Studying Visual Evidence from Using Physical Space to Think

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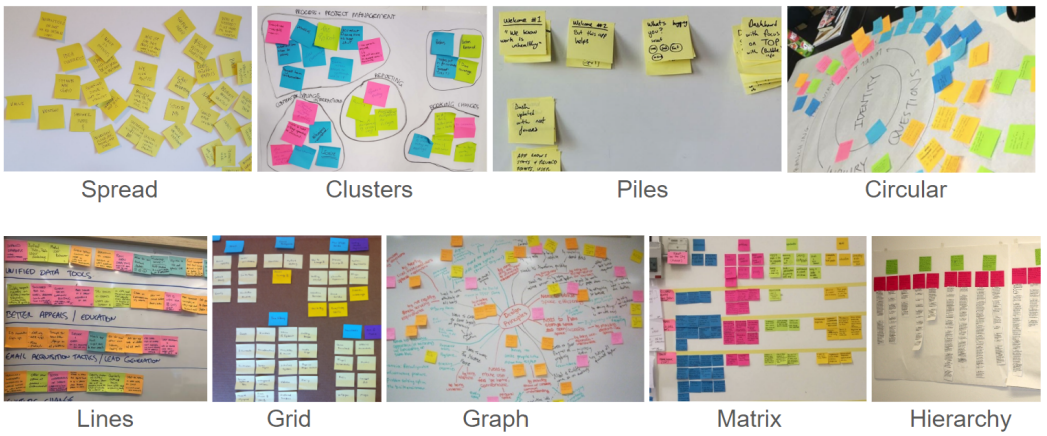

Fig. 1. Examples of spatial organization patterns: Spread, Clusters, Piles, Lines, Grid, Circular, Matrix, Graph, Hierarchy

This paper investigates how people use physical space, free from digital constraints, to organize thoughts and ideas. Such spatial arrangements commonly support sensemaking, idea generation, and data understanding. We collected over 300 publicly shared images capturing these activities collected from real-world contexts. Our visual analysis identifies a small set of recurring spatial patterns such as clusters, grids as well as the techniques people use to build and adapt them, such as color coding, directional lines, and selective rule-following. We discuss how these practices can inform the design of more expressive and adaptable digital spatially-aware tools that better support the diverse ways people think with space.

CCS Concepts: • **Information systems** → *Decision support systems*; • **Human-centered computing** → **Empirical studies in HCI**.

Additional Key Words and Phrases: Spatial Thinking, Sticky notes, Qualitative Data Analysis

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ACM 2573-0142/2025/12-ARTISS011
https://doi.org/10.1145/3773068

ACM Reference Format:
Maryam Rezaie, Samuel Huron, Parnian Taghipour, Lien Quach, Victor Cheung, and Sheelagh Carpendale. 2025. Studying Visual Evidence from Using Physical Space to Think. *Proc. ACM Hum.-Comput. Interact.* 9, 8, Article ISS011 (December 2025), 23 pages. https://doi.org/10.1145/3773068

1 Introduction

People engage with the physical space around them in many different ways to help themselves think. Whether organizing ideas on a wall, clustering sticky notes on a table, or layering sketches on windows, these arrangements reveal how space becomes a medium for cognition [18, 22]. Across design studios, classrooms, research labs, workshops, and homes, spatial layouts of sticky notes, diagrams, and clusters are frequently used to structure problems, surface relationships, and foster collaboration. These practices are widely recognized but under-analyzed in design research, particularly in the context of interactive systems.

Digital spaces, such as large displays have also been discussed as a 'space to think' [9, 29]. To support this kind of thinking and externalization of thought, a wide array of digital tools, from structured diagramming platforms (e.g. draw.io[2]) to freeform canvases (e.g. Miro [4], and FigJam [3]), have emerged to facilitate ideation, planning, and shared sensemaking. Despite the growth of these digital platforms, physical spatial organization remains a persistent practice in individual and group sensemaking. Rather than positioning this as a preference or opposition to digital tools, we view it as an opportunity: what do these analog, and often ephemeral spatial arrangements reveal about how people use space to think? And how might these insights inform the design of future interactive digital spaces and environments whose purpose is to support cognition, externalization of thought, and the flexible organization of ideas in space?

