationship among them. (1995, p.114)

The categories of internal and external tools indicates a degree of technological integration into the human that takes Hutchins' concept of technology beyond the simplistic external view and into a more humanized grounding. Nevertheless, the dichotomy still maintains a degree of separation, the extent of which can be further assessed in how the terms operate in Hutchins' practical analyses.

In *Cognition in the Wild*, Hutchins' arguments about relations between the different parts in the socio-technical system are based on a detailed charting of their functionalities and how these support in achieving the overall goal of fixing the ship's location. Since the technologies involved in the activity of navigation are used collectively, Hutchins' analysis charts the computational transformations that take place as the crew uses their tools, which also involves stages of transmediation from algorithms to visually represented spatial relations – a process by which cognition becomes something to be experienced and thereby available for distribution. For Hutchins, this process is instrumental in tasks carried out by groups of agents, so much so, that activity in the navigation example is “accomplished by *the propagation of representational state* across a series of *representational media*” (1995, p.117). In other words, the stages in the progression of the task become experienced and interpretable through representations formally specific to the task environment and culture. Technology thus gains a crucial medial status in processes of distribution, as Robert Wilson has suggested: “Hutchins argues that technology should not be thought of simply as a way of augmenting individual cognitive capacities, however, but as a means of changing the nature of the representational spaces or media in which computations are performed” (2004, p.175). This medial emphasis in Hutchins’ explication of the means of distribution of cognition is important in setting the stage for later developments in approaches to distributed cognition, but it also marks important dimensions of conceptualizations of technology that can be traced through the various iterations of distributed cognition.

In addition, while for Hutchins, the environment informs interactions with technologies and accomplishment of tasks in complex ways, he also points out the importance of a diachronic view for understanding the significance of technological practices in the surrounding culture:

> Only when we look at the history can we see just how many problems had to be solved and how many could have been solved differently in the course of the development of the modern practices. A way of thinking comes with these techniques and tools. The advances that were made in navigation were always parts of a surrounding culture. They appeared in other fields as well, so they came to permeate our culture. (1995, p.115)

In this description, techniques and tools become reconceptualized as elements in culture, as a stratum of distributed cognition that can be drawn from to deploy elements of cultural knowledge adaptatively for new purposes. The view of technology can thus be seen as historically oriented and accumulative in that technologies are not simply discarded when a replacement arrives, but often become stored in some form in the culture in which they have generated a tradition of application. Simultaneously, this stratum of cultural practices can be seen as a major source of regulative force in human activity, as Hutchins argues: “[t]hat is what makes it so difficult to see the nature of our way of doing things and to see how it is that others do what they do” (1995, p.115).

Combined, Hutchins’ synchronic and diachronic perspectives project a framework for studying human-technology interactions on the micro scale of activity cycles – in which each minute process of transformation can be acknowledged – to macroscale, cultural structures where accumulated systems of cultural practice and knowledge are intertwined with devices and socio-material environments. Resulting from this is an extremely broad field of application, and even though Hutchins’ focused case study restricts the scope to activity cycles measured in minutes (Hutchins 1995, p.133), it is also clear that not all of these dimensions are – nor could they be – examined in any close detail, but to the extent that they inform how the activity cycles are achieved in practice. Consequently, the unit of analysis is limited by feasibility concerns – which are not altogether clear from the outset – and the nature of the activity itself, as Hutchins explains: “[t]he boundaries of the unit of analysis for distributed cognition are not fixed in advance; they depend on the scale of the system under investigation, which can vary […]” (2013, p. 36).

In this way, Hutchins’ method limits the number of accountable technologies to those deemed necessary or consequential to the activity cycle, while other technologies may become part of the context of the activity situation. Interestingly, language is featured as one such tool (Hutchins, 1995, p.140), yet Hutchins' treatment of language as a tool for distributed cognition is tentative and no theory of language or information that could be integrated with his approach to distributed cognition is identified[2]. This tentative view does, however, situate linguistic communication into the processes of medial transformations within activity cycles, thus giving it a status that is functionally comparable to other representational media as means for distributed cognition (Hutchins 1995, p.141).

In later work, Hutchins enters into a dialogue with Andy Clark's extended mind hypothesis in reconceptualizing the role of the environment for distributed cognition as "cultural-cognitive ecosystems" (Hutchins, 2013). With his view of the socio-technical environment Hutchins seeks to broaden the scope of the extended mind view to the environment without placing the individual at the center by default:

> The extended mind framework is a way to approach distributed cognitive systems in a specific range of spatial and temporal scales. In earlier writings, I have referred to these as "functional systems," and Clark has called them "ecological assemblies." Distributed cognitive systems also exist at other spatial and temporal scales. In this article, I propose to shift the focus from ecological assemblies surrounding an individual person to cultural ecosystems operating at larger spatial and temporal scales. […] I intend the discussion of the examples as a sort of intuition pump to help readers shift their attention from particular ecological assemblies to the properties of the cognitive ecosystem in which the assemblies arise. (2013, p.35)

While the description of the new focus closely resembles the view of the socio-technical environment as seen in *Cognition in the Wild*, the difference arises in the how – through its properties – the cognitive ecosystem stands as action potential for a population of agents, but in a way that also regulates the activities by various means. From the perspective of technology, it is interesting that Hutchins describes these means in a way that blurs the boundaries between devices and social constructs, as can be seen in his example of queuing at an airport as an activity specific to the environment in which it takes place:

> This everyday practice often takes place in complex social and institutional settings. Examining such settings can reveal the extent of the network of elements that are related in the cognitive ecosystem. In airports, for example, elaborate material arrangements serve to induce the formation of queues and shape the queues as they form. There may be patterns of lines painted on the floor, guide ropes or tapes, and signs such as "enter here" or "wait here for first available agent." The practice of forming a queue for service exists in a cultural ecosystem that includes services to be rendered (a set of facts about economic systems); the roles of service provider, who renders services, and client, who accesses services (facts about social organization); and locations in space at which service is rendered (facts about architecture). (Hutchins, 2013, p.39)

As with Hutchins' earlier work, the socio-technical environment is described – even in this brief example – in some detail beyond the most apparent requirements of the activity of queuing.

[2] An interesting point is made by Hutchins on language as one of the central tools in collaboration, but as Hutchins notes, the theories of language at the time of writing were not particularly well-suited for his approach (1995, p.140). Since Hutchins is left wondering about "the role of language in the operation of a system of socially distributed cognition" and the "properties of language as a structured representational medium" (1995, p.140), Daniel Dor's theory of language (Dor 2015) as technology – which is also detached from mentalistic accounts of language – could be an applicable amendment to Hutchins' method.

However, Hutchins makes a further phenomenological amendment to explain how an individual perceives the situation that suggests queuing as a relevant activity:

> The phenomenon of enacting meanings by "seeing" the world in particular ways (Stewart, Gapenne, & di Paulo, 2010) is absolutely ubiquitous in human experience and is accomplished via cultural practices. When a line is being seen as a queue, other elements of the setting will be seen as instances of other roles in the queuing for service practice. (2013, p.40)

This experiential turn is interesting in itself and will be discussed more extensively later in this review, but this analysis is also an example of how, technology – when working without problems – ultimately vanishes from view in the perspective of the experiencing individual. A full account of interactions with the other roles (related to signs, architecture, and social organization) would of course be a matter on an entirely different scale, but for research to be able to catch the phenomenon of the airport queuing experience of a person with a disability, for example, some of these details are likely to emerge as consequential. Yet even in such an account, the distributed cognition approach may not be equipped to account for the variables of the agent as an individual with unique traits.

2.2.The 4E+ of Distributed Cognition

It is becoming increasingly difficult to give an overall account of a common ground shared by the 4E of distributed cognition, or approaches to cognition as *embodied*, *embedded*, *extended*, and *enacted* approaches. One way of describing the differences between the distributed cognition approaches within the frameworks of the computational and representational views of cognition and those in the 4E would be to characterize the latter as a rejection of both of these views and a shift towards phenomenologically oriented accounts of distributed cognition. This may not be equally true of all the 4E theses, but it appears to be one that is at least provisionally shared by them as the focus tends to be the embodied, cognizing individual rather than groups. The disciplines involved in these approaches are numerous and diverse yet focusing on the shared subject matter of *the mind (*Alexander 2025). However, some further commonalities can be established:

> The 4E approach should be understood as a set of family resemblances of overlapping ideas, hypotheses, theories and conceptual frameworks about the mind, as well as methods for its study. The family resemblances span several dimensions, including but not limited to a rejection of dualism, non-representational explanations of the mind, phenomenological methods, the importance of embodiment, a dynamical systems perspective, and an evolutionary perspective on the mind. (Alexander 2025)

Indeed, it should be noted that the grouping of the different theses into the 4E collective can mask some of their differences and cases in which some of them are combined. Robbins et al., for example, prefer the 4E hierarchical in the sense that, according to their usage "situated cognition is the genus, and embodied, enactive, embedded, and distributed cognition and their ilk are species" (Robbins 2009, p. 3). Furthermore, as Gallagher has noted, approached in the 4E share the notion of embodied cognition while the group also includes embodied cognition as an approach of its own (2023, p.3), and it would be possible to assume an anthropocentric position in which embodiment is the default position in relation to which the others are assessed (without the body, there is no sense of the environment). However, as a trait common to distributed cognition more generally, 4E cognition builds on an opposition to the notion of cognition residing in “a central processing unit in a brain” (Newen et al. 2018, P.6). In this view, the approaches share a perception of the dependency of cognitive functions on “the morphological, biological, and physiological details of an agent’s body, an appropriately structured natural, technological, or social environment, and the agent’s active and embodied interaction with this environment “(Newen et al., 2018, P.6). An important implication of this claim for human-technology interactions is that the interface between humans and technologies becomes a central interest as well as a less clearly drawn at that.

Embodied cognition

The *embodied cognition* thesis proposes that at least some mental processes are not solely brain-based but constituted by interactions between brain and bodily structures (Shapiro 2004; Rowlands 2010, p.53). In Gallagher’s summary, the claim of the theorists of embodied cognition is that” the body’s neural and extraneural processes, as well as its mode of coupling with the environment, play important roles in cognition” (2023, p.1). Embodied cognition asserts that cognitive processes are influenced by the body’s morphology and sensorimotor capacities, but the claims as to the extent to which cognitive processes are constituted by processes in the body vary (Newen et al. 2018, P.6). While the embodied cognition thesis tends to focus on the body more than the environment, debates about the dynamic between the cognizer and their environment are important in considerations about the role of technology is relevant to the thesis of embodied cognition as it is to all varieties of distributed cognition. One indicator of the role of technology in embodied cognition theory can be seen in Shapiro’s (2007: 338) three research goals for embodied cognition:

> (S1) An emphasis on the contribution of physical bodily processes to the process of cognition
>
> (S2) An emphasis on the contribution of bodily factors to the content of cognition
>
> (S3) An emphasis on the importance of body–environment coupling for cognition.

While these goals may have a different meaning for scholars holding a weak or a strong form of the embodied view (see Gallagher 2023, p.5), the basic implications of these goals for the role of technology must be inferred from an absent presence. A basic inference of this kind could be that, if bodily factors are in this way linked to cognition, technologies that are related to bodily processes (from systems of movement like choreographies to devices like prosthetics), can influence that relationship.

Of course, the crucial question is the way in which technologies take effect in embodied processes, that is, whether bodily movements can be considered to have a technological dimension. A dimension like this could be as instrumental in response to the demands of an activity, such as learning patterns or systems of movement achieved through the conditioning of the sensorimotor system like hunting in a forest, sewing, stonework or figure skating, for example. A further example could be the regulation of emotional states by technologies that could also be seen as embodied, such as the “box breathing” technique used by military and law enforcement (Solan 2023) [3]. An even more basic example would be counting with fingers, and while this activity does not strike one as being highly sophisticated, it fulfills a purpose as a component in activity that is partakes in one of the most sophisticated of technologies: collaborative calculation (Dor 2023).

[3] Solan, M. (2023) Try this: Take a tactical breather - Harvard Health. Harvard Health Publishing.

One salient example of a technological phenomenon related to the embodiment of cognition emerges in the work of Lakoff and Johnson (1999), whose notion of metaphor addresses the way in which it "bridges embodied experience and conceptual thought" (Gallagher 2023, p.10). In this case, the functional principles of the technology – if language is taken as such – are based on a mapping of embodied human perception, as Lakoff and Johnson explain:

> […] the concepts of front and back are body-based. They make sense only for beings with fronts and backs. If all beings on this planet were uniform stationary spheres floating in some medium and perceiving equally in all directions, they would have no concepts of front and back" (1999, p. 34).

The innovation in this technology is, presumably, the metaphorical extension of this body mapping outside the context of the body – into ideas about things in the world having "fronts" and "backs". However, it needs to be pointed out that how this bridging between "embodied experience and conceptual thought" is conceived as a "mechanism" by Gallagher (2023, p.9) rather than as an innovative means to an end. Yet if seen as a technology[4], language in this way exemplifies the long span effects of human-technology interaction – through a pattern of coevolution – as well as the accumulative interactions between technologies, as the technologies of spoken language are developed into written language and various specialized languages, such as languages of instruction for other technologies for example.

In summary, the thesis of embodied cognition seems to hold a significant potential for revisions of the concept of technology. While technology as such may not be in the focus of the approach, the processes by which its functions can be or become embodied can be a vital extension when considering the depth of human-technological integration, or this integration as a state of being from the outset. In the dimensions of the concept of technology, embodied cognition extends what we could call *human technologies*, or technologies in which human biomechanics and cognition form functionally and materially integrated components, sometimes all the central parts in the technology, such as in spoken or sign languages.

Embedded cognition

Further explicit connections between distributed cognition and technology emerge in the thesis of embedded cognition, which proposes, in general terms, that "in some cases the environment scaffolds our cognitive processes, or that engagement with environmental features can shift cognitive load" (Gallagher 2023, p. 14). What "environmental features" refers to here can be anything from natural phenomena to built environments and the tools provided by it or devised by the agent themselves. The thesis thus articulates, albeit without strong commitments, a very broad field of study, particularly when put in a more universalist manner, as Jurgens (2023) does:

> The embedded thesis refers to the assumption that an embodied person is always situated within a particular socio-material environmental setting, and this environmental context shapes the

[4] As has been done by scholars from various disciplines, such as linguistic theory (Mufwene, 2013), neurolinguistics (Dor, 2015; 2017), law (Del Mar, 2021) and natural sciences (Morgan, 2022), while Enfield (2015, p.218) comes very close to doing so. Each of these scholars also stress how, rather than just providing the resource for cognitive offloading, these technologies enable revisions in patterns of thought.

individual's mind and cognitive processes via their embodied engagements with it. (p.3)

Embedded cognition often overlaps with embodied cognition and *situated cognition*, where context and environment constrain and guide activity (see, for example Suchman, 2007, pp. 26; 31). Alternatively, situated cognition is sometimes considered a conceptually weaker form of *extended cognition* as it suggests that cognitive processes are situated within and influenced by the environment but not necessarily constituted by it (Rowlands, 2010). In addition, Newen et al. (2018), for instance, distinguish embedded cognition from extended cognition by emphasizing the causal role of the environment for cognition rather than a constitutive one, which again aligns with the weaker, causal view of environment in the embedded cognition approach. In other words, embedded cognition is more limited form of cognitive extension in that it proposes that cognitive processes are shaped by the environment, but do not extend into as they do in extended cognition, in which the relation is constitutive (Gallagher, 2023, p.29).

However, regarding the concept of technology, it does not seem highly consequential for the study of human-technology interaction – at least from a pragmatic perspective – which version of the causal-constitutive thesis is accepted. As a starting point, it may suffice to posit that cognitive processes are, to some extent, supported by the resources an agent can recruit in their environment. If some of these resources are argued to be technologies, practical questions about the qualities and processual details related to the interactions with the technologies would be far more central than theoretical ones about the mind.

Robbins et al. propose that "[t]he theoretical and methodological import of embedding, however, is much wider" than the pointing out that the effect of embodiment can only emerge in interaction with the environment, a specific situation, as it "points to the importance, in general, of studying cognition "in the wild," with careful attention to the complex interplay of processes spanning mind, body, and world (Hutchins, 1995)" (Robbins, 2009, p.7). Here, the connections between the earlier ecological psychology of James Gibson and the later enactivist approaches become relevant to the extent that they subsume the embedded argument for the purpose of this review. Therefore, the significance of the embedded argument to the concept of technology will be discussed in later sections on *enacted cognition* and *affordance theory*.

