

# Tangible Data

A systematic review of data physicalization and its implications for interaction design

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# From Datafication to Data-Sense

## Datafication

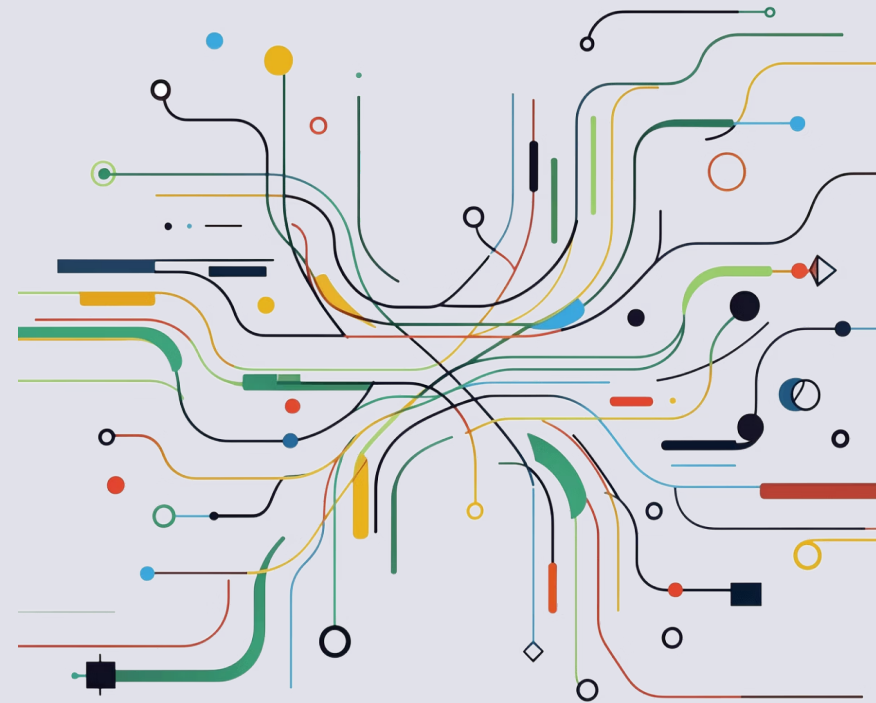
Digital technologies record aspects of human life, rendering them into data — societies are becoming data-driven (Van Dijck, 2014).

## Human-Data Interaction

HDI argues data should be legible and negotiable, centering not only on big data but on personally generated, meaningful data.

## Data-Sense

Lupton introduces "data-sense" — data as co-created assemblages, "lively" and contingent, not static or neutral.



# Foundations: The Tangible Turn



## Tangible User Interfaces

Originating at MIT Media Lab (Ishii, late 1990s), TUIs aimed to "give physical form to digital information," shifting from graphical to embodied interaction.

