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Beyond Cognitive Load: Reframing Information Systems Through the Lens of Cognitive Distance

Preprint · November 2025

DOI: 10.13140/RG.2.2.18657.57449

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Izaías Cavalcanti

University of São Paulo

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Beyond Cognitive Load: Reframing Information Systems Through the Lens of Cognitive Distance

Abstract

For decades, cognitive load theory has guided how we evaluate usability and accessibility in information systems. Yet, this singular focus on mental effort has obscured a deeper phenomenon: the representational gap between how systems encode information and how users conceive their tasks. This paper introduces Cognitive Distance in Information Systems (CDIS) as a theoretical construct for understanding that gap. Drawing from cognitive psychology, human-computer interaction, organizational theory, and accessibility research, CDIS reframes usability as representational alignment rather than mere efficiency. The study synthesizes prior work – from spatial cognition to embodied interaction and AI agency frameworks – to build a multi-layered model describing perceptual, semantic, procedural, and agency distances. The result is a conceptual framework for accessibility that views inclusivity not as simplification, but as cognitive coherence.

1. Context

For nearly four decades, research in Human-Computer Interaction (HCI) and broader Information Systems has revolved around one central psychological construct: **cognitive load**. From the early models of Card, Moran, and Newell (1983) to the instructional frameworks of Sweller (1988) and Paas & van Merriënboer (1994), the idea that human performance hinges on limited mental capacity has shaped how we evaluate usability, design training interfaces, and even structure digital learning environments. The logic is tidy, if interaction requires less mental effort, it must be better.

But something subtle got lost in that obsession. We learned to measure *how much* mental effort users spend, but not *what for*. We optimized systems to minimize the load, yet often ignored whether the system's representation of the world aligned with the user's mental representation of their task. A user might not be overloaded and still be fundamentally misaligned, staring at an interface that makes sense to no one but its designer.

That misalignment is the essence of what can be called **cognitive distance**. The term appears scattered across domains: in spatial cognition, it refers to mental representations of physical space (Montello, 1991); in organizational learning, to differences between actors' mental models (Nooteboom, 2000); in interface design, to the gap between user intention and system expression (Zhang, 1999). In each case, the concept captures not load but *translation*, which is

the mental effort needed to bridge two representational systems that do not speak the same language.

Within **information systems**, this gap takes many forms. Sometimes it's **semantic** (the system describes entities differently from how users think about them), sometimes **perceptual** (information is encoded in a sensory channel inaccessible to the user), and sometimes **conceptual or procedural** (the logic of interaction conflicts with the logic of the user's task). Traditional usability studies might interpret these mismatches as "confusing interfaces" or "poor design," but such labels miss the structural dimension, the distance between cognitive worlds that the system fails to reconcile.

It's tempting to think of information systems only as screens, such as GUIs, dashboards, and apps. Yet, in their most fundamental sense, **information systems are any sociotechnical arrangements that mediate meaning between humans and their environment**. A road sign, a tactile map, a haptic feedback loop, an AI voice assistant... all are information systems because they translate information into perceptible form. When a visually impaired commuter interprets a tactile path on the floor, or a driver reads a minimalistic dashboard, cognitive distance determines whether the translation between human and system is immediate or strained.

The evolution of interface paradigms shows a recurring struggle to shrink that distance. Early symbolic interfaces (command lines, textual prompts) required users to internalize machine syntax, and that is a massive representational gap. Graphical user interfaces (GUIs) in the 1980s and 1990s tried to reduce it by visual metaphors (folders, desktops), yet those metaphors aged poorly as context changed. The emergence of ubiquitous and embodied computing (Weiser, 1991; Ishii, 2008) shifted the goal again, away from visibility and toward *transparency*, where computation dissolves into everyday activity. Wren and Reynolds (2002) described this as *parsimony*: the best interface is one that requires no conscious mediation at all.

Today, that ambition has resurfaced in **human-AI collaboration**, but in more complicated form. Intelligent systems introduce new representational gaps, not just between user and interface, but between user and *agency*. When systems begin to predict, decide, or even "suggest," users must realign their mental models to interpret what the machine is doing and why (Zhang et al., 2025). The question is no longer merely whether users can handle the load, but whether they can inhabit the same cognitive frame as the system.