The main dimension in which technology can be seen to operate with respect to the embedded thesis is, of course, the environment. This underlines the ubiquitous nature of technology, the view that technology is always already there, as elements of the cultural, social, linguistic, architectural milieu or infrastructure. Furthermore, the consequences of being embedded in a technological milieu in this way does not merely suggest the potential for cognitive offloading, but existing practices that guide action to be carried out in certain ways. This also points towards the bidirectionality of technology – to the idea that technology is not merely there to enable action but also affect the ways in which their users carry out the actions or even decide what action is to be carried out.

Extended cognition

Originating with Clark & Chalmers (1998), the thesis of *extended cognition* posits that cognitive processes can extend into the environment. As suggested above, the similarities with the embodied and embedded theses are uncontroversial, but the extended thesis goes beyond these two to make a stronger claim of dependence for cognition. From the perspective of extended cognition, mental processes are seen as hybrid, involving both internal (brain-based) and external (environmental) operations (Rowlands, 2010, p.58–59). For example, external structures (e.g., notebooks, tools) become part of cognition when manipulated to make information available for further processing and, in cases like this, “the human organism is linked with an external entity in a two-way interaction, creating a coupled system that can be seen as a cognitive system in its own right” (Clark & Chalmers 1998, p. 8). This position is considered the constitutive one, and according to Newen et al. (2018), this form of extended cognition thesis has been accused

> […] of the so-called coupling/constitution fallacy (Adams and Aizawa 2008; Rupert 2009), according to which the strong coupling between neural and extraneural processes, including bodily movement and use of pencil and paper, for example, does not suffice to make the non-neural processes constituents, rather than just causal or enabling conditions of the cognitive process. Quite generally, the question is whether, and if so, how, we are able to decide (either empirically, pragmatically, or a priori) whether a particular cognitive process is constituted by or merely dependent upon extracranial or extrabodily processes.

Whether or not the question about the constitution of cognitive processes can be answered does not necessarily inform research into technology and its role in distributed cognition. On the level of analysis of interactions, the view of causal dependency seems sufficient; after all, a view of a “cognitive system” remains a rather vague notion and does not seem to require that all of its constituents are constituents in the same way, or “on par” as Clark and Chalmers put it (1998). Furthermore, while in the early versions of the extended view, the parity claim for the internal and external resources did suggest just this kind of equality between the constituents, later revisions have significantly loosened this commitment (Hutchins, 2013, p.35; Clark, 2008; Michaelian and Sutton, 2013). However, the claim of strong coupling does pose an interesting question as to the extent to which technological systems can be seen as integrating with human activities – or how much of the socio-material environment and its effects are taken for granted, rather than analyzed as systems or conditions comparable to tools? In the earlier discussion of the embodied view of cognition, for instance, some of the embodied *practices* (or *techniques* or *technologies*) such as box breathing involve the body in extracranial coupling on an intensity scale that seems to be at the extreme on a continuum of causality (if not slipping into the constitutive).

From the perspective of technology, the analytical scope of extended cognition is, perhaps, more important than the claims about the ontological aspects of cognition. Hutchins’ (2013) summary of the extended cognition thesis points towards one limitation in this scope:

> Extended cognition refers only to that subset of cognitive events that involve interaction of internal and external resources. The individuation of cases of extended mind depends on empirical claims that are grounded in a container metaphor for mind. The extension of mind is manifest in links and relations that cross the usual boundary of the mind container. Second, extended mind assumes a center in the cognitive system: the organism (or the organism’s brain), which is the normal mind container with respect to which cognition can be said to extend. (p.36)

In such a view, considerations of what technology might be – in theory if not in practice – would have to be limited to cases in which the boundary of the “mind container” is crossed. It would therefore be unclear whether a cognizer engaging with a verbal narrative – as a resource in memory – would be counted as a relevant extended cognitive event only when spoken aloud,

listened to or written down or read, but not if the boundary of the mind is not crossed, for example when the narrative is recalled from memory for the purpose of reflection in the mind, even if the activity would inform or affect the cognizer's behaviour.
Based on the limitations above, the unit of analysis for extended cognition has been described by Hutchins as follows:

> In this review of spatial scales for distributed cognition systems, the extended mind approach occupies a mid-level scale. It picks out a particular class of distributed cognitive systems that operate on a spatial scale somewhat larger than an individual person. Such systems also have a temporal scale, typically completing operational cycles on the order of seconds or minutes. Cognition in such extended mind systems emerges from the interactions among resources inside an individual agent and resources that are external to the agent. (2013, p.37)

Within this limited scope, extended cognition directs attention to the intensity of distribution even within a highly limited "operational cycle", which enables the tracing of interactions in fine detail. However, the rhetoric of the "boundary" that the notion of a mind container establishes between the mind and a world outside it carries implications of a mind/body dualism, which also prohibits a constitutive view of distributed cognition. Furthermore, extended cognition is sometimes characterized as subsuming embodied cognition into a view in which the body – together with the environment – can be seen as forming an external resource:

> When we bring together the arguments and evidence in support of extended, distributed, and embodied cognition we form the view that cognizers are embodied and located in a situation which has both physical and social aspects, and that some bodily interactions with the environment constitute cognitive processing. (Menary 2010, p.227)

Similarly, Hurley (1998) and Rowlands (2006) expand the embodiment thesis and the extended thesis into vehicle externalism in which technology vanishes from view altogether, except in the abstraction of vehicles of thought possibly realizing as "some of the cognitive resources […] inside, and others outside the head" Wilson (2010, p.174). The thesis emphasizes action – manipulating, exploiting, and transforming external information-bearing structures, while the notion of the internal cognitive resources and its mediations are less central. The body, in this view, can be seen as a tool for cognition, but in describing the interactive processes that enable this coupling between the agent and the environment, the focus is not close enough to the external vehicles to enable explications of the processual intricacies of the interactions or what their functions would be:

> There is, of course, a continuous looping causal interaction between neural processes and bodily manipulations of external vehicles; but the focus shifts from this to the nature of the bodily manipulations themselves and how they are integrated with neural processes such that they form a hybrid cognitive process. (Menary, 2010, p.227)

In this description, it is the pragmatics of how the manipulations of external vehicles take place that would need further clarification, but based on this description, it is also difficult to say how the interactions with specific technology would be articulated. Demonstrated via a more practical example, it seems that the concept of vehicle centralizes the experiential – and medial – aspect of technology, again, in the experience of the vanishing technology:

> The blind person does not experience the object as "on the end of the cane," nor does he experience it as a blocking or resistance to the cane. Rather it is in virtue of the object of being on the end of the

> cane, and in virtue of the resistance it provides to the cane, that the blind person experiences the object as spatially located in the world. In employing the cane, the blind person ceases to experience the cane. The cane becomes a vehicle of his experience not an object of it. As revealing activity, his experience passes all the way through the cane to the object itself. (Rowlands, 2010, p.287)

The explication here of the causal looping resembles Hutchins' (1995) descriptions of the processes of medial transformations in tools use. The difference comes across in the experiential, subjective and phenomenological explication of the *vehicle nature* of the cane. For the technologies involved, this view highlights human adaptability in experience: rather than perceiving the cane as external add-on, it becomes integrated in human experience, and while the example may not be very striking in this respect, a wider view of technology – the cultural, social and built environments – helps in reconsidering the vast extent of the technological that becomes experientially humanized in this way, vanishing from view as "external" or "alien" and becoming part of the "natural". Finally, it should be noted that the embodied thesis has informed and continues to inform other views within the 4E of cognition, enacted cognition in particular, as will be demonstrated shortly.

Enacted cognition

First defined by Varela, Thompson, and Rosch (1991), the enactive approaches to cognition elaborate the embodied and situated approaches in the domain of the intentionality of action. As with most of the 4E approaches, proponents of enactive views deny – albeit with variable confidence – "that the best way to explain cognition is to posit the construction of internal representational models built on the basis of retrieved informational content" (Hutto and Myin, 2013, pp. 1–2). Instead, action – cognitive and otherwise – is considered situated and embodied, and these contribute to how an actor is oriented towards action, as cognition "depends upon the kinds of experience that come from having a body with various sensorimotor capacities" (Varela et al. 1991, 173). As suggested above, the shift towards an individual subject carries a strong phenomenological emphasis:

> From phenomenology, enactive approaches draw on Husserl's pragmatic idea that I perceive things in terms of what I can do with them, which shapes our primary experience of the world as a prereflective, action oriented operative intentionality (Merleau-Ponty 2012), rather than as a reflective intellectual contemplation or observation. (Gallagher, 2023 p.30).

By a broader appeal to the sensorimotor (and embodied in the biological sense) makeup of the experiencing subject, the view of enacted cognition shifts the focus towards dynamic interaction with the environment. The similarities with the other 4E are present here as well, as many of their adherents "not only maintain that cognition involves extracranial processes, but also that cognition is enacted in the sense that it involves an active engagement in and with an agent's environment" (Newen et al., 2018, p.7). According to Hutto and Myin, for enactivists, embodiment is not defined with reference to an intuitive, every-day understanding of bodies and their boundaries, but in terms of wide-reaching organismic sensorimotor interactions that are contextually embedded" (2013, pp. 5–6). In practical terms, enactment can be described in reference to a model of interactions, such as described by Jurgen:

> The enactive thesis subsumes the assumptions of embodiment and embeddedness, and maintains that cognition and possibilities for action are dependent upon action-perception cycles that are not only shaped by one's embodiment and embeddedness, but in acting within the world, the

> individuals enacts their own sense of meaning, or sense-making, that shapes the world to suit their needs and actions. (2023, p.3)

In this description, the back and forth of perception and action can be seen as a reiteration of Hutchins' (1995) model, albeit the background assumptions about cognition are likely to differ, since claims about neural computations and mental representations are generally rejected in enactivist approaches, as well as in much of Hutchins' work[5]. In enactivist analyses, the way the interactions are viewed against the context of action is also less linear and less reducible to the purpose of the activity when compared to Hutchins'; rather, as Hutto and Myin characterize it, "these dynamic interactions – in which cognition literally consists – are loopy, not linear" (2013, p.6). This non-reducible character of interactions is due to the manifold causalities that come together in interactions between an organism and its environment:"[v]ariables in the environment influence and are influenced by variables in the brain and the non-neural body in a recurrent manner, making it impossible to conceive of these as linear relations holding between inputs and outputs" (Hutto and Myin, 2013, p. 6). The origins of the enactivist views are in biological theory rather than psychology, which is reflected in the strong focus on the way in which the sensorimotor system is seen as having an important function in maintaining the organism's ability to not only couple with but adapt to the environment (Gallagher, 2023, 33). The action orientation, sense-making and the mind of the organism is thus connected to its basic biological functions albeit not in a deterministic way:

> This does not mean that the organism is causally closed to the environment, however. Rather, it is structurally coupled to the environment, drawing energy from it, and adapting to changing circumstances (Di Paolo 2005). Adaptivity involves the organism, which is never in perfect equilibrium, engaging in a precarious process of regulating itself with respect to maintaining stable, dynamic viability. (Gallagher, 2023, 33)

Consequently, in enactivist views, the model of cognition does seem to do more work as the interactions between the body and the world can have a constitutive role in "shaping minds and cognitive processes" (Jurgens, 2023, p.3) of an individual. In a sense, then, the environment calls for action, further underlining the qualitative aspect of the organism's manner of perceiving it, its sensorimotor system. As Varela et al. have put it:

> In a nutshell, the enactive approach consists of two points: (1) perception consists in perceptually guided action and (2) cognitive structures emerge from the recurrent sensorimotor patterns that allow action to be perceptually guided. (1991: 173)

As with some of the other Es, two versions – strong enactment and weak enactment – of this claim have been articulated:

1. A cognitive process is strongly enacted if it is partially constituted by the ability or disposition to act;

2. A cognitive process is weakly enacted if it is only partially dependent upon the ability or disposition to act. (Newen et al., 2018, p.7)

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[5] In *Cognition in the Wild* (1995), the study of ship navigation is conceived as a computational system, yet the computations are not based on a model in the individual's cognition but emerge in distributed systems between humans and their tools.

Enactivits perspectives thus involve questions of agency quite explicitly, albeit with variable degrees in attributing autonomy. As pointed out by Telakivi (2000, p.17), further differences between enactivist approaches are visible in varying emphasis within different parts of the sensorimotor system and the experience it enables, such as the experience of cognition (Gallagher, 2005), perceptual experience (Noë, 2004), and affect (Colombetti, 2016; Colombetti and Roberts, 2014). Cognition, as a whole, therefore constitutes the means for the cognizer to perceive the environment and its effects on itself as well as to perceive itself and its actions effects to the environment:

> The body shapes, enables and sets the limits for our minds. Its anatomy, structure, motor capabilities, etc. determine how we perceive the world and what we can do in it. (Telakivi, 2020, p.17)

Furthermore, as "higher-order cognitive functions, such as reflective thinking and deliberation, are exercises of skillful know-how and are usually coupled with situated and embodied actions" (Gallagher, 2023, p.33), technology can be seen as an integrated, constitutive component in this system rather than an external addition or augmentation – after all, any change in the relations between the actor and the environment will change how it is perceived, thus transforming the orientation grounds for action. The implications of this view to ability and disability as access points to action are significant, as described by Noë:

> Against this background of this important idea, I argued (Noë, 2004, 2012) that the varieties of presence correspond to the varieties of different ways we can achieve access. Sensory modalities, on this view, are styles of access. Thought, as distinct from perception, is a different style, that is, manner of skillful achievement, of access. Concepts themselves, on this view, are a distinct species of skills-of-access. (2021, p.960)

By incorporating skill into the way sensory modalities are processed as resources to gain action potential in the notion of *style of access*, experience becomes conjoined with agency on the embodied level. Becoming aware – if not conscious – of this relationship enables a self-induced increase in skill, and as Noë suggests, this can involve patterns of thought, and in Noë's enactivism, technology is given a broad definition not only in this interactive and integrated sense, but in terms of its constitution as well:

> There's an intimate link between technology and organized activities. Roughly, a tool (such as a hammer or a computer) is the hub of an organized activity. Technology is not mere stuff. It is the equipment with which we carry on our organized activities. Technologies organize us; properly understood they are *evolving patterns of organization*. Once this link is clearly appreciated - that technologies are patterns or organization - then we can begin to appreciate that breast-feeding, really, is a kind of primitive technology; dancing, likewise, is a technological activity; developed technologies are domains for organizing ourselves in ever more complicated ways. (2015, pp.19–20)

Technology, in this view, is broadly understood, and seen as

human, in the sense that it functions in an integrated relation with the sensorimotor, perceptual and cognitive functions of humans and can even fully embodied, i.e. entirely based on these functions.

accumulative, in the sense that technologies, as evolving patterns of organization build on each other, forming complex, aggregate systems

ubiquitous, in that humans do not, by and large, exist without technology – i.e. it is not optional

bidirectional, as it reorganizes human experience and behavior instead of acting as a neutral augmentation

By virtue of not being unidirectional, neutral tools, technologies also enable novel, creative access to the world, as Noë suggests:

> Technologies don't just fill antecedently existing needs and they don't do so merely by amplifying what we can do. They let us do new things, not only to solve old problems but also to frame new ones. (2015, p.24)

Technology, put in this way, expands action possibilities through the changes that emerge by its use in a bidirectional relation with the user. Yet technology, in this definition, is also specific: if it addresses situated problems in the lifeworld as posited in enactivist approaches, its functions are specific to the possibilities and constraints of the situation and the agent embedded in it. This principle that can be inferred from the context-bound intentionality put forth in the enactivist perspective seems fully compatible with Daniel Dor's proposition about functional specificity of technology:

> Every technology employs a specific functional strategy, and the specificity of the strategy determines the technology's functional envelope: what it can do with high levels of efficiency, where its efficiency declines, where it collapses, and what it cannot do to begin with. (2015, p.2)

While functional specificity does not prevent the technology from being successfully applied in multiple ways, it does imply a strong argument for empirical work in investigating human-technology interactions and thereby introduces boundaries to the analytical scale despite the broadness of the concept of technology. For example, studying language as technology – as a means to an end – always implies a particular use of language and therefore involves the perspective of pragmatics, which in turn limits the scope of inquiry to the event of particular use.