In this paper, we explore how people use physical space to structure thoughts and ideas to inform the design of digital thinking spaces. We describe *spatial thinking* as the use of visual-spatial relationships to externalize and develop information structures.This view is grounded in design cognition and human computer interaction [60]. While this process necessarily involves *externalization* which is the projection of internal thoughts into the external world [30], our focus is on the spatial structures produced through this externalization, attending to how these arrangements scaffold cognitive activity. Sticky notes figure prominently in our analysis since they so frequently serve as discrete, manipulable units that often represent individual ideas or concepts. Their consistent size, visual salience, and reconfigurable nature make them a common material for externalizing and arranging information [14] yet they remain understudied on how they support cognitive activities such as design [25]. Sticky note layouts, whether informal or highly structured, offer visible traces of how information has been grouped, sequenced, layered, or organized across space. These artifacts provide a unique opportunity to study spatial thinking not just as it unfolds, but also as it is materialized in arrangement.

To investigate these spatial traces, we collected over 300 publicly available images shared online that depicted physical sticky note arrangements resulting from a range of contexts, including individual work, group brainstorming sessions, and workshops. To focus on spatial practices that emerge in unconstrained environments, we excluded any layouts created using digital tools. Using qualitative visual analysis, we analyzed how sticky-notes were spatially organized, including compositional features and other spatial properties that contributed to the formation or communication of meaning through structure. We aim to surface design-relevant insights that can inform the development of more spatially expressive digital thinking tools.

The main contributions of this paper are:
- A grounded visual analysis of in-the-wild spatial arrangements used for thinking and ideation.
- A descriptive account of spatial patterns and organizational techniques.

- Design-relevant insights for digital spatial tools.

2 Related Work

In this section, we describe the related work under three headings, covering: 1) how individuals and groups use physical and digital spaces to externalize thoughts; 2) traditional methods of organizing information, both physically and digitally; and 3) previous studies that are particularly pertinent about use of space in externalization and information organization.

2.1 Making Use of Space to Externalize Thoughts

Externalization of thoughts is often an important step in problem-solving. Human cognition often extends beyond person's body [30]. Externalization facilitates the cognitive process by helping to clarify the problem by offloading the information on to external resources. The effectiveness of externalization methods such as writing [52] and verbalization/think aloud in problem solving have been well studied [61]. In particular, spatial forms of externalization, such as arranging physical objects, sketching, or diagramming, play a significant role in supporting cognitive tasks. Kirsh [43] highlights how people use space intelligently to simplify choice, perception, and internal computations by physically organizing information in the environment.

This view aligns with the theory of distributed cognition [38], which proposes that thinking is not limited to what occurs inside the head but is distributed across people, artifacts, and physical environments. From this perspective, tools such as whiteboards, sticky notes, and sketching surfaces are aids to cognition and actively shape the way information is represented, manipulated, and shared. [21, 31]. This is particularly evident in how people use whiteboards as shared spatial canvases during collaborative and individual problem-solving. Prior research has examined the types of visual elements people produce in these settings, showing that whiteboards serve as flexible media for both cognitive and communicative support [23, 63]. For example, Cherubini et al. [23], studied diagrams created by software developers in their developments process and found that developers freely mix different conventional drawings and prefer to use the informal notations such as directed arrows, text labels, etc. to express and communicate their thoughts.

Another widely used form of spatial externalization is the use of sticky notes, which allow ideas to be quickly captured, arranged, and restructured in physical space. Sticky notes are a familiar tool across a range of cognitive and organizational tasks, yet most prior research has emphasized their role in creative ideation [13, 27]. Chapter 9 [33], in the book *Sticky Creativity* [27], addresses information management practices in creative work; however, their study is constrained to practices in one design company. In contrast, our work, by examining these practices in diverse settings, extends the understanding of sticky notes as dynamic spatial elements in distributed cognition.