From an **accessibility standpoint**, this reframing is overdue. Accessibility has long been equated with reducing perceptual or cognitive barriers, yet such reduction is often pursued through the lens of load: simplifying content, reducing working memory demands, minimizing steps. These are necessary but not sufficient. A system can be low-load yet still inaccessible if its representational logic is alien to the user, or in other words, if the distance between the user's cognitive schema and the system's mode of representation is too wide to cross.

Thus, the argument begins here: if cognitive load measures *how much* mental effort is required, **cognitive distance measures *what kind of effort it is, and why it is needed in the first***

place. It is not a property of the user alone, nor of the interface, but of the relational alignment between them. And as information systems grow more adaptive, distributed, and embodied, understanding and designing for that alignment may be the key to the next generation of accessible, human-centered technology.

2. Research Gap / Problem

The language of **cognitive load** has become so embedded in information systems research that it often operates as a default explanation for almost any cognitive or usability difficulty. Whether in e-learning systems (Paas & van Merriënboer, 1994; Kirschner, 2002), interface design (Sweller, 2011), or accessibility evaluation (Seffah & Metzker, 2004), the prescription is consistent: reduce the load, simplify the interface, streamline the process. But this reductionist framing has gradually blurred conceptual boundaries. Cognitive load was never meant to describe *relational misalignment* between human and system – it was meant to describe *internal working memory constraints* during schema acquisition (Sweller, 1988). Yet, decades later, it's invoked to explain friction that arises not from memory limits but from **representational mismatch**.

Consider the typical usability study: a user takes longer than expected to complete a task. Researchers interpret the delay as an increase in cognitive load, but the actual issue might be that the system's conceptual model is foreign to the user's reasoning. The user isn't "overloaded"; they're *lost in translation*. Their mental representation of the task (say, "searching for a document") doesn't map onto the system's representation (say, "querying by metadata"). The problem isn't effort, it's distance.

Despite its presence across scattered literatures, **cognitive distance has never been formalized as a first-class construct in information systems research**. In spatial cognition, the term was empirically operationalized by Daniel Montello (1991) to describe the mental representation of environmental distances—an inherently *non-perceptual* phenomenon requiring movement and integration of multiple viewpoints. In organizational and innovation studies, Bart Nooteboom (2000) used it to describe the epistemic gap between agents' knowledge bases: too little distance leads to redundancy, too much leads to incomprehension. Both usages describe a *relational space of understanding* rather than a measure of load. Yet HCI and accessibility research have largely overlooked these insights, focusing instead on optimizing performance within the user's current cognitive frame, rather than aligning that frame with the system's representational model.

Some attempts to bridge this gap emerged in early interface theory. Donald Norman (1988) distinguished between the *system image*, the *designer's model*, and the *user's model*, arguing that usability depends on the overlap among them. Ben Shneiderman's (1983) notion of **direct manipulation** and Ping Zhang's (1999) concept of **cognitive distance in interface design** further hinted at a broader framework: the less effort required to translate between internal goals and external representations, the smaller the distance. But these ideas never evolved into a

unified construct – perhaps because HCI research, guided by its experimental tradition, privileged quantifiable load over qualitative misalignment.

From an **accessibility** perspective, this absence is striking. Much of digital accessibility research revolves around compliance with perceptual standards (contrast, readability, alternative input methods) or cognitive simplicity (minimal memory demand, consistent layout). These are crucial, yet they only address *surface-level access*. What remains unexamined is **representational access**, the ability of a system's informational structure to resonate with diverse mental models, linguistic frameworks, and sensory modalities. An interface that technically meets accessibility standards can still be cognitively distant to users whose conceptual frames differ from the normative design.

For example, screen readers provide auditory translation of text but often preserve the visual hierarchy of a page, forcing blind users to mentally reconstruct spatial relations that were designed visually. The resulting barrier is not *load* - the user may be perfectly capable of handling information - but *distance*: a mismatch between the representational format of the system and the cognitive architecture of the user.

The same logic extends far beyond disability contexts. In collaborative AI systems, users must interpret probabilistic reasoning and autonomous actions that do not align with human expectations (Zhang et al., 2025). In ubiquitous computing, users must infer the logic of invisible interactions among devices (Weiser, 1991). In each case, friction arises not from excess demand but from the *translation work* users must perform to align their understanding with the system's behavior.