2.4.Approaches to distributed cognition – a summary

In approaches to distributed cognition, technology use is a crucial yet elusive interest. Kirsh's description of a persistent methodological gap illustrates this complication within distributed cognition research: "[p]eople interact with artifacts, technologies, surfaces and other people in ways that overwhelm our current formalisms" (2008, p.57). In addition to Kirsh's worry about the lack of methodological grip on interaction, the way technologies are grouped as separate from artifacts and surfaces is symptomatic of a wider practice across the approaches.

In distributed cognition literature, technology is routinely placed into various abstract categories, such as *epistemic structures* or *external scaffoldings* (Clark, 1997), *cognitive artefacts* (Hardy-Vallée, 2008, p. 3), or simply *artifacts* (Reichelt & Rossmanith, 2008; Suchman, 2007), or "mutual partners in complex work" (McNeese, 2017). Dror and Harnad (2008, pp. 19–20) broaden the scope of the concept by introducing “cognitive technology”, which encompasses both physical tools (e.g., machines) and symbolic systems (e.g., language), though this redefinition is not supported by systematic analysis of either of these as technologies. Sutton includes “external cultural tools, artefacts, and symbol systems” within the group of *cognitive technologies* and notes that “natural environmental resources”, too, may serve as transient cognitive scaffoldings (2008, pp. 47–48). Yet the mechanisms by which organisms transform such resources into cognitive systems are not explicitly defined as technological – or otherwise. Furthermore, Sutton identifies patterns or systems of activity as central to enabling socially distributed cognition (2008, pp. 47–48) but does not categorize them as technological. In discussing “internalized cognitive artefacts,” such as mnemonic techniques, Sutton refers to them as “stratagems to bootstrap, manage, transform, and discipline our minds” (2008, p. 49). Thus, despite the vast body of work in theoretical and empirical research into distributed cognition that has accumulated since Kirsh’s diagnosis of a “failure in catching the phenomenon” (2008, p.57), the concern still seems relevant as far as the role of technology is concerned.

In order to assess the significance of the 4E to the concept of technology and vice versa, we can consider James Carney’s example of a calculator:

> Consider my planning of my monthly finances using an electronic calculator. Depending on the 4E theorist, this process can be described as embedded cognition (it facilitates thinking by causally exploiting an object in the environment) or extended cognition (the calculator constitutes part of my cognitive apparatus). However, the action also enacts a world: by budgeting for the future, certain items in the environment are disclosed to me as affordable or not affordable. Finally, my physical and cultural embodiment as a human being shapes my cognitive processes, such that I am most comfortable using decimal arithmetic (I have ten fingers) and will avoid thinking with degrees of precision greater than is practically useful (enculturated knowledge). Inevitably, the 4 E’s shade into one another, and authors differ in how they define them. Nevertheless, most agree that they constitute a form of dynamic coupling, where the brain-body-world interaction links the three parts into an autonomous, self-regulating system. (2020, pp.1–2)

Purported as critical and somewhat tongue-in-cheek, Carney nevertheless arrives at the same focal point as was done with Hutchins’ approach in this review: dynamic coupling with the environment in which the different Es are difficult to tell apart, particularly when extensions such as “enculturated knowledge” are evoked. As Carney points out, the field of application of 4E (or distributed cognition) seems to be dangerously out of boundaries:

> More speculatively, it is also true that the entire apparatus of culture can, in many ways, be thought of as the displacement of challenging cognitive operations into material and symbolic artefacts in the environment. (2020, p. 3)

What makes this a particularly daunting vision is that it is not just the entire apparatus of culture that becomes a source of individual means for cognitive offloading, but that even for the individual member of the culture, a myriad of these means and systems of means can be active at the same time, and Carney’s calculator is a good example of this, even while it is only a simplified description.

If the propositions of distributed cognition are taken seriously, the concept of technology will need to be examined as well. Thus, for example, when McNeese et al. describe the scope of research into situated and distributed cognition as “inclusive of physical characteristics of a place, the social milieu that surrounds and leads to team cognition, the cultural backdrop that makes sense out of actions, and the technology that supports cognition" (2017, p. 53), it is not altogether clear that technologies are not already part of the physics of a place, the social milieu and cultural backdrop, or at least in deep interaction with them. A compelling example of the potential of a wide view of technology can be extrapolated from the proposition by Hardy-Vallee that language could be seen as "the ultimate cognitive artifact" (2008, p.3). In this view – particularly when expanded into cultures and institutions as Hardy-Vallee proceeds to do – cognitive artefacts "allow our species to extend cognitive processes beyond the brain, the body and the immediate environment" (2008 p.3). Since artifacts of this kind would be present to – and functionally intertwined with – any task carried out with the help of technologies in the narrow definition, the boundary between technology and cognitive artifacts no longer helps understanding the interactions between tools that based on a vague set of material forms (technologies as external objects) and tools based on mental activity that is realized in some material form (technologies as ideas, systems and frameworks).[6]

On the other hand, if one wishes to remain agnostic about the exact locus of cognition and keep the analysis on a pragmatic level, it may be possible to maintain a non-committal phenomenological view on all varieties of the "distributeds" and focus on the empirical and inferable aspects of the relationship between humans and their environment. In both cases, the condition of being cognitively "distributed among agents, artifacts and external structures" (Hardy-Vallee, 2008, p. 4), can be technologically mediated in all directions, no matter what exactly cognition is thought to be.

Based on the review above, a crucial element in approaches to distributed cognition is embodiment. As Telakivi has pointed out, "[i]t is not possible to embed or extend in the environment without a body as part of the process" nor to "enact in an environment without a body" (2020, p.17). While the environment is an essential element in the modelling interaction, it is the embodied state – the organism's capacity to perceive features of the environment – that makes its role in the interactions highly selective and qualified. This is a proposition that also implies the necessity to account for perceptual and experiential aspects of distributed cognition. In this way, too, embodiment points towards phenomenology, and as Barrett and Stout remind us, the notion of embodiment of cognition has its roots in the phenomenology of philosophers like Husserl and Merleau-Ponty, the functional psychology of William James and John Dewey (2024, p.2). Phenomenology does not end with these names, of course, and in a later section, new developments in philosophy of technology will be reviewed to gain a wider footing in embodied interactions with technology. Next, however, we will explore another cornerstone of ecological theories.

While distributed cognition emphasizes systemic interactions between humans, tools, and environments, it leaves open questions about how these interactions are perceived and acted upon in practice. Affordance theory addresses this gap by focusing on the relational properties that make actions possible, offering a lens through which technological features and user capabilities can be analyzed. The next section explores how affordances bridge theoretical insights and design applications, shaping the usability and experiential dimensions of technology.

[6] Taking the state of the approaches to distributed cognition as focused on their respective (empirical) pursuits – in which the scope of analysis alone is likely to discourage speculations over the concept of technology – further insight can perhaps be sought in how specific technologies or interactions with them are examined in practice. A separate review of empirical work would certainly be valuable.

3.Affordance Theory and the Practice of Design

While the theory of affordances does not constitute – or inform to any great extent – the theoretical foundation of any of the methodologies applied in NewWorkTech, its influence can be seen in the application of the concept as a general notion of the action potential that technologies may yield or as a marker for specific ways in which users of technology may gain agency in action. Within multiple disciplines, the concept of affordance is deployed to refer to the ways in which features of artifacts guide interactions with them or provide contextual action possibilities. As a notion, affordance is a frequent item in distributed cognition discourse (and beyond), and its use may or may not be motivated by deeper theoretical agreement. As with the theories discussed earlier, the purpose is not to engage in any debates related to views of affordances, but to examine how technology has been conceptualized in relation to the notion of affordance.

The concept of affordances, as introduced by psychologist James J. Gibson (1966, 1979), emphasized the relational nature of perception and action. Bridging between an organism and its environment, the concept functions as a focal point in Gibson's ecological perspective:

> An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behaviour. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer. (Gibson 1979, p. 129)

At this initial stage, the notion of affordance was introduced as a concept expressing the relationship of organisms and their environment "the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Gibson 1979, p. 127). The ambiguity of the concept in Gibson's loose and abstract definition has generated a number of reformulations across a number of contexts and disciplines (Chong and Proctor 2020; Barsingerhorn et al., 2012). As Chong and Proctor put it, "on closer inspection, a search through the literature quickly shows that there is no singular definition of affordances and that discussions of the concept do not adhere strictly to the theoretical work conducted by Gibson (e.g., de Wit, de Vries, van der Kamp, & Withagen, 2017; Makris, Hadar, & Yarrow, 2013)" (pp.120–1). Among the differing definitions of affordance, Chong and Proctor have identified three influential developmental stages:

> Donald Norman's use of the term for the purposes of design (e.g., Norman, 1988), Mike Tucker and Rob Ellis's use in stimulus-response (S-R) compatibility paradigms (e.g., Tucker & Ellis, 1998), and Michael E. J. Masson and Daniel N. Bub's use and reintroduction of the role of context (e.g., Bub & Masson, 2010). (2020, p.118)

While Gibson's definition of affordance does not exclude an interpretation of the environment as social, cultural or even technological – after all, affordances of the environment could be argued to be those of a built environment or a social environment with various kinds of technological affordances – Gibson's work was primarily engaged in developing a psychophysical theory of perception rather than a theory of human-technology interaction (Chong & Proctor (2013, p.120). In the absence of a more general hypothesis on technology, the initial application of affordance theory on technological fields took form in Gaver's (1991) work with user interfaces for HMI research and development (Albrechtsen, pp. 8–9). However, affordance theory has also been combined with distributed cognition approaches in multiple ways (see, for example, Windhager and Mayr, 2024, p.11). Zhang and Patel (2006), for example, have explored how affordances relate to internal and external representations in distributed systems7, whereas other (Gallagher 2017; Hutto and Myin 2017) have adapted affordance theory to enactivist approaches and embodied cognition

3.1.Affordances in Design Perspective

Donald Norman, whose background is in cognitive psychology and engineering, has developed a highly influential version of affordance theory that revised the concept of affordance for the study of technology. Norman's revision – and comprehensive expansion in the fields of design and methods of technology analysis – of affordances sought explicitly to explain how users perceive and interact with the environment, much of which could be described as technological or consisting of technological systems.

In Norman's definition an "affordance is a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used" (2013, p. 33). The definition maintains the basic idea from Gibson's affordance – the relationship between the organism and its environment – but emphasizes the perception of the environment – or object – as a tool and shifts the model into an anthropocentric perspective. The relationship that comes from the combination of "qualities of the object" and the "abilities of the agent" further incorporates notions of instrumental specificity and ability (or disability) in tool use. This reformulation of affordance for the purposes of technology design is also visible in how Norman introduces restrictions to action, or "anti-affordance" which is "the prevention of interaction" (2013, p.33), and a theory of how technological designs communicate about their affordances to the user (Norman, 2013, pp. 13–19). Consequently, Norman's version of the concept has come to be known as perceived affordances as opposed to Gibson (1977), whose "affordances of the environments are facts of the environment, not appearances" (p. 70). As Proctor and Chong (p.121) explain, Norman

> […] used the concept of affordances to refer to the perceivable actionable properties of objects. For instance, a chair could be considered to afford sitting, a knob to afford turning, and so on. […] Gibson, on the other hand, might state that a large number of objects might afford sitting regardless of the intentions of any particular designer. However, Norman's use of the term affordance was geared specifically toward the design of common objects, and after its initial introduction, Norman came to refer to his reformulation as perceived affordances, as distinct from Gibson's original formulation, which Norman called physical affordances, in an effort to reduce confusion in subsequent editions of his book (Norman, 2002).

Considering the concept of technology, the differences between perceived and physical affordances is an interesting one. Norman's definition of affordance focuses on features relevant for interaction: "[a]n affordance is a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used." (2013, p.33). The relationship is given in analytical terms, as "qualities" are posited in a relation to "abilities", and the possible action emerges, presumably, via an ability that matches with a quality. Affordance is

[7] In Zhang and Patel's formulation, "[i]n distributed cognition, affordances can be considered as distributed representations extended across the environment and the organism" (2006, p.337).

thus not a property, as Norman (2013, p.33) states, and while the lack of a desired affordance can be due to a lack of a match between the qualities of an object and the abilities of an agent, an "anti-affordance" is also possible in cases in which interaction is prevented by design (Norman, 2013, p.33), although it seems possible to imagine cases in which an anti-affordance emerges by mistake, such as when a feature like stairs is not accompanied by a ramp, therefore providing a set of qualities that do not match with the ability profile of a person using a wheelchair.

What is very clearly expressed in Norman's formulation of affordances is the analytical system of conditions for action potential; with it, it is possible to conceptualize any technological object as a paradigm of qualities that give it a profile for potential use, whereas the user can be conceived of having their own ability profile, a paradigm of abilities that determine the extent to which they can exploit the qualities of the object. These ideas being central to the interests in the NewWorkTech project, we will give particular focus to Norman's systematic theorizing of technological affordances.

On one hand, design – commonly understood as activities aiming for the development of technologies – can make affordances in the environment recognizable, whereas perceived affordances are already recognized as such, as tools (or action potential) for a recognized purpose. As explained by Norman, affordances determine what actions are possible, but what communicates to the user where the action should take place are signifiers (2010, p.14). By the concept of the perceived affordance – and the signifier – Norman integrates the idea of affordance to the social and the historical, i.e. culture: "[t]he interpretation of a perceived affordance is a cultural convention" (Norman, 2010, p.145).

What is significant here is not the demarcation criteria for what technology is (or what it is not), but the role of knowledge, the *logos* of technology. The argument seems to be that, through perception of the action potential, an affordance becomes a relation between an agent and the environment, and the practical efficacy of this relationship is determined by the kind of knowledge that the agent has. In this relation, perception of affordances is also dependent on both the perceiver and the environment: whatever there is in the environment must be perceived by the agent, whose ability to actualize affordances is further conditioned by their cultural knowledge and the way in which the individual can put this knowledge into use.

While Norman's perspective is partly rooted in the practice of design, it can be read as theory and some of the most prescriptive notions about design provide insights into further theorizing of affordances and technology. In relation to successful design, for example, Norman states, for example, that

> Good design is actually a lot harder to notice than poor design, in part because good designs fit our needs so well that the design is invisible, serving us without drawing attention to itself. (2013, p. xi)

When Norman suggests that technological design becomes visible, the implication is perceived without conscious effort, in an effortless "coupling" – to use a term from distributed cognition – with the environment. It could be argued, of course, that there are technologies, such as hazard stripes and fire alarms – whose exact purpose is to disrupt the ongoing activity by drawing attention to themselves, but this example is also based on the assumption that the imagined person in these scenarios is already engaged in activity that could be potentially disrupted.

Norman's practical perspective thus combines the intentionality of human behaviour with the basic principles of distributed cognition, as for Norman, human cognition, perception and action is embodied and embedded in a technology-rich environment. Yet human ability to function is context bound in more subjective ways, as the action of opening a door involves both the subjective goal of traversing to a destination as well as the subjective ability to perceive the door and the technological features that afford opening it. Norman theorizes the initial, perception-bound interactions with technology as *discoverability* and *understanding* (2013, p.3). Discoverability refers to whether it is "possible to even figure out what actions are possible and where and how to perform them", whereas understanding is related to things like "what does it all mean? How is the product supposed to be used? What do all the different controls and settings mean?" (2013, p.3).

The role of perception and interpretation thus become crucial for human-technology interactions, and Norman uses this as a foundation for a theory of design in which human experience is given central place. This becomes most visible in Norman's partitions in design practices, in which industrial design is amended, first, with *interaction design*:

> The focus is upon how people interact with technology. The goal is to enhance people's understanding of what can be done, what's happening, and what has just occurred. Interaction design draws upon principles of psychology, design, art, and emotion to ensure a positive, enjoyable experience. (2013, p.5)

By stipulating interaction as a specific category for design goals, Norman necessitates further elaborations of what human-technology interactions are like. Norman's second category is *experience design*:

> The practice of designing products, processes, services, events, and environments with a focus placed on the quality and enjoyment of the total experience. (2013, p.5)

The emphasis given to experience through this category introduces a bidirectional view of technology as not only means to ends, but as something that affects the user. In fact, Norman makes a further point of emphasis for technological affect by proposing that the user experience is "critical, for it determines how fondly people remember their interactions" (2013, p.10). In Emotional Design: Why we love (or hate) everyday things (2004), Norman expands this view into further design domains (p.5), namely visceral, behavioural, and reflective that correspond with appearances, the pleasure and effectiveness of use, and the rationalization and intellectualization of a product. The articulation of the experiential requirements may seem as prescriptive – in service of a consumerist view of customer-pleasing – but the experiential aspect does not need to be seen as narrowly as that. Interpreted through a broader ecological frame, it could be said that the design principles of interaction and experience design extend the scope of design beyond making affordances reliable (as would be the task of industrial design and production) and make it about stabilization of affordances in the experiential sense. In other words, the domain of the concept of technology begins to cover the ways in which affordances are reliably perceived and experienced.