2.2 How do People Organize Their Information?

Organizing collected information into cohesive structures is a necessary part of making sense of information [45]. Previous studies have examined organizing and archiving behaviors in detail. For example, Whittaker and Hirschberg [64] conducted surveys and interviews to analyze how office workers organize their paper-based information. They investigated the factors that

influence staff to be either filers (i.e. systematizing their archives) or pilers (creating piles of unorganized papers). Similarly, other studies investigated management of paper documents [42]. Researchers were also interested in digital information organization; for instance, studying the file structure that people tend to use when planning a special event [40] or the way people organize files on their desktop [37]. These related works are considering strategies that people take to manage their personal information; usually the goal for this information organization is fast

access [40] when they need the information after a period of time. In contrast, our work focuses on the organization of thoughts in spatial thinking that is part of the process of generating and communicating ideas [26, 32].

Our interest in spatial layouts overlaps in part with the field of data visualization, since both involve organizing information spatially. However, while visualization research often focuses on algorithmic layout for presentation or analysis (e.g., graph drawing [15], dashboard design [12]), our study examines how people manually organize data and ideas into structures, without the constraints or templates imposed by digital tools. Understanding these naturally occurring layout patterns can inform the design of visualization tools as well as digital whiteboards so that these tools better align with how people naturally organize and interpret information.

2.3 Studies about Use of Space in Externalization and Information Organization

Studies have shown that activities take place spatially strongly affect people's information processing ability [60], and are often used to promote creativity [59]. There are also studies about the processes people use when organizing their information spatially [51], how they organize their physical desktops [37], and what that might mean for the organization of information in desktop computers [6].

The process of collaboration and working on information often involves a large surface such as wall, tabletops or whiteboards. Analyzing how people interact and make use of such surfaces has been a popular subject of study. For instance, Scott et al. [53] conducted observational studies to understand the way people collaborate when they are collocated around a table. By spatial analysis of the interactions they found that collaborators tend to have 3 types of tabletop territories: personal, group and storage. Collaborating on digital surfaces such as large displays and tabletops using notes were also studied [44]; however, few studies reported about the spatial organization of the notes on these displays. For example, Andrews et al. [10] studied group sensemaking of digital documents on a high-resolution large display. They observed people used structures such as clustering, piling and horizontal arrangement to organize their text documents. Following up on this work, Andrews et al. [11] investigated whether using a conventional display or large display that can provide a large virtual space affects the spatial structure that users create with text documents. Isenberg et al. [39] examined how visual analytics team members organize information items on a table-top workspace. They observed members tend to create personal storage piles of documents at the beginning of the process and spread them throughout the process of data sense making.

Affinity diagramming has been investigated from different perspectives such as when people choose affinity diagramming [46] and the processes of working with affinity diagrams [35]. Also, designing tools to facilitate distributed affinity diagramming has been studied [47]. Although previous work provides some evidence of spatial thinking and organization, such as clustering into groups [35], they did not thoroughly investigate practices of spatial thinking and how people visually think and communicate through affinity diagramming. Sticky notes are one of the key tools in affinity diagramming. Fischel and Halskov [32, 33] analyzed information management in diagrams created by a design company using sticky notes. They reported a framework of sticky note configuration patterns. Our work, on the other hand, is based on a data set that is gathered from multiple contexts such as design thinking and personal and group ideation processes, and is collected from various resources openly accessible on the web.

Despite this variety of research, there remains a necessity to understand the visual and spatial structures of representation involved in collective data collection and organization, particularly in settings such as meetings and brainstorming sessions. In these brainstorming sessions, sticky notes are frequently utilized, each representing a small unit of information and functioning as an individual data item.

3 Exploring the Use of Spatial Thinking In the Wild

Our primary goal is to develop a better understanding of spatial thinking design patters: the ways in which people use physical space to organize thoughts, ideas, and data during sensemaking processes. To achieve this, we sought real-world examples of such spatial organization, capturing how individuals and groups visually structure information in diverse settings.

We conducted a qualitative study in which we collected over 300 images of in-the-wild spatial organization and visual organization of items during collective and individual reflection. By "in the wild," we refer to naturally occurring, unscripted instances of spatial organization captured outside controlled research settings, in real-world environments such as workplaces, studios, or educational contexts, without researcher intervention. In what follows, we detail our approach to data collection, explain our focus on sticky notes as a medium for spatial thinking, and describe the procedures used for visual analysis.

