Codebook Definitions

Tasks

Examines the *functional purpose* of each physicalization, including (7 codes; multiple could apply).

Analyze: Focuses on revealing data insights

Educate: States a goal of educating or teaching a particular concept to a broader audience

Express: states a goal of encouraging users to express their thoughts, feelings, or ideas

Reflect: States a goal of encouraging observation and analysis of one's own internal state - thoughts, emotions, behavior, habits, and decisions.

Collaborate: Focuses on using physical artifacts to collaborate with another person

Enjoy: Focuses on hedonistic purposes for enjoyment

Unspecified: When in doubt, we put unclear and did not assume what the author meant

Audience

Examines *who* the physicalization is meant for, including (8 codes; multiple codes can apply)

General Public: All members of the public with no restrictions on age, gender, and expertise.

Children: A young human being below the age of puberty (13y/o or younger)

Family: A group of one or more parents and their children living together as a unit.

Researchers: Anyone who has professional expertise about data, digital fabrication, craft

People with Disability: Individuals who has a physical or mental disability that limits movements, senses, or activities

Creator: Intended for the actual individual who created the artifact. This sometimes includes researchers who created the artifact (e.g., Friske et al., 2020, Desjardin and Tihanyi, 2019**)**

Other: Any user of focus not already listed, such as sport fans

Unspecified: When in doubt, we put unclear and did not assume what the author meant.

Location

Examines *where* the physicalization exists, including (7 codes; multiple codes could apply).

Home: a place where the individual lives

Workspace: A place where an individual works, can be in a research lab

Public space: a place that is generally open and accessible to people (e.g., concerts, museums, parks)

Body: Worn as garments, shoes, accessories, or body art (e.g., tattoos, piercings)

Outdoors: In an outdoor environment that is surrounded by nature (e.g., rivers, forest, ocean)

School: A K-12 learning space designed to educate students under the direction of teachers

Unspecified: when in doubt, we put unclear and did not assume what the author meant

Data Source

Examines the *data source* the physicalization is representing, including (7 codes; multiple codes could apply).

Biological and medical: Referring to biological and/or medical datasets, including collected biosensing data (e.g., heart rate, galvanic skin response, gait, breathing)

General Statistics: Referring to physicalization whose aim is to communicate general statistics and topics such as civic data, GDP, population, unemployment, financial data, etc

Personal: Data that is created to raise awareness about an individual's personal habit or behavior and is typically collected from self-tracking activities

Fitness & Wellness: Data is collected and physicalized for the purpose of reflection or improvement of one's own level of fitness or mental well being

Geographical: Refer to spatial location or geographical scene

Environmental: Measurements of the environment, its systems, and impacts on its ecosystems

Image/video: Transforming images and videos into physical artifacts

Embodiment:

Examines how the data is physically manifested. (11 codes)

Shape-Changing Displays: An interface that uses physical change of shape or change in materiality as input and output. Often uses actuators

Swarm Robots: A system that consists of the coordination of multiple robots which exhibit a collective behavior

Fluidic Displays: An interface that uses the position, volume, surface, or movement of a liquid to display information

Voxel Prints: An interface where color has been defined for each point throughout the entire volume of the printed model

Embedded Tags: A system where custom embossed/engraved shapes within 3D printed or laser cut models are used to embed data to be retrieved using a smart device.

Light Displays: An interface that displays encoded data through color, position, or brightness of LEDs or other forms of electronic illumination

Edibilization: A system that encodes data through edible materials

Tangible User Interface: A physical interface for sensing interaction

Environmentally-Embedded: Data is manifested through a specific object which is meant to be used within a specific environment (home, workspace, in-nature)

Personally-Embedded: Data is manifested through the user's personalized meaning making and data mapping

Activity-Embedded: An artifact where the data and meaning-making (analysis or reflection) occurs during an activity

Material

Examines if physicalizations employ manufactured electronic components in its *material*s or as a material. (2 codes)

Electronic: Uses manufactured electronic components to control the direction of current for the purposes of gathering, encoding, or displaying data (e.g., computers, microcontrollers, active and passive components, sensors, etc.)

Non-Electronic: Does not use any electronic components

Encoding Channel

Examines the *material properties* the physicalization is using to represent information, including (7 codes; multiple codes can apply)

Color: Using an object's color property to represent information

Form: Using an object's physical structure to represent information while preserving the approximate volume of the shape

Position: Changes in the x, y, z axis (or combination) of the physicalization (e.g., actuation, moving robots)

Volume: Maintain the approximate form by expanding or contracting a form

Texture: Small changes on the surface that add visual and tactile properties without affecting the overall form

Light: The transmission or reflection of light through programmable electrical stimulation (e.g., blinking LED's, electroluminescent wire)

Vibrotactile: Stimulators (e.g., haptic motors, air flow) that can apply pressure to the skin

Mobility

Examines the mobility of the physicalization. (2 codes)

Bounded: The physicalization is confined to a particular position and is not meant to be repositioned

Unbounded: The physicalization are designed for mobility and can freely move across space

Data Scalability

Examines how flexible the physicalization can be in representing multiple, distinct datasets (2 codes)

One: Can only represent one dataset

Many: Physicalization has the ability to represent various datasets and/or other data sources

Data Duration

Examines the length of time that the data is communicated to the user through the physicalization. (3 codes)

Ephemeral: Data is displayed for a short period of time

Persistent: Data is displayed for as long as the user desires.

Permanent: Data is permanently embedded into the physical structure of the physicalization

Interactions Mediator

Examines *how* interactions are mediated, including (4 codes, multiple codes can apply).

GUI: Introducing interactions through a graphical interface

Direct: Introducing interactions by requiring users to intentionally touch or manipulate the representation of data

Sensed: A sensor informs the user, and the user interacts with the physicalized based on the sensor information

Not Applicable: No interactions are introduced

Sense Modality

Examines which *sense* the physicalization utilizes, including (4 codes; multiple codes could apply).

Visually: Perceived through the sense of sight

Tactilely: Perceived through the sense of touch

Aurally: Perceived through the sense of hearing

Gustatory: Perceived through the sense of taste

Data Interactions

Examines the *interactions* of each physicalization with respect to the user's intention. We reference Yi et al.'s framework (Yi et al., 2007) (10 codes; multiple could apply).

Select: Interactions techniques to help users mark a data item(s) of interest and to keep track of it

Explore: Interactions techniques to enable users to examine a different subset of data cases. Explore interactions do not necessarily make complete changes in the data being viewed. More frequently some view new data items enter as others are removed (e.g., panning)

Reconfigure: Interaction techniques to provide users different perspective onto the dataset by changing the spatial arrangement of representations (e.g., changing the axis scale of a chart, sorting data)

Encode: Interaction techniques to enable users to **map** data fields to physical properties (e.g., x, y color, size, shape) of an object

Abstract/Elaborate: Interaction techniques to enable users to adjust the level of abstraction of a data representation (e.g., details-on-demand)

Filter: Interaction techniques to change the set of data items being presented on some specific conditions (e.g., query based on select ranges by moving sliders or particular values). The user is not changing perspective on the data, just specifying conditions on which data are shown.

Connect: Interaction techniques to (1) highlight associations and relationships between data items that are already represented and (2) show hidden data items that are relevant to a specified item

Annotate: Interaction techniques to help users mark a data item of interest. Differs with "select" as "annotate" typically focuses on physically marking or using external props (e.g., stickers)

Collect: Interaction technique that helps user collect data typically from a sensor to serve as the input for the physicalization

Assemble: Interaction techniques of manipulating objects (typically discrete components) to create a physicalization based on encoding rules