3.2.Affordance theory and the scope of technology

Assessed in terms of its openness, Norman's view of technology can be characterized as a relatively wide one. In *Living with Complexity*, Norman (2010, p. 5) offers three views of technology:

> Almost Everything Artificial Is Technology
>
> New stuff that doesn't work very well or that works in mysterious, unknown ways.
>
> Technology: the application of scientific knowledge to the practical aims of human life or, as it is sometimes phrased, to the change and manipulation of the human environment.

Using these three alternatives, Norman discusses popular, everyday perceptions of technologies critically and extends the concept beyond these boundaries. Norman's own characterization of technology (2) as [n]ew stuff that doesn't work very well or that works in mysterious, unknown ways" ironically points to his notion about the disruptive experiences with technology – that the user becomes conscious about technology when the coupling between the user and the technology is failing[8]. The dictionary definition (3) presents the standard connection between science and technology (discussed with reference to Pitt (2000) in the Introduction to this review).

Saving (1) last, the idea that "almost everything artificial is technology" is an interesting opening - a chapter title even – that Norman rather curiously leaves without further investigation. However, the logic of the statement is exemplified by indirect means in Norman's discussions of the law and baseball as *complex rule systems* and food preparation and coffee making – among many other things – as complex practices (2010). As opposed to what we have called a narrow view of technology, these examples show concrete and deeply human elements in technological solutions. The human body is inextricably embedded in these practices without simply becoming a "user" who pushes a button to initiate an automated process. The same is true of *optionality*: the technologies involved in these examples co-constitute, together with the human agent, practices that are so integral to the cultural and biological systems that opting out of them does not usually come to the picture. The activity of eating is certainly actionable without technology, but without even the most rudimentary technology – a fire and a sharp stick perhaps – it can become an unpleasant and potentially lethal undertaking. Without the accumulated knowhow about hunting and foraging, there might not even be the option to eat to begin with. A tentatively accumulative view of technology emerges in this context, as Norman makes the perception that "some apparently simple things are complicated because to use them properly requires knowledge of culture and customs a well as the behavior of others." (2010, p.6). Including such accumulated know-how into the technological *gestalt* would suggest a view of technology with a wide grasp on historicity and cultural conventions.

Consequently, Norman's idea of the artificial as technological can be seen, tentatively at least, to apply to artificial systems that are not artifacts or devices. We have already discussed language as such a technological system, and Brian Arthur (2009), for example, argues for a definition of technology in which the artifacts of the mind could be justifiably seen as technologies as well. Applying this kind of view of technology, some of Norman's analytical concepts seem highly

[8] Such failures are not, of course, limited to novel technologies. For a discussion on how technology becomes visible in failure as put forth by Martin Heidegger and Bruno Latour, see Verbeek 2005, pp.157–159.

integrated with a wide view of technology. For example, Norman postulates the category of functional constraints (2010, p.125) that can be effective in four domains: physical, cultural, semantic and logical. One example Norman gives of constraints is in relation to epic poetry in the oral tradition (2010, p.83– 84), in which constraints to what can syllables can be inserted to which point in the hexametric pattern, what words to use for what kind of description or event and what kinds of scenes belong to what kinds of narrative structures (or *Bauformen*, as put forth in Reitz and Finkmann, 2019). These constraints in the Homeric tradition, for instance, combine into patterns of oral composition in a system that, once learned, enables hour-long singing of tales without rote memorizing9. In being medial domains within which designs can be created, the idea that such designs could be seen as technologies that differ merely by the phenomena harnessed to create means to ends – some through physical objects, others by patterns of language – does point out continuities between them that are difficult to otherwise acknowledge.

By expanding the concept of technology, Norman arrives at an expanded view of technological systems that enables a shift of attention beyond the workings of a single device. An example of this view – applied as a unit of analysis – is seen in the differentiation between *device centered controls* and *activity centered controls* (2010, p.140). A lecture room, for example, can be a system of separate devices, each operated through their own set of controls. However, a lecture room with activity centered controls would enable a coordinated switch from slide presentation mode to discussion mode – the lights, projectors, audio devices etc. all orchestrated according to the desired activity mode. In the activity centered view, technology is humanized, bi-directional and accumulative (with tools, machines and embodied technologies existing in integrated systems) both synchronically and historically (a result of gradual development and expansion).

The technological system – in Norman's thinking – is thus assessed from a functional perspective that acknowledges the basic premises of cognitive ecology – that in order for the technology to work according to the goal of the activity, it is not enough for it to do this on the level of individual subsystems or components, but it must meet the needs across the entire system. Here, we have again discussed an example of modern communication technology which has not become naturalized enough to vanish from view, but turning attention to others may illustrate how much technology goes unacknowledged. One example is built environment; the architecture of not only the urban areas, but the rural and even uninhabited wilderness can be technologically structured in ways that communicate very clearly what kinds of activities can be undertaken in these spaces. Roads and paths are one part of a habitual "design language"[10], which has become so familiar to us that we rarely consider their role in informing and organizing what exactly can be done and with what technologies. On maps, for example, one can take the cue of the breadth of a line indicating a road to decide whether driving a fourteen-wheel truck will be feasible or not.

Furthermore, in Norman's wide view of technology, the role of epistemic systems shows a convergence of the technological: the collective epistemic system of cultural conventions informs users of technologies about action possibilities. This is commonly recognized in relation to culturally specific sign systems, but when understood as rule systems – the law, traffic rules and less codified sets like behavioral norms – systems like these emerge as ubiquitous technologies for

[9] Narrative and literary devices have, of course, been studied as technologies and as affordances – see, for example: Alarauhio, 2024; Toikkanen, 2024; Cave, 2016; Coeckelbergh and Reijers, 2016; Reijers and Coeckelbergh, 2016; Pence, 2000.

[10] Referring to the idea that visual and functional cues that communicate a product's purpose and how to use it (Norman 2010).

communicating how other technologies should be used – often in the form of constraints. Epistemic systems that are designed for increasing affordances could be technologies like user manuals, tutorial videos online, or educational institutions. In this way, Norman's design principles reflect a view of distributed agency, as the technologies humans use to mediate their actions are crucial in determining how agency is achieved: "[p]oor design leads to the emotional distress we have come to associate with modern technology" whereas "[g]ood design can provide a desirable, pleasurable sense of empowerment" Norman (2010, p.10).

Scope of analysis

In addition to the scalable – and readily expandable – view of technology implicit in the concept of affordance, the versatility of the concept is also evident in the way it does not prescribe a set or common scope of analysis. Norman's methods of sequencing human-technology interactions also show flexibility in this respect, as an analysis of interactions can be scaled within the stages of action cycles or limited to technology use in larger scale activities ("go shopping") or the smaller scale tasks that comprise them ("drive to the market", "find a shopping basket") (Norman 2010, pp.56; 172; 232).

Although affordance theory provides actionable principles for design, it does not resolve conceptual ambiguities surrounding technology and how it mediates human experience. To address these foundational questions, the following section turns to philosophical perspectives, which offer deeper insights into technological intentionality, mediation, and the bidirectional nature of human-technology relations. These views expand the discussion beyond usability to consider how technologies co-shape subjectivity and world-disclosure.

4.Philosophy: Perspectives on Technology

In this section, we return to the concepts of technology briefly mentioned in the Introduction. The review of approaches to distributed cognition and affordance theory has shown a general vagueness in the ways technology is conceived in these theories of human-technology interaction. In philosophy of technology, the discourse is, understandably, more oriented towards definitions of technology, but this perspective also provides significant import to the ways in which interactions are conceptualized.

Some of the basic differences in definitions of technology have been summarized by Dusek (2006, pp. 31–33), who gives three main categories of definitions, technology as *hardware*, as *rules* and as a *system*. The narrow view of technology as hardware has been challenged from a historical perspective by Lewis Mumford in the 1930s already, in a view of cultural adaptation in which technology may be evolving, but hardly a novelty in human cultures:

> Machines have developed out of a complex of non-organic agents for converting energy, for performing work, for enlarging the mechanical or sensory capacities of the human body, or for reducing to a mensurable order and regularity the processes of life. The automaton is the last step in a process that began with the use of one part or another of the human body as a tool. (1934 pp. 9-10)

This embodied view is further expanded into the social domain in views of technology as rules by not only Mumford, but Max Weber, B.F. Skinner, and Jacques Ellul, in particular, for whom "[p]hysical tools or machinery are not what is central; instead it is the means-end patterns systematically developed" (Ellul cited in Dusek, 2006, pp. 32).

The view of technology as system, as described by Dusek (2006), poses an interesting question about the contextual nature of technology by proposing that "[i]t is not clear that hardware outside of human context of use and understanding really functions as technology" (pp. 32-33). The examples of scenarios in which this would be the case are far from clear-cut, but the idea that technologies come to be in relations with their users, so that a *technological system* is something that "includes hardware as well as the human skills and organization that are needed to operate and maintain it" (Dusek, 2006 p.33). This formulation includes the human aspect of technology in a minimalist form, but the notion deserves further examination. It seems plausible that, when abandoned completely, no artifact can function as technology, but Dusek's first example of an airplane treated as a religious focal point by the "cargo cults" in the Pacific and the second one about "[i]ndigenous implements and twentieth-century Western abstract art objects" (2006, p.33) being exhibited side by side in a museum do not constitute abandonment of the artifacts, but their function in another context. The question of art as technology aside, the artifacts can be seen as assemblies in the technology of presentation for the exhibition, and it can be argued that not only the function of the indigenous implements, but the objects of modern art were transformed by the arrangement of juxtaposition.

Another, more systematic effort to reconceptualize technology is offered by Pitt (2000), who argues that, in order to be a functionable, a definition of technology needs a model (p.12). Pitt's definition, "technology is humanity at work" (2000, p.11), is broad at the outset; rather than a limited category of things, Pitt proposes it as a phenomenon of human activity. Pitt's clarification of the implications of this relocation of technology into interactions shows a shift towards a human-centered approach:

> Finally, this definition allows us to make the distinction we need, which I between the tools and their use. The tools themselves are not the technology; it is the use to which they have been put that marks out a technology, and it is people who do the putting to some use for some purpose. (2000, p. 12)

In this definition, a purpose-driven activity that applies some means developed to achieve the purpose becomes the human centred set of relations that give rise to technologies. Some further definitions are, however needed, and Pitt provides one for work "I propose to characterize work as the deliberate design and manufacture of the means to manipulate the environment to meet humanity's changing needs and goals" (2000, pp.30-31). The contextualization of technology thus becomes ecological, which opens many possibilities to reflect on the variety of technologies as the purposeful use of tools with respect to natural, social and cultural environments. However, in analysing technologies Pitt returns to what could be seen as modern technology – devices and machines resulting from processes of engineering. This not only makes it difficult to see how the model could help in investigating technologies of other kinds, but this also cuts off some of the multiplicity of technology – that there are always many technologies that converge to make functional system. Furthermore, the discussion on the individual designer as distinct from an institutional designer (an engineer) and Pitt's focus on the latter as the productive agent of technology (2000, pp. 29–32) also sidelines linguistic and cultural technologies – which are often not products of a process of engineering – as well as technologies predating modern engineering. A speculative proposition about human technologies is, however, presented, but merely to point out the difficulty of explaining the "laws" for such technology (Pitt, 2000, p.44).

While Pitt builds the model on an input-output view – in which the effects of human-technology interactions are unidirectionally consequential, he gives three kinds of cases in which a technical explanation is generally needed, and one of these is suggestive of a broader consequentiality of technology use. Technical explanation is, therefore, needed in the following cases:

> An artifact has failed to perform to expectations
> Someone wants to know how an artifact does the things it does or achieves the results it does; and
> Unintended consequences
> (Pitt, 2000, p.45)

The third case is rather interesting, and in relation to this, Pitt gives the example of the contraceptive pill, giving social consequences as an example of unintended consequences (2000, p.46). What is of crucial interest here is how these consequences become distributed across not only the biological systems that they chemically affect – the bodies of the people who use the medical technology – but the organization of the society, or even the cultural system in which this takes place. Appropriate causal pathways are indeed suggested in the wide view of technology, provided that the organization of human social systems, sign systems of human communication and cultural systems of meaning are interconnected, purposely developed systems. In such a multilayered technological environment, the reverberations of the effects caused by the introduction of a new technology could, perhaps, be accounted for as they travel through the media of interconnected technologies, triggering series of "domino effects" in the process. While ways of explaining such phenomena do not emerge in Pitt's model[11], he envisions a manner of providing technical explanations of how artifacts work like they do, which is "to reason backwards from the end effect to its immediate cause and then to its immediate cause, etc" (2000, p.47). At some point in such analysis, one might expect that there is a cause that connects the physical artifact to some kind of sociocultural framework and at this point, we approach, again, the theme of human technology. It appears that in each case in which the boundaries of technology begin to close in on an isolated tool or device, the difficulty is in accounting for the human elements in technology, its use and the dynamics of human-technology interaction. One manifestation of this is in Heidegger's perception of the danger of modern technology, which is based on the effect of the technological on the human:

> It remains true nonetheless that man in the technological age is, in a particularly striking way, challenged forth into revealing. Such revealing concerns nature, above all, as the chief storehouse of the standing energy reserve. Accordingly, man's ordering attitude and behavior display themselves first in the rise of modern physics as an exact science. Modern science's way of representing pursues

[11] Others have provided a more grassroots level of analysis for unintended consequences that also acknowledges beneficial side effects of technologies, as Mitcham states:
"[…] technologies or artifacts often have unintended consequences either as side effects or as second, third, n-order effects (see Averill 2005). In response to the unintended consequences thesis, however, Michel de Certeau (1980) and Andrew Feenberg (1999), among others, have argued that human beings are as creative in adapting technologies to new intentions as technologies are in foisting their own secondary intentions off on humans" (2014, p. 18).

> and entraps nature as a calculable coherence of forces. Modern physics is not experimental physics because it applies apparatus to the questioning of nature. The reverse is true. Because physics, indeed already as pure theory, sets nature up to exhibit itself as a coherence of forces calculable in advance, it orders its experiments precisely for the purpose of asking whether and how nature reports itself when set up in this way. (1977, pp. 302–303)

What Heidegger describes is one possible ideological construct spurred by increase in scientific knowledge and a single minded, exploitative view of nature. However, as Peter Paul Verbeek has pointed out, Heidegger's claims about the way technology plays its effects back on the human rise the kinds of questions that reveal the full significance of technology as experience and understanding of the world: "[w]hat is the significance of technology for the way human beings encounter reality; and how does it affect the manner in which they interpret the world? (2005, p.49).

The approach here differs fundamentally from Pitt (2000, p. 69), who seeks to counter Heidegger's implication of a technological subversion of experience by shifting it into the domain of human behaviour – "why do people do what they do to other people" – but this isolates the matter within a human agent, making technology vanish again from the picture. What could be explored in this disagreement is an interactional view, a view that recognizes a bidirectional relationship between human agents and technology.

Perhaps the most influential response to the unidirectional approaches to technology is Bruno Latour's Actor-Network Theory (ANT), which treats humans and non-humans (e.g., technologies) as part of distributed networks. At the outset, Latour's view seems broad, as he famously stated that "[t]he bizarre idea that society might be made up of human relations is a mirror image of the other no less bizarre idea that techniques might be made up of nonhuman relations" (1992, p. 239). Technologies and humans, in Latour's thinking, are both actors that emerge as they come together in networks of action in which agency is distributed across the network rather than a single identifiable agent putting the resources in the environment in motion. As Verbeek notes, "Latour identifies this complexity of actorship or "agency" as a second meaning of technical mediation, which he calls "composition."(2005, p.156), by which he means that action "is simply not a property of humans but of an association of actants" (Latour, 1999a, 182).