Therefore, the central research gap is this:

Information systems research has deeply theorized cognitive load, but not cognitive distance — the relational effort required to translate between human and system representations.

This omission limits both our theoretical understanding of interaction and our practical approaches to accessibility. Systems designed merely to reduce load risk remaining cognitively distant. Optimized for efficiency yet detached from meaning. If cognitive load defines the *quantity* of mental effort, cognitive distance defines the *quality* of representational alignment. And without accounting for both, accessibility remains partial, usability superficial, and human-system understanding fundamentally incomplete.

3. Objectives

This study sets out to reclaim **cognitive distance** as a central construct in understanding how humans interact with information systems. Not as a metaphor borrowed from other fields, but as a formal dimension of accessibility, usability, and comprehension. The premise is simple but far-reaching: *to interact effectively with a system, users must not only manage cognitive load but also traverse – or ideally eliminate – cognitive distance.*

Where traditional HCI research has sought to make interfaces lighter on the mind, this work seeks to make them **closer to the mind**, conceptually, perceptually, and semantically. That shift from *effort* to *alignment* redefines what it means for a system to be “accessible.” An accessible interface should not merely minimize the amount of mental processing required; it should minimize the representational translation between what the user means and what the system means by the same action, command, or symbol.

Thus, the first and most fundamental objective of this paper is to **define cognitive distance within the context of information systems**. The term must be stripped of its disciplinary fragmentation and reframed as a coherent construct that captures the relational effort between user cognition and system representation. This definition must encompass a spectrum of distances – semantic, perceptual, procedural, and epistemic – that jointly shape how accessible a system truly is.

The second objective is to **differentiate cognitive distance from cognitive load**, both conceptually and methodologically. While load is measured through indicators such as task completion time, working memory strain, or error rate (Sweller, 2011; Paas et al., 2003), distance resists such direct quantification. It is revealed not by how hard the mind works, but by how *misaligned* two representational systems are. This paper therefore aims to propose the conceptual contours of what a “measurement” of distance might entail, from qualitative mapping of user-system conceptual models to new forms of semantic and perceptual evaluation.

A third objective is to **expand the scope of what counts as an information system**. Interfaces are not limited to screens, keyboards, or voice agents. Physical signage, ambient displays, tactile or auditory guidance systems, all these mediate meaning between humans and their environment. Understanding cognitive distance at this broader level allows accessibility research to bridge digital and physical domains, recognizing that representational mismatch can exclude users even before a device is involved. A sign designed for one cultural or cognitive schema can be as inaccessible as a website with no alt text.

A fourth objective is to **build a theoretical framework** that articulates how cognitive distance manifests and interacts with other constructs: cognitive load, trust, agency, and inclusivity. The framework will draw from multiple traditions:

- the information processing model of Card, Moran, and Newell (1983),
- Norman’s (1988) mental models,
- Montello’s (1991) spatial cognition metrics,
- Nooteboom’s (2000) epistemic distance, and
- contemporary frameworks of human–AI collaboration (Zhang et al., 2025).

Through their synthesis, the goal is to articulate a *Cognitive Distance in Information Systems (CDIS)* model capable of explaining not just usability outcomes but also the deeper epistemic accessibility of technological systems.

Finally, this paper aims to **spark a shift in how digital accessibility is conceptualized**, from a narrow compliance paradigm to an epistemological one. Accessibility should no longer be seen solely as removing perceptual or procedural barriers; it should be seen as aligning cognitive worlds. The central thesis is that *a system is accessible to the extent that it minimizes the distance between its internal model and the user's cognitive model of the world it represents*.

In short, this study pursues five interlinked objectives:

1. Define cognitive distance as a foundational construct in information systems.
2. Differentiate cognitive distance from cognitive load both theoretically and empirically.
3. Extend the definition of information systems beyond screens to encompass all representational media.
4. Develop an integrative framework (CDIS) to analyze and design for minimized distance.
5. Reframe digital accessibility as cognitive alignment rather than mere cognitive simplicity.