3.1 Methodology

Given the visual nature of spatial thinking and the importance of ecological validity, we conducted a qualitative study with visual data grounded in previous methodological precedents (e.g.[36]). We adopted a constructivist qualitative approach. Our goal was not to test predefined categories but to uncover emergent patterns through interpretive analysis of naturally occurring visual data. This stance aligns with established qualitative traditions in visual research and thematic analysis [28]

We focused on sticky notes for two main reasons. First, their facility for spatial manipulation and rearrangement makes them particularly well-suited to observing emergent structures and patterns. Second, sticky notes are widely used yet under-analyzed in comparison to digital tools and whiteboards in existing literature (e.g. [63]). By selecting this medium, we deliberately constrained the scope of the study to enable the development of a consistent and interpretable coding framework.

While our dataset includes both individual and collaborative instances of spatial thinking, our primary concern lies in the visual structure of spatial patterns, not in inferring authorship dynamics. Thus, the analysis is agnostic to whether a space was used by an individual or a group, though we do note where it is visually apparent.

To obtain a rich and diverse dataset of images, we decided to collect images from the web because it provides a wide variety of real-world examples and contexts, supporting a comprehensive analysis of spatial thinking and organization. This richness is necessary because a comprehensive analysis is essential for informing the design of spatial thinking tools and other spatial thinking work-spaces. Our research methodology consists of two main phases: 1) data collection and 2) data aggregation and analysis.

3.2 Data Collection

We used an online collection approach similar to that by Choe et al. [24], Kauer et al. [41] and Harley [36]. For about a month the data collection team (comprised of three researchers) used online general search engines: Google and Bing. We also used internal search functions on these image-hosting and content-sharing platforms: Flickr, Pinterest, Twitter (now X), Medium, and Behance.

The collected images are examples of spatial thinking in wild, that is they are unconstrained in that they come from different labs, studios, or companies, where policies and practices may differ widely. We used diverse keywords to find our examples. Some of the popular keywords were post-it notes, sticky notes, affinity diagrams, collaborative thinking, UX design, brainstorming, story-boarding, collaboration, and design thinking. These terms were chosen because they are commonly associated with activities that involve rich visual and spatial methods for organizing

information, making them ideal for analyzing how space is used to facilitate cognitive processes and idea development. We specifically included the key word "stickies notes", thinking that more diverse situations might show a greater variety of uses than previously discussed. The non-permanent and reusable "stickiness" of sticky notes allows for continuous rearrangement. Since stickies do serve as a dynamic and flexible tool for externalizing and structuring information and have been less studied, we made sure to include them in our study.

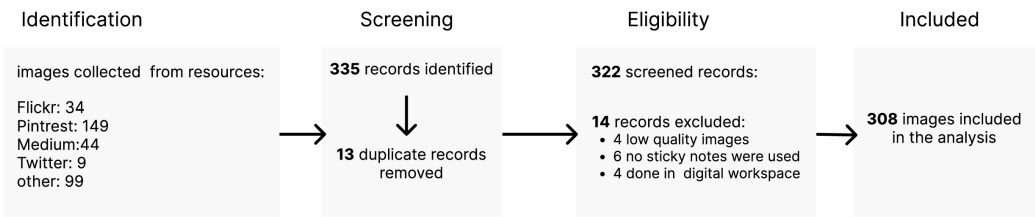

Fig. 2. A flow diagram of the different stages of our image collection process.

During the collection phase each team member individually performed their searches and populated their findings on a common online platform Airtable [1]. For each image collected, we captured relevant metadata to support transparency and traceability. Specifically, we recorded: the source URL, the exact keywords used to discover the image, the date of access/download. Any accompanying description or contextual text that explained the image, whether the website included a visible statement regarding the image's privacy, copyright, or sharing permissions. All collected images were publicly available on the open web. We did not collect any personally identifying information and made efforts to exclude photos with faces or sensitive content. This metadata was logged in Airtable [1] alongside the images, allowing us to track provenance, confirm public availability, and revisit contextual cues during analysis. While we only included publicly accessible images, we exercised care by excluding content that was marked as private, embedded in password-protected content, or ambiguously licensed. We note that the dataset was collected prior to widespread AI-generated image labeling on platforms like Pinterest, and before generative visual tools became commonplace. While we did not read the content of the handwritten notes, we ensured that all selected images visibly contained sticky notes identifiable through their size, shape and physical context (e.g., attached to whiteboards, windows, desks).