In action, the technology used and the user of the technology form a composite to achieve the action in a particular way which is determined, in part, by the intentionality of the user and partly by the way the technology suggests ways of performing the action – a process of interaction Latour labels translation. Verbeek describes the process in terms of technical mediation, highlighting the co-construction of technology and its user in an example involving a gun and a person using it to achieve an act of revenge:

> His "program of action" – the "intention" to take revenge – is blocked. This person, however, can take on a relation with a gun (actant 2). This gun mediates the program of action of actant 1, on the basis of its own program of action – the "function" of shooting. A new actant arises (actant 1 + actant 2), with a new, translated program: the killing of the person against whom one wants to take revenge. The concept "program of action" should be read symmetrically here: it refers as much to the intentions of human beings as to the functions of artifacts, without invoking a distinction between humans and non-humans on the level at which the terms are applied. 5 The original program of action is thus "translated" or "transformed" in the technical mediation into a new one.

> Both the gun and the person change in the mediated situation: the person is different with the gun than without, and the gun is different with the person than without. Neither has an "essence"; they have existence, they exist, and they are transformed in their relation to one another.(2005, p. 156)

In this account, the view of technology is strongly bidirectional, the technology affecting, even defining, the user as an actor and vice versa. However, it could be said that the analytical level of the actor networks is nevertheless unilateral. This becomes evident in the analytical chains – concatenations of human and non-human actors – by which Latour makes actor networks visible (Latour, 1997, 39), which can be seen in the example above. The actors, the person and the gun, are considered as a selected pairing without further actors intervening or entering the co-construction of identities. While this could be seen as a limitation in this exemplary case, Verbeek has examined another example to show how the analysis maintains an externalized view of human-technology interaction:

> […] to illustrate these dimensions at work, Latour cites the bulky key rings that hotel managers often attach to room keys to encourage hotel guests to remember to return them when leaving the hotel. The manager might well also hang a sign politely requesting that the guests return the keys upon departure – but the guests might not see the sign or know the language in which it is written. The bulkiness of the key ring saves the manager endless trouble, and relieves guests of the responsibility of worrying about the matter, for it is simply too inconvenient not to return it. (Verbeek, 2005, p. 157)

If the goal of an approach to technology is to be able to account for subjectivities (which is what being in the world is), an externalist view alone cannot support a wide view of technology. Verbeek illustrates this through a postphenomenological reading of the example:

> When hotel guests have the room key in their possession, the bulky attachment mediates the way in which they experience the key – namely, as something annoying – and therefore the way they deal with the key – namely, returning it to the reception on their departure. In the latter case, there is a translation of action, a displacement or transposition of the way in which humans are present in and deal with their world. (2005, p.171)

In this reading, the subjectivity of the actor is evoked to explain why the guests would be likely to return the key, which imports an experiential aspect of interaction and agency into the analysis. However, considered from a more widely embedded and situated perspective, this account replicates the unilateral view of the technologies and the subjectivities involved in the action as well as the subjective experience. A multilateral view of the technologies involved in the scenario would seek to account for multiple simultaneous relations. For example, the willingness of the guest to return the key is likely to be conditioned by far more factors than either of the analyses suggest. Factors like this could be the combined contingencies and capabilities of the situated individual: the human actor could be disabled permanently (wearing an arm prosthesis) or temporarily (wearing a plaster cast) that prevents them from easily carrying their baggage and the bulky key at the same time. Their clothing might not have pockets wide enough for the key and they might be in a hurry because they have ordered a taxi via an application that gives a fixed pickup time. There might not be an elevator available, which could further dissuade the guest from carrying the key in some awkward position down the stairs, or the reception could simply be located in a different wing of the building, remote to the guest's room. In the end, the guest might simply decline to adhere to the regulative system of cultural norms, or they might not have the language skills to understand the sign asking for the key to be returned. It should be noted that, taken multilaterally, none of these various factors might be a decisive one, but the actor's "program of action", as Latour would call it, would be translated by the effects of the interactions of the multitude of relations. While the possible sources for and combinations of such relations are endless, they are, in principle, accountable in an empirical situation, particularly if the view of technology does not stand as a constraint.

4.1.Postphenomenology

Seeking a more balanced perspective on the bidirectionality of technology, Verbeek, proposes an expansion to Latour's approach by including an experiential perspective to analyses of human technology relations, or to account for the "domains both of praxis and experience" (2005, p.172). Through a reinterpretation of Karl Jaspers' and Heidegger's work and by building on Latour's Actor Network Theory and Don Ihde's and Albert Borgmann's philosophies of technology, Verbeek develops a co-constructive view, "a postphenomenological perspective on technology that is able to do justice to concrete technologies without abandoning the hermeneutical and existential questions that inspire it" (2005, p.95). Initially, this new course reorientates itself at a junction where earlier views of technology have diverged:

> Ihde's work allows the possibility of adding a hermeneutic dimension to the postphenomenological approach […] and thus offers an entirely different perspective on technology than that of the traditional hermeneutical perspective developed by Heidegger. For however much both Ihde and Heidegger pose the same question on the matter – "What does technology mean for our relation with the world?" – they arrive at completely different conclusions. Whereas Heidegger sees technology mainly as a controlling way of world disclosure, Ihde articulates a much more nuanced picture of the hermeneutical role of technologies. (Verbeek, 2005, p.143)

Focusing on human relations with the world, Verbeek's project pursues a postphenomenological view through a reworking of the subject-object relationship, with the suggestion that, since the subject and the object "are always already intertwined thanks to the intentional engagement of human beings and world, a new interpretation of phenomenology can take this a step further by emphasizing that subject and object constitute each other" (2005, p.112):

> Not only are they intertwined, but they coshape one another. Human beings can only experience reality by relating to it, which does not involve any reality-in-itself but rather reality-for-them. As consciousness (perception, experience) can only exist as consciousness of something, reality is always reality for someone; in their engagement with reality, human beings always disclose it in a specific way. At the same time, humans themselves are constituted in this relation. The environment with which they are involved always codetermines in which ways they can be present to the world and each other. In the encounter between humans and world, each manifests itself in a particular way. In the mutual relation of humans and world there arises, therefore, a specific "objectivity" of world and a specific "subjectivity" of human beings. (Verbeek, 2005, p.112)

Postphenomenology thus arranges the interactive elements involved in the causal-constitutive debates of distributed cognition in a tiered model in which causalities take effect in two directions, the subjective and the objective, in an emergent dynamic that becomes constitutive for both. In other words, it is not that cognition, for example, would need to be identified as a construct that included the brain and a selection of extended cognition scaffoldings (the exact number depending on which version of the 4E is in question) but that whatever cognition is, it does not become accountable through isolating it from it from its environment. Verbeek's approach thus comes with a strong medial emphasis, which is consequential for the manner and scope of the study of human-technology interactions:

> The facts that technological artifacts can be conceived as constructions, always exist in a context, and are interpreted by human beings in terms of their specific frameworks of reference do not erase the fact that systematic reflection can be undertaken of the role that these contextual and interpreted constructions play concretely in the experience and behavior of human beings. That "the things themselves" are accessible only in mediated ways does not interfere with our ability to say something about the roles that they play, thanks to their mediated identities, in their environment. And it is precisely the postphenomenological perspective that offers a new way of so doing. (2005, p.113)

The medial status thus granted to technology is constitutive for both the effects of technology as actualized in its use by its user and the effects of the technology that work right back at the user. To illustrate this, Verbeek borrows an example from Ihde:

> As an example, Ihde mentions the difference in writing style that arises when one writes with a fountain pen, typewriter, or word processor. One writes slowly with a fountain pen, with the result that it allows one to think over the sentence several times while composing it. The compositional speed is much faster with a typewriter, which tends to promote a style much closer to that of spoken language. And a word processor, in contrast to pen and typewriter, vastly expands the ability to compose a text; for instance, sentences can be moved around and footnotes inserted at will. These writing technologies are therefore not neutral means, but rather play an active role in the relation between author and text. They have an intentionality, a trajectory that promotes a specific kind of use (140–43). They do not have a determining influence, for one can indeed write a slowly composed and carefully thought out text on a word processor, and write conversationally with a pen. But the technologies in question *promote* or *evoke* a distinct way of writing. Technologies, as it were, contain an "implicit user's manual" (Procee 1997, 159).

Interpreting this example through the lens of distributed cognition, it could be said that the style by which the agent achieves coupling with the environment, and distribution of cognition, is suggested by perceptions about the environment.

The notion of affordance is also evoked here, but there is, perhaps, more emphasis, perhaps, on the preferences and skills of the agent using the tools. What Verbeek does not comment here – despite a potentially wide view of technology – is the complex interplay of multiple technologies simultaneously present to the situation. Language, for example, could be accounted for as a set of technologies that become reassembled in different ways when transformed from speech to symbols, depending on which writing technology is selected and on how it ends up being used. Strictly speaking, technologies like a fountain pen, typewriter, or word processor have, of course, more to do with inscribing the language than composition of the text, but having their functionalities combined with the technologies related to lexis, syntax and narrative structuring – just to give some examples – the net result provides further technological possibilities; writing down a story makes it possible to edit the text iteratively and thereby develop narrative forms that would be impossible to commit to memory. As Verbeek suggests, these kinds of assemblages are possibilities for action that also affect the way the agent subjectively experiences and engages with the activity. The medial status of technology is thus not only present in multiple ways, but a prerequisite for interaction and a determinant of what the user interactions can amount to.

Verbeek's perspective provides further clarification for the question of agency as well. While an externalized view of technology as non-human – or a one directional input-output model – would see the use of technology as optional and isolated in terms of agency, possibly a force-multiplier by which an agent may augment their agency. The key notion for agency is "technological intentionality":

> The postphenomenological perspective […] allows a more radical extension of Ihde's concept of "technological intentionality." The "intentionality of artifacts" consists of the fact that they mediate the intentional relation between humans and world in which each is constituted. When human beings use an object, there arises a "technologically mediated intentionality," a relation between human beings and world mediated by a technological artifact. Two different meanings of "intentionality" are therefore intertwined here, a first referring (in Ihde's sense of "technological intentionality") to the "intentions" of the technology itself, the second (in the more general phenomenological sense of "technologically mediated intentionality") to the relations between human beings and world that are mediated by the technology. Both meanings are relevant for a phenomenological understanding of the role of technologies in human-world relations. When technologies mediate the intentional relation between humans and world, this always means from a phenomenological perspective that they codetermine how subjectivity and objectivity are constituted. Their "intentionalities," in Ihde's sense, consist of the fact that they coshape the contact between human beings and their world; they determine how human beings can be present in the world, and the world to them. (Verbeek, 2005, p.116)

The phenomenological perspective thus rejects the idea that "technology can be spoken about independently of the humans that engage with it" (Verbeek 2005, p.116). This view also carries a claim of functional specificity of technologies: since technologies have a "instrumental intentionality" (Ihde 1990, 32), which refers to the way it suggests its possible uses, and deployed in order to do something in interaction with the human using it, it is inconsequential to speak of technologies independently. In relation to this, Verbeek quotes Ihde's term "humantechnology" (2005, p. 116; Ihde, 1993, 34) to emphasize "the active relational pair" between technologies and their users, without which talk about technology is liable to fall into essentialism.

A postphenomenological view of human-technology relations can be further characterized in terms of Heideggerian revealing of the world in a very concrete way. Verbeek formulates this relation as access to the world via technologies:

> In hermeneutical terms, things can mediate the ways in which human beings have access to their world by the roles that such things play in human experience. Questions such as the following arise: In what way do telescopes and electron microscopes, automobiles and airplanes shape our access to the world? In what way are others present to us when we contact them via telephone or email? An analysis of the technological mediation of our experience produces a new interpretation of hermeneutics. In place of the traditional emphasis on language and text, in this "material hermeneutics" things take center stage. In the next chapter I shall use the work of Ihde to elaborate this postphenomenological perspective on technology. (2005, p.119)

While proposed here as a novel form of hermeneutics not based on formal languages, the term "material hermeneutics" does not need to be understood as alien to hermeneutics based on any combination of any of the modalities available to human experience. Rather, the significant addition is the central place given to human experience – that technologies always involve this aspect, which can be subjected to close inquiry. The way experience gains this status is articulated by Verbeek (borrowing from Ihde) as a set of human-artifact relations. Embodiment relations, for instance, emerge under conditions of "embodiment" of technology, as presented by Ihde:

> (1) The artifact must be technically serviceable; that is, its physical characteristics must allow it to be embodied. A pair of glasses made with opaque lenses cannot serve embodied perception;
> (2) a certain skill or technique is required to perceive through the artifact; those not trained in dentistry cannot use dental probes to detect tooth decay;
> (3) the artifact should aim at making mediated perception take place according to a measure comparable to unmediated perception; a telescope ordinarily delivers a picture of a planet with roughly the same size as the picture of a red blood corpuscle delivered by a microscope – "the image size of galaxy or amoeba is the same" (Ihde 1990, 79). (Verbeek 2005, p.125–6)

In each of these conditions, human experience codetermines the functioning of the technology; in (1), the artifact must enable a functional coupling with some parts of the human sensorium, in (2) the functionality of the artifact only becomes actuated by application of human skill, and (3), the functionality should be available for actualization in the scale of human experience. The accumulation of technologies could, again, be pointed out here, since the skill in probing teeth is not only a necessary component in the technological assemblage that makes dental care achievable, but can be seen as a technology in itself – a formalized system of diagnosis based on the systematic application of haptic, visual and quite possibly auditory and olfactory perceptions.

In the second type of relations, *hermeneutic relations*, "the world is not perceived through the artifact but by means of it" (Verbeek 2005, p.126), as in representations of the world. Therefore, the salient feature of the bidirectional model of human-technology interaction in Verbeek's formulation is the experiential consequentiality: "[t]he technological mediation of perception, whether embodied or hermeneutic, has consequences for the ways in which human beings experience their world: artifacts transform experience" (Verbeek 2005 p. 126). The same seems to be true of the third kind of relations, *alterity relations*, in which "humans are not related, as in mediating relations, via a technology to the world; rather, they are related to or with a technology (Verbeek 2005, pp. 126–127). The role of human experience in alterity relations seems to be more about affectual than an instrumental mediation, as the term refers to the kinds of relations humans may develop with a "quasi-other", such as an artifact they care for or one that appears to display some kind of agency. One might also speculate whether the category might include non-device technologies such as the written portrayal of a character in a book of fiction.

In addition to relations of more conscious interaction, Verbeek discusses Ihde's notion of background relations, in which "we are related neither explicitly to a technology nor via a technology to the world; instead, technologies shape the context of our experience in a way that is not consciously experienced" (2005, p. 127). Verbeek's examples of technologies of this kind are refrigerators and central heating (Verbeek, 2005, p. 128), but we could include much of the infrastructure we encounter in our daily lives in this category. It may be true that "[t]echnologies such as these give rise to a background "field" in which we can have experiences without explicitly experiencing the technologies in question", but this category is so constitutive of the overall human experience (particularly the urban share of humanity) that its significance is difficult to overestimate. Interestingly, this category hinges entirely on perception:

> Their "absent presence" is usually experienced only when they stop functioning – when a storm knocks out the electricity, for instance. In such cases the context shaped by the background technologies, which we otherwise take for granted, is suddenly not self-evident any more. (Verbeek, 2005, p.128)

In Verbeek's postphenomenology, these background relations are picked up into a critical discussion with Borgmann's notion of *device paradigms,* the final component in Verbeek's project. By doing this, Verbeek includes a perspective of macro scale accumulation of technology from Borgmann's propositions about the paradigmatic effect of technology on human societies:

> He calls his approach "paradigmatic," insofar as he understands technology in terms of paradigms. Technology, in his view, contributes "a characteristic and con- straining pattern to the entire fabric of our lives," a "pattern" or "paradigm" that "inheres in the dominant way in which we in the modern era have been taking up with the world" (3). He calls this pattern the "device paradigm." Borgmann's entire philosophy of technology consists of an attempt to bring to light and understand this paradigm inhering in the way in which human beings engage the world. (Verbeek 2005, p.175)

The overall argument is that the accumulated technologies constrain human ways of engaging with the world. However, Verbeek does not accept the pessimism of the view – the extent to which Borgmann deems that "[t]he relation that human beings have with devices […] becomes characterized by disengagement" (Verbeek, 2005, p.177). However, Borgmann's proposed corrective to the disengagement caused by technological automation through devices is an interesting one.