Together, these objectives aim to reposition cognitive distance not as an ancillary curiosity, but as a missing dimension of human-system interaction, a construct whose neglect has subtly distorted decades of usability and accessibility research.

4. Research Questions and Hypotheses

Every mature research domain eventually reaches a point where its central construct begins to overextend its usefulness. In information systems and HCI, *cognitive load* has reached that point. It has explained so much, for so long, that it now explains almost everything, and therefore, perhaps, too little. To move beyond optimization toward understanding, this study poses a new set of questions centered on the relational construct of **cognitive distance**.

The guiding assumption is simple: usability problems, accessibility barriers, and even miscommunications in AI-mediated environments often emerge not from excessive cognitive effort but from **misaligned representational structures**. Users are not always overworked; they are often *out of sync*. From that premise, four primary research questions arise.

RQ1. How can cognitive distance be formally defined within the context of information systems?

This question seeks to clarify what has so far been treated only implicitly across related literatures. In spatial psychology, cognitive distance refers to subjective estimations of environmental separations (Montello, 1991); in organizational theory, it refers to epistemic gaps between agents (Nooteboom, 2000). Yet, in human-system interaction, there is no coherent definition that binds these notions to the way systems represent, encode, or visualize information.

The goal is to establish a **theoretical definition** of cognitive distance that accounts for semantic, perceptual, and procedural misalignments, since they are the very mechanisms by which systems fail to “think like” their users.

RQ2. In what ways does cognitive distance differ from, and complement, cognitive load?

The second question addresses a conceptual confusion that has persisted for decades. Cognitive load, in the sense of Sweller (1988), measures internal strain during schema formation and task performance. Cognitive distance, by contrast, measures the *translation gap* between two cognitive systems: the user’s and the system’s.

Hypothesis **H1** follows:

Reducing cognitive load without reducing cognitive distance does not necessarily improve usability or accessibility; in some cases, it may even obscure deeper representational misalignments.

This hypothesis challenges the prevailing assumption that less effort always equates to better design. A system can be mentally light yet cognitively alien; easy to operate, hard to understand.

RQ3. How does cognitive distance affect accessibility and inclusion across diverse modalities of information systems?

Accessibility is traditionally defined by perceptual and motor access, ensuring that all users can *reach* content. But representational alignment is a subtler form of access: can users *make sense* of what they reach? This question explores how cognitive distance manifests across **different types of systems** – textual, visual, tactile, auditory, embodied, and AI-driven – and how such distance affects users with varying sensory, cognitive, and cultural profiles.

Hypothesis **H2** proposes that:

Cognitive distance mediates the relationship between interface modality and user comprehension; systems that are perceptually accessible but representationally distant still produce exclusionary effects.

This extends accessibility research beyond compliance, positioning comprehension and cognitive resonance as measurable forms of inclusion.

RQ4. How can cognitive distance be identified, measured, and reduced in the design of information systems?

While load has established quantitative metrics (reaction times, secondary-task methods, NASA-TLX), distance demands new methodological creativity. Mapping conceptual alignment between users and systems may involve qualitative modeling, semantic differential techniques, concept mapping, or even neurocognitive correlates of mental translation effort.

Hypothesis **H3** suggests that:

Design interventions that explicitly target representational alignment, such as adaptive metaphors, multimodal redundancy, or participatory model-building, will yield measurable reductions in cognitive distance and improvements in perceived accessibility.

This hypothesis also implies a methodological challenge: distance cannot be reduced by simplification alone; it requires *coherence* between how a system represents and how a user understands.

Together, these research questions and hypotheses carve a path toward a deeper, more systemic theory of accessibility, that views interaction not as a unidirectional act of cognition but as a **dialogue between representational worlds**. The study does not abandon the insights of cognitive load theory; it reframes them. Load describes the cost of mental processing, but distance describes the cost of meaning-making. Both matter, yet it is distance that ultimately determines whether cognition, perception, and design ever truly meet.

5. Research Method

This study is **theoretical and integrative** by nature. It does not test a single variable but seeks to synthesize concepts scattered across cognitive psychology, human–computer interaction, and accessibility research into a unified model of **Cognitive Distance in Information Systems (CDIS)**. The method follows the tradition of *conceptual synthesis*, connecting partially overlapping constructs to expose what has been implicitly shared but never fully articulated (Jaakkola, 2020).