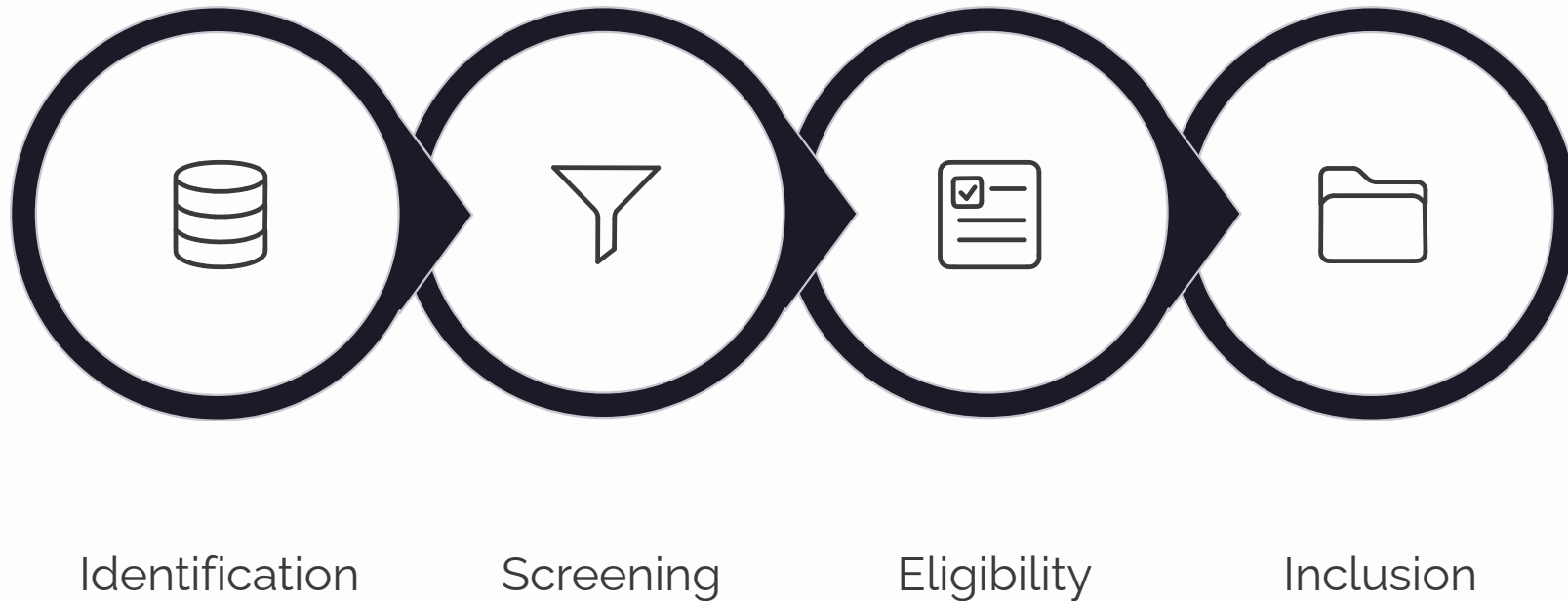
## Embodied Interaction

Rooted in phenomenology (Heidegger, Wittgenstein), this approach emphasizes bodily ways of knowing. Hornecker and Buur expanded TUIs to include spatial, cultural, and social dimensions.

## Data Sculpture

Zhao and Vande Moere linked embodiment to "data-oriented artefacts," using metaphors to map abstract data onto lived experience.

# Methodology: A Two-Phase Study



The systematic review was complemented by an **annotated portfolio of 30 case studies** drawn from academic and grey literature, selected for diversity in typology, interaction modality, and application domain.

# Epistemological Perspectives on Data

## Positivist

Data as objective, quantifiable, pre-existing — dominant in InfoVis.

## Constructivist

Data shaped by perception, context, and engagement — embraced in interaction design.

## Material

Data inscribes itself within material traces (Offenhuber, 2020), challenging neutrality.

## Entangled

Data co-emerges through observation, interpretation, and materialization (Sanches et al., Barad).

□ These perspectives move beyond data as a singular *datum* toward material, contextual, and performative dimensions.

# Four Main Physicalization Outputs



## Everyday Objects

Data objects acting as interfaces, activating behaviors and emotions. *e.g. a cup encoding health data (Barras, 2016)*



## Interactive & Discursive

Artistic-driven outputs in unconventional forms, sparking debate. *e.g. pollution-absorbing jacket (Bowker, 2013)*



## Personal Physicalizations

Tied to self-tracking and Quantified Self, often developed by users via autobiographical methods. *e.g. menstrual calendar (Wu, 2020)*



## Research Toolkits

Physicalizations as tools to spark ideas and guide design research. *e.g. Protobricks (Domnink et al., 2024)*

# Three Methodological Approaches



## Hacking Digital Fabrication

Encoding datasets into object geometry via 3D printing, CNC, or laser cutting.

*ListeningCups* (Desjardins & Tihanyi, 2019) mapped sound levels to tactile bumps on ceramic cups.



## Co-Design Processes

Bottom-up, community-driven physicalizations. *Data Strings* (Domestic Data Streamers) lets citizens collectively build a data graph by fixing threads to values.



## Emerging Materials & Technologies

Shape-changing interfaces, soft robotics, bio-actuators. *Sensbiom* (craftingplastics!, 2023) uses biopolymer lattices changing color to signal UV radiation in real time.