> Borgmann discusses two concrete examples of focal practices: running and the culture of the table, with the associated focal things being the running shoes along with the environment in which one runs, and the kitchen utensils along with the food that they are used to prepare. Long-distance running – or trekking – is an intensive way of being present in one's surroundings. A run or trek is physically demanding, but it provides an experience of freedom and pleasure, and a special kind of involvement with the surroundings along the route. The culture of the table – what is involved in preparing, sharing, and enjoying a meal – requires considerably more effort than warming up something in a microwave. […] Both practices are valuable in and of themselves, and are not pure means of "getting from one place to another" or of "obtaining nutrition." (Verbeek 2005, p. 184).

An intriguing and relevant aspect of the pessimism of Borgmann (and Heidegger) is how technology wields a power that does not seem to be fully connected to the fact that it is humans who produce and use them. Perhaps because of this disconnect[12] losing control of technology is perceived as inevitable, except for Borgmann's surprising response to the encroachment of technology in human life, which is found in technology, albeit of a very different kind. Borgmann's counter to the experiential dearth caused by device technologies is the valorisation of activities that involve

[12] Pitt identifies the pessimism with a kind of crypto-essentialism as follows: "[…] it is the basic assumption , that there is an essence of technology that is uncoverable, that I find fundamentally flawed. It is the same assumption that lies at the heart of the arguments put forth by contemporary social critics. Technology is seen as a thing, a force, in and of itself. It is made into an object against which we can rail. But Heidegger gives reason nor any argument for the existence whatever it is that is the force that pushes us using human beings as resources" (2000, p.69).

technologies of embodied and social engagement and experience. In Foucauldian terms, the shift enacted by these activities is an application of a kind of a "technology of the self" (Foucault, 1988), practices that enable a person to effect change in themselves. In this sense, Borgmann's focus on devices and automation distracts from the ways in which technologies can support – it that is what humans decide to do – what he calls *focal practices* and engagement, as Verbeek is also quick to point out (2005, p.188–191). Borgmann's contribution – in Verbeek's adaptation – to a postphenomenological view of technology is in how technology mediates involvement:

> In this chapter I have implicitly pointed out three different variants of involvements: they can concern the artifact itself (playing a piano requires effort), its environment (a fireplace requires that wood be gathered and chopped up), or the product that the artifact makes available (the CD player makes it possible to enjoy music). Involvement with the artifact itself is often diminished by technological devices, for their physical presence (machinery) is usually subordinated to their function (delivering commodities) – they are meant to call as little attention to themselves as possible to reduce the effort needed to use them. But devices can also invite involvement, both in the focal sense (an electronic piano, for instance) and in the sense of effort (dental equipment, for instance, which must be constantly cleaned and maintained). (Verbeek, 2005, p.192)

The pessimism about technological determinism and encroachment tempered, Borgmann's work provides an insight into the way human-technology interaction patterns, particularly in terms of the effects on historical macro scale, albeit the notion of engagement is functional in considerations of individual users as well.

As a result of his postphenomenological project, Verbeek presents a revised vocabulary for a discourse on technology that "makes it possible to describe technologies not simply in terms of their functionality but also as mediating the relation between human beings and their world" (2005, p. 196; 197). The approach is demonstrated through an analysis of a Personal Digital Assistant, a miniaturized personal computer with a clock, calendar, address book, email and Internet access – a proto smartphone of sorts. Verbeek's summary of the analysis showcases the full scope of the postphenomenological view of technology:

> A PDA, in short, helps to shape the way in which its user and the user's world are present to each other. Even on the train, a small computer can mediate one's entire world, directing one's attention to a text unscrolling in one's lap instead of the landscape outside. One can contact others via email, but this contact has a completely different character than conversations with a neighbor. And one is sure to handle the PDA carefully lest it be damaged, lost, or stolen. A PDA helps to shape its user's existence and experience; it shapes specific aspects of its user's subjectivity and the objectivity of that user's world. It is more than a functional instrument and far more than a mere product of "calculative thinking." It mediates the relation between humans and world, and thus coshapes their experience and existence. (2005, p. 198–199)

At the time of Verbeek writing this, the routinely careless handling of smartphones was yet to be witnessed, but in other respects, the described effects of the technology can now be seen as accurately assessed. The view of technology in this account is broad in the sense that it charts the interactions, or human-technology relations, on the levels of functionality, embodiedness, situatedness, human experience and human-environment relations. What receives only limited attention is the convergence or accumulation of technologies: it is acknowledged that the PDA device is an assembly of various device functionalities that connect to technologies like language, but the technologies involved in the situation – embodied or otherwise – are not acknowledged in the analysis.

In the last part of the postphenomenological project, Verbeek gives up the term "technology" and turns to artifacts in the aesthetic domain, which he deems to be outside of the philosophy of technology (2005, p. 203). Artifacts, nevertheless, have a mediating role (Verbeek ,2005, p. 204). The difference between a technology and an artifact is not easy to pinpoint, as the artifacts seem to take up roles that could well be seen as technological:

> In fulfilling their functions, artifacts do more than function – they shape a relation between human beings and their world. The way in which a table organizes the relations between guests can only be described as a means for an end when the host deliberately chooses an "egalitarian" or "authoritarian" table in expressing a preference for a particular meal culture. But in describing how a table mediates meal culture, the issue does not concern the function of a table but a phenomenon that arises on the basis of its functionality. When the table is used (that is, when it fulfills its primary function by making it possible to lay out table settings so that people can sit in proximity), it is absorbed and incorporated into the practice of eating that it makes possible without this being consciously experienced – and from that position it mediates the relations between the people around it. (Verbeek, 2005, p.209)

Various household items could be described in a similar manner, and the way in which a device technology – such as a television – can function as a focus of a family ritual evokes questions about differences in the social experience rather than about categorical differences between the objects. However, this categorization is a conscious choice:

> By the term "technology" I follow current usage and generally mean to refer to the specifically modern, "science-based" technological devices of the sort that began to emerge in the last century. The term "technical" is broader, and describes all sorts of techniques and their associated objects. The "technical" thus encompasses the "technological." For stylistic considerations I shall use both interchangeably to refer to modern scientific devices. (Verbeek, 2005, p.3, note 1)

For analytical practice, Verbeek notes, the postphenomenological vocabulary remains the same, whether focusing on technologies or artifacts.

4.2.The scope of technology in philosophical perspectives

Regarding human-technology interactions, the authors reviewed in this section vary significantly in their emphasis. Pitt's model is largely unidirectional, focusing on input-output and consequences, including unintended ones, a category that seems most promising for a bidirectional view, but which is not developed into one. In his formulation of postphenomenology, Verbeek navigates via Heidegger, Ihde, Latour and Borgmann to arrive at a strongly bidirectional or co-constructive view of technology that places human experience in the centre of his model of interactions. Verbeek's view thus comes close – in principle if not in practice – to the embodied, embedded and enacted approaches to cognition, particularly in arguing that technologies are not neutral tools but active mediators of reality. This broadened view shows potential for a more comprehensive understanding of how technologies influence and are influenced by human agents in complex, multilayered environments. [13]

While the challenges of relating distributed cognition approaches to human-technology interactions was identified in a lack of consistent or even comparable views on technology, the difficulties with philosophical approaches is a lack of clear paths to formulating more analytical perspectives where the scope of technology could be put to the test. Pitt's model is just one example, as it proposes that, while the unintended consequences of technologies are relevant and interesting, the experiential level of technology use is not acknowledged, even though it would be a rich resource for analyses of the kinds of consequences technologies can have in everyday life. Verbeek's postphenomenological view seems promising as it aims to account – via elaborations on technological mediality – for the concrete conditions and processes of human-technology interactions. At the same time, the postphenomenological perspective connects technology quite organically to intentionality and hence to ethical questions.

In terms of the overall goals of this review, however, Pitt raises important questions with respect to the span of the magisteria of technology:

> "But, it might be argued, aren't we risking confusion if we reduce all of humanity's achievement to mere tools? Don't we really need finer-grained analyses, ways of differentiating between kinds of tools?

The questions are immediately relatable ones the principle behind them form the core of resistance – and healthy scepticism – regarding the dramatic conceptual expansions of any kind. Pitt's answer does, however, give reasonable grounds for such expansion, and grounds that seem to align with the kinds continuities that have been discussed in this review between what are commonly understood as technologies and things that have not:

> Well, it is not clear that we obtain a more refined understanding of technology by dividing physical and social mechanisms into separate categories. If something can be used to achieve a goal, it is a tool and, being used, can become a technology" (2000, p.9).

Elaborating on answers to this question is not, however, within the scope of this review, but the pursuit for them will continue in Deliverable 3.2, which will report on a new user experience evaluation method.

The philosophical frameworks reviewed above highlight the complexity of technological mediation and its impact on human experience. These insights become particularly significant when applied to contexts where diversity in embodiment and cognition is central. The next section examines models of disability, exploring how different paradigms – social, cultural, enactive, and ecological – intersect with views of technology and influence strategies for inclusion, accessibility, and agency.

[13] The high-tech paradigm continues to inform more recent writing as well. See, for example: Aydin, C., González Woge, M., & Verbeek, P.P. (2018). Technological Environmentality: Conceptualizing Technology as a Mediating Milieu. *Philosophy & Technology*, 32, 321 - 338. At the same time, it is also true that new technologies are constructing environments that are experientially novel, for example: Reijers, W., & Coeckelbergh, M. (2016). The Blockchain as a Narrative Technology: Investigating the Social Ontology and Normative Configurations of Cryptocurrencies. *Philosophy & Technology*, 31, 103 - 130.

5.Models of Disability

Perceptions of the relationship between disability and technology are profoundly influenced by the theoretical models used to conceptualize disability. These models span a spectrum from individualistic and medical frameworks to relational, ecological, and cultural paradigms. Each perspective carries implicit assumptions about technology – how it is understood, utilized, and experienced – alongside openly voiced strategic ideas about technology development and use in the context of disability. While this review primarily focuses on theoretical and methodological approaches to technology and human-technology interaction, the NewWorkTech project investigates the actual use of technology by individuals with diverse embodiments, minds, ways of being and sensing the world. This empirical orientation raises important questions about how different models of disability intersect with technological mediation and human-technology interaction.

We begin with the premise that the prefix *dis-* in *disability* need not signify an undesirable condition. As Ashley Shew (2023) argues, it can instead denote a state of differentiation that enables forms of cognition, which should not be subject to value judgments or normative preferences. To avoid reinforcing assumptions of pathology or disorder, we follow Jurgens (2023) and Hoffman (2017) in treating *disability* as an umbrella term encompassing a wide range of phenomena (Jurgens 2023, p. 1) that are not treated as pathologies.

In this sense, understanding disability is not about normalizing or assisting to overcome it, but to learn to appreciate how disabled condition enables diverse skills. Embracing diversity and sustaining a perspective that can do so places further demands on how models of disability can be deployed. Although this review is theoretical in nature, the empirical goals of *NewWorkTech* require that theory remain attentive to the individuality and contingency inherent in disability. Ellen Samuels reminds us of the risks associated with categorical thinking:

> Ellen Samuels observes shrewdly: The overwhelming fantasy of modern disability identification is that disability is a knowable, obvious and unchanging category. Such a fantasy permeates all levels of discourse regarding disabled bodies and minds, even as it is repeatedly and routinely disproved by the actual realities of those bodies' and minds' fluctuating abilities. (2014, p. 121)

Consequently, models of disability must be examined in terms of the conditions and restrictions they put in place for research on the relationship between technology, society and disability. In addition, conceptions of technology come with their own generalizations and assumptions about disability. Nevertheless, as has been discussed in earlier sections in this review, the individual, even when seen as embodied, experiencing subject, is not the isolated unit of the individualist model of disability. Seen from a posthuman perspective, as Stuart Murray prompts us to do,

> […] the body is no longer sovereign but rather implicated in a host of relationships across boundaries. It is precisely here that humanism's profound fear of the body with disabilities turns into the potential appreciation of the varieties of embodiment that disability presents, both in terms of the human body itself and its interactions with technology. Seeing bodies within networks and connections, and operating across limits, opens up possibilities of understanding subjectivities of all kinds in a space beyond humanism, but allows for an especially profitable focus on those bodies that speak of and to disabilities and their difference. (2020, pp. 12–13)

Approaching technology from this perspective, the first thing to be noted is that, in its practical effects, it cannot be assumed to be neutral. As Ashley Shew has argued in regard to assistive technologies:

> But even technologies that can be helpful are not the simple replacements they are imagined to be. Things don't work the same, or even as expected. … The push for automation in bionics – of wheelchairs and of fake limbs and, well, of bodies more generally – changes not only how people are thought about others but how people think about themselves. (2023, p.74)

Consequently, technology – or its effects – constitutes not only technological solutions (understood widely as devices, systems or practices), but the meanings its presence generates in discourses about the human body and cognition. Murray gives an example of how the "technological augmentation of the non-disabled body (in military contexts for example) can function to stress fragility and vulnerability in ways that create complex equations around embodied precariousness" (2020, p. 18).

Similarly, what Shew describes already highlights one crucial aspect of technology: that it is not a neutral add-on but can cause significant and unanticipated changes in the experience and action possibilities of the people interacting with them. According to Mills, discourses and terminology can sometimes reinforce this kind of unidirectional view of technology, for example, by the word "assistive technology", leading to new configurations in human-technology interactions that are not always anticipated or beneficial:

> What these technologies "assist" is sometimes questionable. They may be designed for "compensation" or extension, augmented or alternative communication. They may promise to facilitate independence but instead require new patterns of dependence […]. (2005, p.178)

In seeking for a model for a concept of technology that could meet the requirements – in connecting with the everyday reality of diverse people – Geoffrey Reaume's characterization of the position of critical disability studies is a good starting point:

> Critical disability studies view disability as both a lived reality in which the experiences of people with disabilities are central to interpreting their place in the world, and as a social and political definition based on societal power relations. (2014, p.1248)

The aim of this review is not to propose a new model of disability, but rather to map the technological intersections within existing models, examining how each constructs the relationship between disability and technology. Some models are addressed only briefly, for clear and practical reasons. For instance, the "charity/tragedy model," which portrays disabled individuals as victims deserving pity and charity, offers no meaningful connection to technology. In contrast, the medical model – by pathologizing disability (Jurgens, 2023, p. 2) – tends to adopt an extremely narrow perspective.

Indeed, the medical model encapsulates many of the core challenges in rethinking the concept of technology in relation to differences in ability. As Shew (2023, pp. 20–22) explains, this model exemplifies narratives that treat disability as a condition to be cured or eliminated. Such narratives transfer agency to an assumed group of "non-disabled" individuals and serve to justify top-down interventions. In doing so, Shew argues (p. 21), these narratives become totalizing constructs that obscure the diversity within the disabled population. Simultaneously, perceptions like this promote the applicability of the narrow view of technology as unidirectional means to ends, thus limiting the discussion on the relations between- or coexistence of disability and technology.

The *enactive medical model* (Maiese, 2021) addresses this problem by incorporating enactivist principles such as sense-making and adaptivity. Here, disability is seen as a disruption in the individual's ability to engage with environmental affordances. While this model expands the scope of intervention to include environmental factors, it still centers on individual adaptivity, and as Jurgens (2023) argues, it is not entirely free from reiterating epistemic injustice and methodological individualism.

Approaching disability as diversity or variation (as done by Milton, 2017, and Jaarsma and Welin, 2012) enables models that have a less prescriptive view of disability, and such models can be used to interrogate concepts of technology, charting where gaps emerge between notions of what technology is and how ability differences manifest in lived reality.

A further point needs to be made with respect to the individual. According to Jurgens:

> Thus, taking these problems into consideration, we can see how an individualistic methodology is potentially harmful for disabled individuals both in terms of epistemic injustice and intervention strategies that may result from even an enactive medical model that aims to provide a wide, relational account of disability. (2023 , p.7)

It should be noted that *individualistic* is here used in a one-directional sense, and needs to be detached from the meaning of individual as a person with unique traits and capacities, and as subjective and experiencing agent; by maintaining a distinction on individualist methodology and methods that acknowledge the individual, it is possible to ensure that notions of autonomy, autotelic action, and agency are not neglected[14]. Similarly, focusing on the situated, individual human-technology relation should not be taken as aligning with an individualistic model of disability, the view that disability is "a personal problem afflicting individual people, a problem best resolved through strength of character and resolve", as Alison Kafer (2013, p. 4) has put it.