The approach unfolds across three analytical layers: **(1) historical–conceptual review**, **(2) cross-domain comparison**, and **(3) framework construction**. Each is guided by the principle of parsimony: retaining theoretical precision without sacrificing human interpretability.

5.1 Historical–Conceptual Review

The first phase involves tracing how *cognitive distance* has appeared, explicitly or implicitly, across domains that have shaped the study of information systems. Key sources include:

- **Cognitive Psychology & Human Performance** — Card, Moran, and Newell’s *The Psychology of Human–Computer Interaction* (1983) established the information-processing architecture underlying mental workload models. Norman (1988) later reframed this architecture in terms of mental models, introducing the “gulf of execution” and “gulf of evaluation,” which already hinted at representational gaps between user and system and the earliest articulation of cognitive distance.
- **Spatial Cognition & Measurement of Mental Distance** — Montello’s (1991) empirical work on how individuals estimate large-scale environmental distances provided the methodological foundation for conceptualizing *distance as cognitive representation*, not physical separation. His categorization of scaling methods (ratio, interval, mapping, route choice) informs how distance might be operationalized in information systems – not as geography, but as mental displacement between models.
- **Organizational and Knowledge Systems Theory** — Nooteboom (2000) reinterpreted cognitive distance as the difference between knowledge bases among agents in innovation networks. This formulation captures both the productive and destructive sides of distance: too little yields redundancy; too much prevents learning. The same dialectic applies to system design: an interface too close to user cognition risks stagnation; one too distant risks exclusion.
- **Intelligent and Embodied Interfaces** — Chignell and Hancock’s *An Introduction to Intelligent Interfaces* (1989) and Fishkin’s (2004) embodied taxonomy illustrate how computational systems progressively reduce mediation, moving toward direct, sensory–motor coupling. Their work demonstrates how physical embodiment can collapse certain forms of cognitive distance by making digital actions perceptually continuous with physical intentions.
- **Contemporary Accessibility and AI Agency Frameworks** — Recent work by Zhang et al. (2025) on human–AI co-creation reframes user–system interaction as a negotiation of *agency distribution*. This aligns with the current study’s hypothesis that cognitive distance expands when the user’s model of system agency diverges from the system’s actual behavior model, and reveals a new form of representational misalignment.

By integrating these threads, the study establishes a genealogy of the concept, showing that “distance” has been present in the discourse of cognition and design all along, only never unified under a single theoretical lens.

5.2 Cross-Domain Comparison

The second phase applies a **comparative analytical lens** to identify structural analogies between these traditions. The goal is to uncover how *different disciplines describe the same relational phenomenon* — the effort to align internal cognition with external representation.

The analysis examines four recurring **dimensions of distance**:

1. **Perceptual distance** – the gap between sensory encoding and perceptual decoding of system cues (e.g., visual icons, auditory signals, haptic feedback).
2. **Semantic distance** – the gap between the system’s symbolic structures (labels, data hierarchies, metaphors) and the user’s conceptual schema.
3. **Procedural distance** – the gap between how a task is executed within the system and how the user conceptualizes that task in their real-world workflow.
4. **Agency distance** – the gap between perceived and actual control distribution in systems that act autonomously or intelligently.

Each domain contributes a partial vocabulary for one or more of these distances. Spatial cognition formalizes measurement; HCI operationalizes perception and procedure; organizational theory explains epistemic divergence; AI collaboration introduces agency. The comparative analysis aligns these vocabularies into a multidimensional structure that defines cognitive distance as a *relational metric of representational alignment*.

5.3 Framework Construction: The CDIS Model

The synthesis culminates in the construction of the **Cognitive Distance in Information Systems (CDIS)** framework, a conceptual model designed to map and eventually measure the representational gap between user cognition and system design. The CDIS framework organizes cognitive distance across **three interacting layers**:

1. **Representation Layer** — the structures by which information is encoded and externalized (visual layouts, physical signals, data schemas, algorithmic outputs).

2. **Interpretation Layer** — the user’s perceptual, linguistic, and cultural decoding of those structures.
3. **Mediation Layer** — the dynamic interface mechanisms (interaction modalities, feedback loops, adaptivity) that attempt to bridge the two.