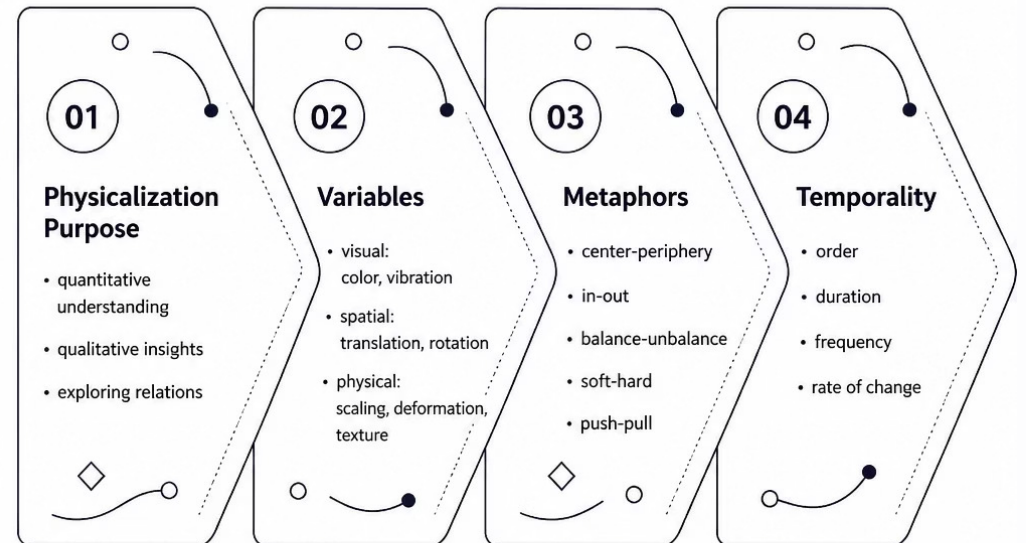
# Encoding, Variables & Temporality

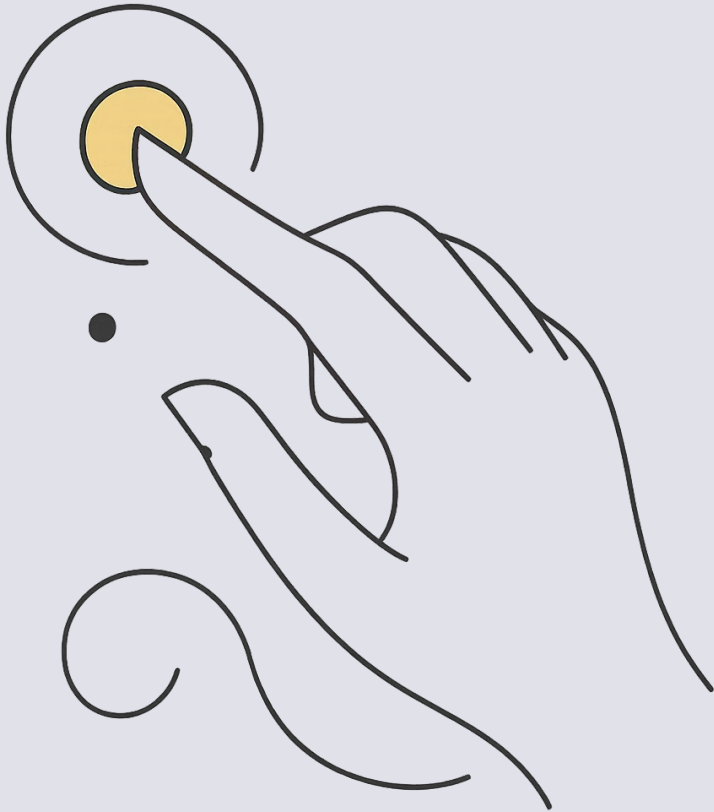
## Physicalization Types

- **Static** – does not update
- **Constructive** – assembled or manipulated by users
- **Dynamic** – updates in real-time

## Variables + Metaphors Scheme

The authors propose integrating **encoding variables** (visual, spatial, physical) with **embodied metaphors** (center-periphery, in-out, balance-unbalance) and **temporality indicators** (duration, rate of change) – a tool for practitioners and students.





# Meaningfulness & Design Challenges

## Temporalities

How long is data "physicalized"?  
Physical transformations can serve as both feedback and feedforward, blurring distinctions — especially in slow, gradual material changes like Sensbiom.

## Vocabulary Gap

The field lacks a systematic tool uniting encoding variables, embodied metaphors, purpose, and temporality. The authors' proposed scheme addresses this.

## Meaning Beyond Accuracy

Meaning emerges from aesthetic, sensory, and interpretive dimensions — not just informational clarity. Situatedness and participation are key (Mekler & Hornbæk, 2019).

# Conclusion & Future Directions

Through a PRISMA-based review of **85 papers** and **30 case studies**, this study maps a multifaceted landscape where data physicalization intersects with product design, InfoVis, HCI, and co-design.

→ Test the Variables +  
Metaphors Scheme

Mini-workshops with design researchers and students; expansion to auditory variables for accessibility.

→ Implicit Properties & BLV  
Accessibility

Ongoing study on tactile memory and multisensory recall for blind and low-vision individuals.

→ Emerging Materials

Responsive materials, soft robotics, and Engineered Living Materials (ELMs) to rethink control and legibility in data mapping.

□ This study invites a reorientation — from static representation toward living, meaningful, materially expressive engagements with data.