Due to the reasons explained above, models that seek to discover pathologies (chiefly "medical models") are given less attention compared to social and cultural models, which approach disability from a broader perspective and are thus more likely to view technology with a similar, wide-ranging relevance to the discourses on disability and technology.

5.1.Social model of disability

Emerging in the early 1980s, the social model of disability locates the source of disability not in individual impairments, but in societal barriers (Oliver, 2013, p. 1024). Within this framework, technology becomes a potential site of either exclusion or inclusion. Universal design principles and accessibility standards are rooted in this model, emphasizing that disabling environments – not bodies – are the true source of limitation. As Adams et al. explain, the social model is grounded in

[14] It has also been stated by Mike Oliver that the purpose of the social model of disability was not to abandon the individual model, but to provide another perspective on the subject (2013, p. 1024).

the belief that “particular physical or sensory differences only become disabling when the environment creates barriers to access” (2005, p. 8).

While this approach shifts attention to the organization of the environment, Shakespeare has identified specific challenges related to technology. For instance, he notes that “if disability is about social arrangements, not physical or mental impairments, then attempts to mitigate or cure medical problems may be regarded with intense suspicion” (Shakespeare, 2013, p. 18). Another concern, tied to the lived experience of disability, is that a strong social model – focused primarily on macro-level social structures – may overemphasize the social construction of disability and fail to adequately capture the complexities of disabled people’s lives (Shakespeare, 2013, p. 46). According to Kafer, the consequences for the practical solutions can thus be highly counterproductive:

> In a complete reversal of the individual/medical model, which imagines individual cure as the desired future for disability, a strict social model completely casts cure out of our imagined futures; cure becomes the future no self-respecting disability activist or scholar wants.” (Kafer 2013, p. 7)

The political consequences of the differing, and not always sincere, interpretations of the social model have been noted by Mike Oliver (2013), and while the macro perspective of the social model touches on technology mostly in indirect ways, its significance also depends on the breadth of the concept of technology. In terms of the concept of technology, the social model may, for example, help in acknowledging how the application of systems of organization – form language to private corporations to national institutions – can be seen as technological, but the scale of interest does, as Shakespeare and Kafer argue above, make it difficult to redress the issues as technological in an analysis that would also account for the role of the individual within the social system.

In so far as the problematic is institutional, such as in the case of shifting government policies and the opportunistic use of models of disability themselves (Oliver, 2013, 1026), a technological perspective on the systems and institutions as sites of distributed cognition and agency could possibly shed light on how decision-making is enabled and agency channeled within them. A wide view of technology might also be able to account for the bidirectional effect of such systems regarding the kinds of conditions they put in place for individuals and groups.

5.2.Cultural model of disability

Adopting a version of the social model, as Shakespeare suggests, Cultural Disability Studies “tend to be more interested in cultural representations than in economic questions” (2013, p.46). In Snyder’s and Mitchell’s description, the model reinstitutes the experience of the individual:

> […] the cultural model has an understanding that impairment is both human variation encountering environmental obstacles and socially mediated difference that lends group identity and phenomenological perspective. (Snyder and Mitchell, 2006,p.10)

The cultural model of disability involves “a critical turn”, through which “Critical Disability Studies moves away from simplistic binaries, and how the struggle for social justice ‘is not simply social, economic and political, but also psychological, cultural, discursive and carnal’” (Meekosha and Shuttleworth, 2009: 50 cited in Shakespeare, 2013, p.48). The result is an “emphasis on embodiment; awareness of the cultural imaginary; deconstruction of binary thought in favour of fluidity of all categories; and recognition of the importance of emotion and affect" (Shakespeare, 2013, p.48).

While, from the point of technology, it may initially seem that the cultural model distances itself from the topic, applying a wide view of technology can help in seeing how the communications around disability and the experience of it play a major role, as Shakespeare explains:

> The impact of this work is to show how disability is not simply about having a medical condition, but is about how medical conditions come freighted with meaning and symbolism and connotation. Thus, Lennard Davis brings the focus on texts and discourses back to the definition of disability itself: 'Disability is not so much the lack of a sense or the presence of a physical or mental impairment as it is the reception and construction of that difference' (2002: 50). An exploration of how disability is regarded differently across cultures and times helps establish that disability is locally variable, at the least, and entirely relative and contingent, at most (Bickenbach, 2009). (2013, p.50)

Furthermore, a focus on the technologies by which disability is represented can introduce a corrective to an overemphasis of medical, social or economic perceptions of how technologies are related to disability, for example, when a totalizing view of materialism combines with a narrow view of culture and technology, as Shakespeare describes:

> Indeed, often the reliance on materialist understandings of the world means that culture has to be analysed through economic categories: the theory that ideas about disability reflect underlying material social relations (Oliver and Barnes, 2012: 99). (Shakespeare, 2013, p.49–50)

In relation to this, the cultural model views disability as a subjective experience shaped by cultural representations and environmental interfaces, and technology is seen as not merely functional but symbolic and expressive. In postphenomenological terms, technology thus mediates identity and social meaning in a bidirectional relationship of human-technology interaction. In this way, the cultural model of disability expands the horizon of disability models, yet in terms of technological inquiries, its role comes across as complementary.

The cultural model does, however, enable deeper analytical connections between technology and disability; assuming that it is the cultural environment as a whole that provides the fundamental, shared meaning-making resources for the individuals living in its sphere, technologies – even in the narrow view – have an ubiquitous presence among those resources and thus in any cultural representations as well. Applying a wide view of technology, on the other hand, enables an analytical approach to the way representations – narratives across the media and everyday discourses, for example – are technologies for mediating the experiential aspects of disability in addition to the political communications on which the cultural model of disability has mainly focused.

5.3.Enactive medical model of disability

Enactive and ecological models are of interest to the *NewWorkTech* project due to their alignment with the neurodiversity paradigm, which conceptualizes disability as a form of difference. As Jurgens (2023, p. 2) notes, these models are characterized by a strong commitment to the principles of embodiment, embeddedness, and extension. Practically, this commitment involves examining “an individual’s particular form of embodiment in order to determine what stimuli in the environment the individual is sensitive and responsive to” (Maiese, 2018).

Although these approaches have primarily been developed in the context of mental disorders, their theoretical foundations – drawing from distributed cognition and ecological psychology – offer broader applicability to the experiences of diverse individuals. By emphasizing the dynamic interaction between embodied agents and their environments, these models provide a nuanced framework for understanding how technology can support diverse forms of engagement.

Michelle Maiese’s (2021) revision of the medical model applies enactivist principles like autonomy, adaptivity, and sense-making to detach it from the external individualism that has generated so much criticism against it. The notion of adaptivity is introduced as central to determining dysfunction, as inability to adapt to socio-material environments leads to pathology (Maiese, 2021, p. 966) in the context of mental disorder. Pathology, then, is defined as “disordered patterns of sense-making that are maladaptive” (Maiese, 2021, p. 974). The medicalization notwithstanding, Maiese’s description of disordered patterns of sense-making can be relevantly explored through a wide view of technology:

> One way to make sense of this is in terms of a breakdown in the structure of the field of relevant affordance, which involves at least three key dimensions (de Haan et al., 2013): (1) Width” of the field refers to the broadness of the scope of affordances that an individual perceives, which relates to her having a choice or action options; (2) “Depth” of the field refers to the temporal aspect: the individual not only perceives affordances that are immediately present here and now, but also is pre-reflectively aware of future plans and action possibilities; and (3) “Height” of the affordances in the field refers to the relevance or importance of the affordances that one is responsive to, i.e., “the experienced solicitation or affective allure” (de Haan et al., 2013, p. 7), and relates to salience and motivation. (p. 977)

The notion of disorder is thus conceived within a framework of an ecology; in order to be considered a “cognitive agent” the individual must be able to “regulate its coupling with the environment according to self-generated norms” (p. 968–969). For someone suffering from depression, for example, the possibilities for coupling with the environment – affordances – seem closed off (Maiese, 2021, p. 974). As has been suggested in this review, affordances in human cultural environments can be seen as technological, even predominantly so, and in Norman’s view, the design of technology has a significant hold on our experience of our daily activities. In this respect, Maiese’s model for defining mental disorder becomes intimately linked with technology, even in narrower views of it. However, a wide technological view can also provide a critical perspective on the charting of the affordances that are deemed relevant to the diagnostic work, such as: how are the affordances confirmed as being shared across the range of diverse people? What kinds of technologies – artifacts, systems, practices – come together to provide the relevant affordances? How is the relevance of the affordances decided and are there affordances that an individual could perceive differently from others and engage with them in ways that are not apparent to the observer? Technology viewed narrowly, assessments of sense-making therefore seem to be in danger of sidelining a multiplicity of factors that could contribute to the individual’s ability to “regulate its coupling with the environment according to self-generated norms”.

By substituting pathology with the kinds of inadequacies and failures that everyone may encounter, the enactive and ecological models suggest a framework for mapping technological affordances in the environment and their accessibility to diverse individuals. Maiese's (2018) concept of a three-dimensional field of affordances allows for a highly granular assessment of situated action, particularly when combined with an analysis of the technologies involved.

However, this approach also raises concerns about potential normative bias. Specifically, it may presuppose that there exists a fixed set of affordances that individuals ought to perceive and utilize in particular ways. Jurgens (2023, p. 7) cautions that such assumptions risk reinforcing epistemic injustice by perpetuating the notion that neurodivergent traits are inherently dysfunctional. For example, Jurgens argues that if "many of the social difficulties autistic individuals face result from problems with neurotypical individuals in understanding autistic individuals […] we have a reason to intervene on the environment, including neurotypical individuals and neurotypical social practices and institutions, as these aspects of the environment set the norms that a disabled individual" (2023, p. 7).

Yet, it is not necessarily accurate to assume the existence of clearly defined "neurotypical social practices and institutions". Rather, what exists is a complex network of normative social structures that may not effectively serve the majority of individuals subjected to them. From this perspective, *NewWorkTech* has the potential to illuminate how normative socio-technological practices and institutions may fail or even harm a wide range of diverse individuals. By exploring these contingencies, the project can contribute to a deeper understanding of how technological and social environments might be reimagined to better support cognitive and functional diversity.

5.4.Ecological enactive model of disability

The ecological enactive model combines enactivism and ecological psychology to distinguish between disability and pathology. The basic elements of the model resemble the enactive medical model:

> We propose a model of disability which we will call the Ecological-Enactive (EE) model of disability, that takes into account the valuable contributions of both the medical and the social model, without being reducible to either of them. […] From ecological psychology we borrow the conception of the environment as furnishing affordances – possibilities for action the person can make use of because of the bodily skills and abilities they have developed (Gibson, 1979; Stoffregen, 2003; Chemero, 2009; Rietveld and Kiverstein, 2014). The EE model proposes to understand disability in terms of a person's embodied skills for responding to the affordances of their environment. (Toro et al., 2020)

Toro et al., however, claim it as their purpose to avoid "pathologizing the disabled person's living body" (2020), which distances their model from medical models of disability. Pathology is nevertheless defined:

> The distinctions between normality and pathology and health and illness are thus not to be understood in terms of a statistical deviation relative to some reference class. The embodiment of the disabled person should not be understood in terms of a generic bodily impairment. We should instead understand the distinction between normality and pathology in relation to an individual organism and its capacity to adapt to its environment, which in the case of humans is a sociomaterial environment.

To illustrate the normal capacity to adapt to the environment, Toro et al. describe the adaptive efforts of a "28-year-old woman with spastic cerebral palsy that affects motility in her legs and her right arm" (Toro et al. 2020):

> Despite the movement limitations SG experiences, she's still able to be spontaneous in the performance of the tasks at hand. She is constantly looking for better ways to perform the exercise, and even though she might find a way in which she feels comfortable performing, she feels she can keep looking for better ways to perform an activity. Sometimes she fails to improve, sometimes she succeeds in coordinating her actions to new affordances that allow her to establish a new way of acting.

The description underlines the individual's achievement in discovering new ways of doing things, which is, of course vital, but as Jurgens suggests, they also highlight the "importance of the structure of socio-material environments in determining how easy it will be for disabled individuals to adapt to them" (2023, p.8). Here, Toro et al. address the very issue that was discussed in relation to Maiese's enactive medical model of disability, namely that "if the socio-material environment is built around only able-bodied people, practical engagement with the world will become much harder and the risk of becoming pathologically embodied will increase" (Toro et al., 2020, p. 13). Here, it could be added that, in situations like this, the risk that outside observers miss crucial features of the socio-material environment as perceived and experienced by the person being observed may also be heightened. As a measure of mitigating this risk, in the model by Toro et al., the individual's lived experience is acknowledged, as Jurgens describes:

> Rather, by examining an individual's embodiment utilizing the tools and methodology of ecological psychology and enactivism it is possible to distinguish between pathological and normal forms of embodiment. At the same time, this kind of examination can do justice to the lived experience of disability through employing phenomenological analyses and interviews with disabled individuals. (2023, p.8-9)

Other criticisms of this model aside, Jurgens identifies a problem that could "potentially lead to undue pathologization of disability and intervention strategies too heavily aimed at the individual, as opposed to the social level" (Jurgens, 2023, p.9). Here, again, the conditions of adaptation seem to be divided into multiple levels, such as the individual and the social, a division that could be corroborated by a narrow view on the means of adaptation, such as technology and the abilities of using it. A wider view of technology could therefore help in discovering concrete interdependencies between the different levels by showing how technologies are functionally connected to multiple levels rather than operating in isolation.

5.5.Ecological functional model of disability

The third and final ecological model of disability to be discussed in this review is Jurgen's ecological functional model. This model develops a response to the problems partially discussed above, as Jurgens describes:

> While the enactive medical model and the ecological enactive model attempt to offer relational approaches for disability, as we have seen both model's reliance on the notion of individual adaptivity leads to an implicit embracement of a problematic body-social form of methodological

> individualism. However, as we'll see, Chapman's ecological function model avoid these problems by through its strong commitments to the extended and embedded theses and a multi-level analysis, while still taking into account the intersubjective lived experiences and wellbeing of disabled individuals. (2023, p.10)

As suggested already, the narrow and wide views of technology have a parallel in the multi-level analysis. However, before discussing the methods, it is relevant to acknowledge how the ecological aspect in Jurgen's model differs from the previous two. Jurgen's perspective combines a macro level of the ecosystem to the micro perspective of the individual's functions within it:

> According to Dussault and Bouchard (2017, p. 1117), an organism's contribution towards biodiversity is best understood at the system level in terms of the "systems' ability to thrive and perpetuate themselves in the future," where an emphasis is placed on how organisms (or species) contribute to the ecosystem's ability to persist in the face of change. On this view, functions are understood as relational and contextual instead of as intrinsic features of the organism itself. In this sense, the organism cannot be deemed to be functional or dysfunction in itself, function and dysfunction have to be understood in relational and contextual terms in regard to the organism-environment-ecology relationship. While the "propensity of an effect will be intrinsic" to the organism, the function or dysfunction will always be relational and dependent upon the actual behavior of the organism at a given time, and the relation itself can only be understood across the organism environment-ecology context (Chapman, 2021, p. 1365). (Jurgens 2023, p.10)

From this perspective, adaptation is not solely the responsibility of the individual through private effort, but rather a systemic process involving a collective of individuals. Such a social unit could take various forms, including organized entities like companies, as illustrated in an example from Chapman (Jurgens, 2023, p. 10). The premise of the systemic model is that as the ecosystem undergoes changes – such as those brought about by the COVID-19 pandemic – these events alter the configuration of action possibilities, thereby reshaping the kinds of abilities that enable the social unit to adapt and thrive.

Chapman's example demonstrates the dynamics of collective adaptation, showing how autistic employees contributed to their company's resilience during the 2020 lockdown (Jurgens, 2023; Chapman, 2021). In this case, workforce diversity – embodied in diverse individuals – emerges as a source of resilience within the company's adaptive capacity. As Jurgens notes, "In this sense, the differences between the autistic and neurotypical employees' ways of experiencing, navigating and managing the lockdowns meant that the autistic employees provided an ecological advantage for the persistence of the system" (2023, p. 10).