Cognitive distance is conceived as the *residual misalignment* after mediation occurs. It is the degree of translation still required for the user to integrate system information into their task model. In accessibility terms, this misalignment represents a *latent barrier*: invisible yet often more disabling than any perceptual limitation.

The CDIS framework thus proposes that **design quality is inversely proportional to residual cognitive distance**, provided that distance is not entirely eliminated at the cost of flexibility or learning. Systems should aim for *optimal distance*, close enough for comprehension, distant enough for cognitive growth and adaptability. This mirrors Nooteboom’s (2000) insight that difference drives innovation as long as it remains intelligible.

5.4 Methodological Integrity

Because this is a conceptual synthesis, validity depends not on statistical inference but on **construct coherence and theoretical integration**. Each source is examined for:

- conceptual precision (does the construct define a relationship, not just an attribute?),
- contextual relevance (does it apply to human–system interaction broadly defined?), and
- potential for operationalization (can distance be observed or measured empirically?).

To preserve replicability, the analysis retains explicit bibliographic traceability — every conceptual borrowing is documented, not paraphrased into abstraction. This ensures the framework remains falsifiable and open to empirical testing in future research on cognitive alignment and accessibility.

In short, the method treats theory-building as a form of design: each conceptual component must fit the next, reducing internal incoherence — the *cognitive distance within theory itself*. The result is a unified structure that can inform future empirical work, guiding designers and researchers toward systems that do not merely *lighten the mind*, but *speak its language*.

6. Contributions

Every theoretical construct earns its place by clarifying what others have blurred. The **Cognitive Distance in Information Systems (CDIS)** framework does precisely that: it reframes long-standing assumptions about usability, accessibility, and cognition by shifting the analytical focus from *how much* effort users expend to *why* that effort exists at all. Its contributions span four dimensions — conceptual, theoretical, practical, and societal — each addressing a different layer of this reframing.

6.1 Conceptual Contribution: Naming the Missing Construct

At its core, CDIS introduces **cognitive distance** as a formal construct within the vocabulary of information systems research. While the term has appeared sporadically — from Montello’s (1991) mental mapping to Nootboom’s (2000) epistemic gaps — it has never been codified in HCI or accessibility studies as a measurable relational property. By consolidating these disparate origins, CDIS positions cognitive distance as the *translation cost* between user and system representations.

This conceptual precision allows researchers to disentangle cognitive distance from cognitive load. Load measures mental intensity; distance measures *representational misalignment*. Without this distinction, decades of interface optimization have mistaken low effort for high alignment — a category error that CDIS corrects.

In doing so, the framework reorients usability away from task efficiency toward *representational coherence*, establishing a shared foundation for future empirical work on mental models, multimodality, and inclusive design.

6.2 Theoretical Contribution: Reframing the Foundations of Interaction

Theoretically, CDIS expands the cognitive foundations of information systems by integrating insights from four historically separate traditions: cognitive ergonomics, spatial cognition, organizational learning, and accessibility research. It reinterprets Norman’s (1988) gulfs of execution and evaluation as *distance functions*, measurable not just through behavioral timing but through the relational geometry of understanding between user and system.

This reframing has two important consequences.

First, it anchors interaction theory in **representational alignment** rather than user capacity. The central question becomes: *How close is the system’s world model to the user’s?*

Second, it introduces a **multi-dimensional taxonomy of distance** — perceptual, semantic, procedural, and agency — that can be empirically mapped and manipulated in design research. Each dimension contributes to the overall accessibility of a system, yet each requires distinct design strategies to minimize.

By providing this taxonomy, CDIS offers a theoretical grammar for describing misalignment. It transforms vague complaints about “confusing interfaces” into analyzable phenomena with definable structure.

6.3 Practical Contribution: Designing for Alignment Rather Than Simplicity

Practically, the CDIS framework provides a new set of design heuristics:

- **Diagnose** distance before reducing load. Designers can use concept-mapping or participatory model-building to reveal where users’ conceptual schemas diverge from system logic.
- **Mediate** distance through adaptive representation. Systems can dynamically translate between user and system models — through personalization, multimodal feedback, or progressive disclosure.
- **Balance** distance, not erase it. Total alignment can hinder learning or innovation; optimal cognitive distance preserves enough difference to stimulate engagement without exclusion.