By rejecting the assumption of environmental stability, the ecological-functional model challenges the notion that the environment offers a reliable criterion for assessing individuals' functional capacities. In conclusion, Jurgens proposes that:

> […] a neurodivergent individual's mental traits and cognitive style cannot be examined solely in terms of their embodiment and their capacity for adaptivity to their environment, but must also be considered in terms of how their environment facilitates or hinders (1) their individual capacity for adaptivity and wellbeing and (2) their contributions to group adaptivity (2023, p.12).

Events that cause such changes in the environment can, of course, be much smaller in scale, taking place in small communities and with less overwhelming effects, but they can also be technologically induced, as has happened with the emergence and consolidation of the internet and the ongoing, rapid expansion AI applications[15].

For analytical work, Jurgens' model offers a framework based on three levels:

> 1.Individual Mental Traits: How traits affect personal wellbeing and interactions
> 2.Cognitive Styles in Collectives: "Niche contributions" to group functioning
> 3.Group-Level Functionality: How collective traits affect systemic adaptability
> (2023, p.11).

While the model is discussed in regard of autistic individuals as the group of interest, it can be discussed on the more general context of human-technology interactions and the diverse.

Level 1 of analysis focuses on "examining the how a disabled individual's traits support or hinder both their wellbeing and their interactions with their sociomaterial environments", and thus provides a charting of how the ability profile of the individual matches the makeup of the environment. The method is to examine "particular interactions the individual has with their socio-material environment, and their reported lived experience from these interactions" (Jurgens 2023, p.11) which provides an empirical and subjectively experiential basis for assessments of whatever technologies the sociomaterial environment can be perceived to include. However, this level of analysis also involves "examining the traits of non-disabled individuals that disabled individuals encounter, as these also in part determine the kinds of interactions and lived experiences the disabled individual has" (Jurgens 2023, p. 11). In this, the model enables the acknowledgement of technology use in a far broader manner compared to the idea of an individual applying their abilities in isolation. The abilities of an individual may well go unrecognized or they can be fully empowered in applying them, depending on the success of the social interactions in the environment.

The second level of analysis operates on the already recognized roles of individuals in groups, their "specific cognitive styles" or "collections of traits and patterns of thought and behaviour of individuals" (Jurgens 2023, p.11) that result to their "niche contribution" (Chapman, 2021, p. 1365) in their social group. In other words, the individual's unique ability profile enables them to become a specialist in the community, thus improving their individual adaptive success as well as that of their group (Jurgens 2023, p.11).

The third level shifts the perspective again towards the collective, as Jurgens explains:

> Utilizing Hoffman's (2017) work, Chapman (2021, p. 1365) argues that there may be collective cognitive traits that are "more or less adaptive for the collective, in relation to the environment, that emerge from the group rather than being directly traceable to individual members." (Jurgens 2023, p.11)

The description somewhat tentatively moves towards a notion of distributed functional capacity,

[15] Human history is, of course full of examples technological changes that change the action possibilities and, consequently, the social organization of groups.

which further opens the model to a wide-ranging technological analysis. If the collective competence and adaptive potential of a group can be distributed in this manner, the technologies – communicative and cultural in addition to the most commonly recognized – that can support in mediating such collective capacities are of vital interest.

Finally, while Jurgens' model appears to have a grasp on the complex dynamics by which individuals that form a group contribute to it within an ecology that includes the particular environment in which they are embedded and vice versa, it also exposes a particularly daunting challenge related to technologies. The charting of the traits, abilities and experiences of the individuals in dynamic interaction with others and the environment already presents a formidable scale of analytical complexity, and the entanglements of technologies added, analyses of activities in real-life environments require robust and flexible analytical tools that can account for the workings of technologies to an adequate detail.

5.6.Models of disability, models of technology

As the model of disability changes from individualist, deficit-based views to relational, ecological, and cultural paradigms that embrace diversity and complexity, views of technology shift from being an instrument for curing bodies to a site of political contestation, a cultural artifact of representation, a relational mediator, and an omnipresence individuals and groups adapt to their uses and to which they must adapt themselves. Of the models discussed, the ecological functional model and political relational model offer the most promising frameworks for integrating technology into disability studies in ways that acknowledge the complexities of agency, context, history and diversity.

6.Discussion

Having reviewed theoretical approaches to technology and disability, the report now synthesizes these perspectives to address the guiding research questions introduced earlier. The discussion evaluates how technology is conceptualized across frameworks, identifies gaps in methodological integration, and considers the implications for developing inclusive, multi-level models of human–technology interaction. First, however, this section presents summaries of the reviews sections as responses to the research questions presented in the Introduction, starting with the three questions related to technology.

1. *How is technology acknowledged, or what constitutes technology?*

The conceptualizations of technology encountered in this review can now be placed on a continuum from narrow views to wide views. First, the key characteristics of both extremes on this continuum will be summarized. Most views of technology are, of course, somewhat removed from the extremes.

Narrow views of technology make a distinction between devices, often modern machines, and other artifacts that are not considered technology, and do not engage with the notion of technology beyond a commonplace view of devices and machines. In narrow views of technology, it is *external to humans* and introduced to the sphere of culture from outside it and can therefore be *disruptive* as it is not connected to the human sociocultural environment. Technology is also present when needed, and thus *optional* in the sense that it merely performs some function more efficiently than humans or animals would; conversely, actions can always be performed – in this view – without technology. In narrow views, technology is also often seen as the domain of specialist – engineers and other professionals – and something emerging from scientific knowledge, and therefore *historically exceptional* and a relatively new phenomenon.

The critical feature of the narrow view is *unidirectionality*; when technology is considered to perform its function in a process where no feedback loops exist in the direction of the user, it is seen as a neutral means to an end. A perception like this is often accompanied by the view of *unilaterality of technology*: that technology produces results on a single level of consequences – within the confines of the context of use of what is seen as a single technological tool – and whatever else it causes to happen are anomalies and accidental.

Wide views of technology reject the notion of technology as an external, optional add-on and instead conceptualize it as deeply integrated with human life and culture. In these perspectives, technology is *human-centered*, emerging from and co-evolving with sociocultural practices rather than being introduced from outside. It is *ubiquitous* and *accumulative*, forming layered systems that include not only devices and machines but also symbolic systems, embodied practices, and organizational structures. Technologies are seen as *constitutive* rather than merely instrumental: they shape human perception, experience, and agency while being shaped by human intentions and cultural norms. Unlike narrow views, wide views emphasize *bidirectionality* – technologies do not simply perform functions but actively mediate and transform human-world relations. They influence how humans think, act, and imagine, and in turn, humans adapt and redesign technologies in iterative cycles.

This perspective also acknowledges *historicity*, viewing technologies as evolving and accumulating over time, creating complex socio-technical ecologies. Far from being neutral, technologies carry *intentionality* and affordances that guide action, embed cultural conventions, and structure environments. Wide views often incorporate *phenomenological and ecological dimensions*, recognizing that technologies shape lived experience and are inseparable from embodied, situated cognition. They extend beyond hardware to include language, design principles, and institutional systems, framing technology as a pervasive condition of human existence rather than a set of isolated tools.

In this sense, opting out of technology is rarely possible; technologies are constitutive of the very practices through which humans engage with the world. Finally, technologies are seen *multilaterally*: human-technology interactions are characterized by the engagement of multiple technologies simultaneously, and as each component in these assemblages of humans and technology produce their effects, the results take place in multiple levels yet are not mysterious once they are acknowledged and accounted for.

Views of technology: from narrow to wide

FEATURE	NARROW	WIDE
Scope of definition	Devices and machines only	Systems, social and embodied practices, symbolic tools
Human integration	External to humans	Integrated with human cognition and body
Cultural embeddedness	Introduced from outside culture	Co-evolved with culture
Optionality	Optional and situational	Ubiquitous and constitutive
Directionality	Unidirectional (input to output)	Bidirectional (co-shaping)
Stratification	Unilateral	Multilateral
Agency attribution	User or specialist (engineer)	Distributed across users and systems
Historical perspective	Modern and exceptional	Multi-level, contextual
Analytical scale	Limited to a scale	Multi-level from micro to macro scales, contextual
Exemplary technologies	Mechanical tools, gadgets	Language, institutions, built environments
Adoption process	Often disruptive	Humanized and adaptive

Figure 2. Key characteristics of narrow and wide views of technology

2. *What is human-technology interaction conceived to be? What is the scope and scale in which the interactions are considered.*

As encountered in the reviewed theories and approaches, human-technology interaction is increasingly understood as a dynamic and constitutive relationship rather than a simple input/output process. While actual definitions or models of technology are lacking, technologies are not seen as neutral instruments that merely perform functions; they actively mediate and transform human perception, cognition, and action, while humans simultaneously adapt and redesign technologies.

Distributed cognition provides one of the most influential frameworks for this understanding. Hutchins' (1995) work on navigation systems illustrates how cognitive processes extend beyond individual minds into socio-technical systems composed of tools, representational media, and organizational structures. Here, interaction is systemic: technologies are not isolated devices but elements in "ecology of tools" and "cognitive ecologies" (Hutchins 1995; 2010) that enable representational transformations and coordination across multiple media. The scope of analysis ranges from micro-level activity cycles – such as the propagation of representational states – to macro-level cultural frameworks that accumulate historically and regulate collective action Hutchins (1995, pp.112–117; 2013, p.36).

The 4E approaches – embodied, embedded, extended, and enacted cognition – shift the focus toward the role of the body and environment in shaping cognitive processes. Embodied cognition emphasizes sensorimotor coupling, suggesting that technologies influencing bodily processes, such as prosthetics or movement systems, become integral to cognition (Gallagher, 2023; Newen et al., 2018). Embedded cognition stresses the scaffolding role of socio-material environments, highlighting the role of the technological milieu, while extended cognition goes further, treating external resources like notebooks or calculators as constitutive parts of cognitive systems (Clark and Chalmers, 1998; 2008). Enactive approaches deepen this view by framing interaction as looping action-perception cycles, where technologies reorganize experience and expand possibilities for action (Varela et al., 1991; Noë 2015, pp.19–20).

Affordance theory introduces a close view on interaction by conceptualizing it as the perception of action possibilities (Gibson, 1979). Norman's design-oriented interpretation underscores how technological features communicate affordances and constraints, linking usability to cultural conventions and experiential design (Norman, 2010; 2013). This perspective situates interaction within a continuum from device-level affordances to systemic design principles that shape entire environments.

Philosophical accounts broaden the discussion on human-technology interactions through more specific revisions of the concept of technology itself. Pitt's (2000) model, while largely unidirectional, defines technology as "humanity at work," emphasizing purpose-driven activity. Latour's *Actor-Network Theory* (1999a) reconceives interaction as distributed agency across human and non-human actants, whereas Verbeek's (2005) postphenomenology foregrounds technological mediation of experience, arguing that artifacts co-shape subjectivity and world-disclosure. These views come close to enactivist views of cognition in extending the scope of analysis from embodied relations – such as using glasses – to background infrastructures that silently structure everyday life.

Across these approaches, the scale of human-technology interaction spans multiple levels. At the micro-level, it involves sensorimotor coupling and tool use; at the mid-level, organizational and collaborative systems; and at the macro-level, cultural and historical structures such as language, institutional frameworks, and design paradigms. Importantly, interaction is increasingly understood as multilateral: multiple technologies operate simultaneously within complex assemblages, producing effects across physical, cognitive, social, and cultural dimensions.

3. *Where do the gaps in research emerge when the concepts of technology and models of human-technology interaction put forth in the reviewed approaches are overlaid?*

While Hutchins' notion of "cognitive ecologies" acknowledges the systemic role of tools, it remains unclear whether an analytical model exists for charting technologies beyond their immediate functional role. This results in methodological gaps: technologies are often grouped under vague categories such as "artifacts" or "external representations," without systematic differentiation of their properties or effects, or an analytical framework for the interactions of different technologies at the same time.

Second, the 4E approaches introduce valuable insights into embodiment, embeddedness, and enactment, yet they rarely articulate how technologies operate within these dimensions. For example, embodied cognition emphasizes sensorimotor coupling but leaves open questions about how technological mediation alters these couplings. Similarly, extended cognition posits that external resources can become constitutive of cognitive systems, but the criteria for such constitution in regard to technology remain unclear.

Affordance theory, while influential in design research, narrows its focus to perceived action possibilities and usability of a technological unit of a single product or system, potentially neglecting the broader socio-cultural and historical contexts in which affordances are embedded. The existing analytical tools in Norman's work, for example, are tried and tested industry staples, but understandably focused on the user experience of a selected product in the design process or being tested. This creates a gap between micro-level design principles and macro-level systemic interactions.

Philosophical perspectives such as and Ihde's and Verbeek's postphenomenology and Latour's Actor-Network Theory attempt to bridge these gaps by emphasizing technological mediation and distributed agency. However, how these approaches can be made methodologically viable for empirical research technological mediation seems less firmly established. While they provide rich conceptual vocabularies – such as Verbeek's notion of technological intentionality – they do not always translate into frameworks that can capture multilateral interactions involving multiple technologies across scales. Furthermore, a view of technology as *high technology* persists, necessitating further interdisciplinary work if a diachronically informed methodology is the goal.

Finally, across all approaches, there is a challenge in integrating micro-level analyses of embodied technological interaction with macro-level accounts of cultural and institutional structures as technologies. Existing models tend to privilege one scale over the other, leaving a gap in understanding how technologies function simultaneously as material tools, embodied practices, cultural artifacts, and systemic mediators. This lack of integration hampers efforts to develop comprehensive models capable of addressing the complexity of human-technology interaction in real-world contexts.

Two more questions from the Introduction to this review remain. As these questions relate to the relations between models of disability and conceptualizations of technology, the answers will be highly tentative – first steps in ongoing work, rather than fully explored ones.

1. *How do views of technology connect with those of disability, or the diversity of people in general?*

The conceptualization of technology – appearing explicitly or implicitly in models of disability – often reflects underlying assumptions about disability and diversity. For instance, the medical model of disability, as discussed by Jurgens (2023) and critiqued by Shew (2023), aligns with a narrow, instrumental view of technology as a corrective mechanism to "fix" impairments. This perspective positions technology as a unidirectional solution and reinforces deficit-based understandings of disability. In contrast, the social model of disability (Oliver, 2013; Adams et al., 2005) shifts the focus to environmental barriers, framing technology as part of an enabling infrastructure that promotes accessibility and inclusion.

More recent frameworks, such as enactive and ecological models (Maiese, 2018; Jurgens, 2023) extend this relational perspective by treating technologies as integral components of cognitive systems. These models resonate with the neurodiversity paradigm (Shew, 2023), which values difference rather than pathologizing it, and conceptualizes disability as a form of diversity that can enable unique cognitive strategies. These kinds of connections suggest that views of technology – whether as neutral tools, mediating agents, or systemic components – may carry implications for how diversity and disability are understood and addressed.

2. *What are the gaps in research related to how views of technology coincide with the diversity in human abilities?*

Despite theoretical advances, gaps remain in linking conceptual views of technology to empirical diversity in human abilities. As long as the multilateral complexities of human-technology interactions remain nebulous – in terms of how technologies, human abilities and the natural environment become intertwined – it is difficult to form a clear picture of how the diversity of human abilities becomes channelled in workplace environments, for example. This also has to do with the temporal dimension of views of technology: technologies are frequently conceptualized as static artifacts rather than evolving socio-material assemblages that interact with changing abilities over time, as Due and Rasmussen (2025) or Latour (1999) would suggest. Scholars like Mitcham (2014) and Allenby & Sarewitz (2011) highlight the complexity of technological interdependencies, yet analyses on the micro scale do not often become connected to perspectives on the macro scale. Bridging these gaps requires frameworks that combine micro-level interaction analysis with macro-level systemic perspectives, ensuring that diversity is treated as a foundational principle rather than an afterthought in technological development.

7.Conclusion

This review has mapped a diverse landscape of theoretical and methodological approaches that present views of technology, ranging from distributed cognition and affordance theory to postphenomenology and ethnomethodology, and explored their intersections with models of disability and human diversity. The analysis highlights how conceptualizations of technology influence design principles, accessibility strategies, and normative assumptions about ability and inclusion and vice versa. By situating these perspectives within the broader aims of the NewWorkTech project, the review underscores the need for close examination of the variability of understandings of technology and how it relates to understandings of what is human.

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