These principles apply across the full range of information systems: from websites and learning environments to tactile signage, data dashboards, AI assistants, and smart physical infrastructures. They also intersect naturally with existing accessibility guidelines — extending standards like WCAG from perceptual reachability to *cognitive reachability*.

For evaluation, CDIS suggests a hybrid methodology: combining cognitive walkthroughs (Polson et al., 1992) with conceptual alignment mapping — effectively treating usability testing as a study of representational translation rather than performance efficiency alone.

6.4 Societal Contribution: Redefining Accessibility as Cognitive Inclusivity

Beyond the lab or design studio, the societal impact of CDIS lies in its redefinition of **accessibility**. Traditional frameworks view accessibility as the removal of barriers; CDIS views it as the *alignment of worlds*. Inaccessible systems are not simply harder to use — they are ontologically distant, forcing users to inhabit alien representational structures.

For users with disabilities, this manifests as continuous translation labor: turning spatial cues into auditory form, or navigating logical hierarchies built on visual metaphors. For neurodiverse users, it appears as semantic dissonance — when interface logic assumes a normative pattern

of inference or perception. By framing these barriers as cognitive distance, CDIS provides a vocabulary for describing exclusion without reducing it to deficit.

At a broader societal level, the framework challenges the moral economy of design. Efficiency, often mistaken for inclusivity, can conceal epistemic privilege: systems that seem “intuitive” usually mirror the cognition of their creators. Cognitive distance exposes that asymmetry and invites co-design practices that expand who gets to define what “intuitive” means.

6.5 Future Theoretical Resonance

Seminal theories endure not because they close questions but because they open better ones. The CDIS framework introduces a conceptual lens that future research can extend in multiple directions:

- empirical measurement of distance using cognitive modeling or eye-tracking,
- adaptive algorithms that infer and minimize distance in real time,
- longitudinal studies of how users internalize new representational grammars,
- ethical analyses of when distance should *not* be reduced, such as in transparency or algorithmic accountability contexts.

Each of these directions transforms cognitive distance from an abstract metaphor into a testable, designable property of human–system interaction.

In sum, the contribution of this work lies not merely in proposing a new construct but in exposing a blind spot that has shaped decades of information system design. **Cognitive distance reframes accessibility, usability, and interaction as problems of shared understanding rather than individual limitation.** It invites designers, researchers, and technologists to ask a different question — not *How much can users handle?* but *How far must they travel to understand?*

7. Discussion and Future Directions

Every generation of information systems research has been defined by the construct it chose to measure. In the 1980s, it was *efficiency*; in the 1990s, *usability*; in the 2000s, *user experience*; and for the last two decades, *cognitive load*. Each offered clarity — a way to quantify and improve interaction. Yet clarity often comes at the cost of depth. By focusing on how much the user can handle, we’ve lost sight of *what they’re being asked to handle in the first place*.

The concept of **cognitive distance** reintroduces that depth. It exposes interaction as not merely an act of information processing but an act of *translation* between representational worlds. The system speaks in data structures, logic, or probabilities; the user speaks in goals, metaphors, and context. Interaction happens — or fails — in the overlap.

This framing has several implications for theory, design, and accessibility.

7.1 Reinterpreting “Ease of Use”

Ease of use has long been treated as the gold standard of design, but CDIS suggests that *ease* and *closeness* are not the same. A system can be easy yet distant — frictionless to operate but opaque to interpret. Consider voice assistants that perfectly parse commands but conceal reasoning, or “smart” environments that anticipate actions without explanation. These systems reduce load while increasing distance. They make interaction feel smooth, but comprehension remains shallow.

A more complete notion of usability must therefore incorporate **cognitive alignment** — how faithfully the system’s representational logic mirrors the user’s model of reality. An interface that is intuitively learnable but conceptually alien cannot be called accessible, no matter how effortless the interaction appears.

7.2 Cognitive Distance and the Ethics of Automation

In the era of intelligent and autonomous systems, the stakes of representational misalignment are not just cognitive but ethical. When an AI acts on behalf of a user, its decision space must remain *cognitively reachable*. Otherwise, users lose epistemic control — they no longer know *why* outcomes occur.

Reducing cognitive distance here is not about efficiency; it’s about accountability. Zhang et al. (2025) point out that agency in human–AI co-creation is distributed across perception, reasoning, and action. If users cannot mentally reconstruct the logic of the system’s decisions, accessibility collapses into opacity. CDIS therefore offers a conceptual bridge between **usability** and **explainability**, linking interaction design with AI ethics.

7.3 Accessibility as a Gradient of Alignment

Traditional accessibility frameworks tend to classify systems as either accessible or not — binary outcomes based on compliance checklists (e.g., WCAG). But cognitive distance invites a

gradient model of accessibility. Systems can be perceptually accessible yet cognitively distant; conversely, they can be conceptually aligned yet perceptually demanding.

For instance, a tactile map may be perceptually reachable for a blind user but cognitively distant if it encodes information through spatial conventions derived from visual design. Likewise, a “simple” digital interface may still alienate users with cognitive disabilities if its task logic assumes neurotypical reasoning patterns.

Cognitive distance reframes accessibility not as a static property of the interface but as a *relational state* between system and user — one that varies with context, experience, and adaptation. This opens an empirical agenda: measuring not compliance, but **cognitive reachability** — how far users must travel, conceptually or perceptually, to make sense of a system’s information.

7.4 Design for Cognitive Alignment

Designing for reduced cognitive distance means **treating representation as infrastructure**. It’s not just about visual layout or interaction flow but about shaping how meaning travels between human and system.

Several design implications follow:

- **Adaptive representation:** Interfaces should modulate their level of abstraction or modality based on inferred cognitive distance — a system might shift from symbolic to pictorial, or from explicit instruction to gesture recognition, depending on user behavior.
- **Participatory model-building:** Co-design practices can expose cognitive distance before deployment, aligning system logic with diverse user schemas.
- **Embodied interaction:** Systems that physically anchor data (e.g., tangible or spatial computing interfaces) can collapse certain forms of distance by engaging the body as part of cognition (Ishii, 2008; Fishkin, 2004).
- **Transparent automation:** Intelligent systems should make their representational assumptions visible — showing how they interpret user input rather than only what result they produce.

Such practices do not eliminate distance altogether — nor should they. As Nooteboom (2000) reminds us, difference drives innovation. The goal is *optimal distance*: enough misalignment to invite reflection and learning, but not so much that comprehension fails.

7.5 Future Research Directions

The CDIS framework opens several empirical and theoretical frontiers:

1. **Operationalization and Measurement**

Developing methods to measure cognitive distance quantitatively remains an open challenge. Techniques from spatial cognition (Montello, 1991), semantic similarity metrics, and conceptual mapping could be adapted to estimate alignment between user and system representations.

2. **Dynamic Cognitive Distance**

Distance is not static — it contracts and expands as users learn or as systems adapt. Longitudinal studies could explore how representational proximity evolves over time, and whether systems that adjust dynamically maintain accessibility more effectively.

3. **Cross-Modal and Cross-Cultural Studies**

Cognitive distance may vary across sensory modalities or cultural frameworks. Understanding these variations could inform global accessibility design, revealing how systems privilege certain cognitive or linguistic norms.

4. **Ethical Calibration**

Future research should also explore when *not* to minimize distance — for example, in safety-critical systems that must preserve explicit reasoning steps, or in educational technologies designed to challenge users' conceptual frames. Cognitive distance, like tension in art or dialogue, can sometimes be productive.

5. **Integration with AI Explainability and Transparency**

In the coming years, measuring cognitive distance might become as critical for AI as measuring bias. A system that produces correct outcomes but remains cognitively unreachable perpetuates a new form of exclusion — epistemic opacity disguised as intelligence.

7.6 Closing Reflection

If cognitive load was the defining construct of the information-rich 20th century — a measure of how much we could process — cognitive distance may well define the 21st, an age where the problem is no longer volume but **alignment**. Our systems are not overwhelming us by quantity; they're outpacing us by abstraction.

The work ahead is not to make interfaces easier but to make them *coherent*. To design systems that meet users where they already think, and then, gently, invite them further. Cognitive

distance gives us the language for that journey — not as a metric of limitation, but as a map of understanding.

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