On a weekly basis the team gathered together with a supervising researcher to touch base on the collection process During the discussion, the group clarified, added, and updated keywords to better describe the ideas. In summary, we identified a total of 335 candidate images during the collection phase. These included 34 images from Flickr, 149 from Pinterest, 44 from Medium, 9 from Twitter (now X), and 99 from other sources. The "other" category refers to images discovered through general web search engines namely Google Images, Bing that linked to publicly accessible content hosted on personal blogs, portfolio websites, design agency retrospectives, or online articles. These sources were not part of dedicated image-hosting platforms but still offered rich, contextual examples relevant to our inquiry. In the last data collection meeting, the team reported an increase in duplicated images, indicating that the collection process was reaching saturation. These 13 duplicated images were subsequently removed. Additionally, the team reviewed the samples and eliminated those that did not depict physical spatial organization or consisted solely of whiteboard images. We excluded whiteboard-only images because the types of spatial practices they depicted had already been extensively documented in prior work [23, 49, 50, 63], and thus offered limited new insight for our study. Additionally, some images were excluded due to their very low resolution.

Finally, 308 images were included in the data analysis phase. Figure 2, illustrates the various stages in which data were screened before analysis.

3.3 Data Aggregation and Analysis

Given that the visual arrangement for making sense of items inherently takes a visual form, we employed a blend of visual content analysis [16] and codebook thematic analysis [19, 20]. The collection team first familiarized themselves with the data by reviewing the collected images individually, noting preliminary observations about spatial structures, repeated patterns, and contextual clues. This phase allowed researchers to engage deeply with the visual material before initiating formal coding. In the next phase, the collection team split the dataset into three equal sections. Each researcher randomly selected one section and began with an open coding phase without a predefined list of codes. To guide the analysis, in the initial coding phase, we focused on coding visual structures such as grouping and visual features that revealed how spatial organization was visually constructed such as annotations.

This phase resulted in a preliminary codebook based on the recurring themes. The codebooks included codes for spatial organization patterns, the definitions for these codes as well as some examples from the dataset. All codebooks and coded examples were documented in Airtable [1], which served as a shared visual repository for organizing and reviewing codes collaboratively.

During weekly meetings with the supervising researcher, team members shared their initial codes and engaged in collaborative reflection. These discussions were used to collaboratively compare their initial codes, resolve discrepancies, and refine definitions. Through iterative discussion, overlapping codes were merged, ambiguous ones clarified, and inconsistent interpretations resolved. This process served both to triangulate interpretations and to support the construction of a shared analytical lens.

After this collaborative convergence, each team member then reviewed the other two sections of the data, marking any instances that required clarification or re-coding. When consensus was reached on the final codebook, one researcher conducted a systematic pass through the entire dataset to quantify the frequency of each identified spatial organization pattern. This final step provided a descriptive overview of the pattern distributions across the 308 images.

4 Findings

We report our findings from the data aggregation and analysis phase. We start with definitions of spatial organization design patterns. For each pattern we note the number of these pattern types found in our 308 examples, and its percentage. We then describe and define attributes and augmentations, explaining how these factors were used as techniques for clarifying the spatial organizations. Another aspect of the organization that we considered is the level of complexity of the organization which is explained in section 4.7.

4.1 Spatial Organization Patterns

We coded for recognizable spatial patterns in the spatial configurations of information. One sample of these basic design patterns is shown in Fig. 1. People often used additional visual elements, which we call attributes and augmentations, to make these patterns more recognizable, to indicate or clarify relationships between items and to add meaning and more information to the spatial organization. We discuss these factors in the following sections.

 **(a) Spread:** Items are arranged randomly over the space in use, with no noticeable spatial pattern, often featuring irregular distances, and/or irregular angular orientations. A spread arrangement results from a deliberate yet unstructured use of space, forming a pattern where systematic organization is not discernible. This pattern was found in 28 examples.

 **(b) Clusters:** Clustered items refers to the arrangement of information into visually distinct groups. In clustering pattern, which occurred in 124 images, the groups, and whether an item is part of a given group or not, are visually recognizable. **Piles** is one example. Piling is a form of clustering where items are grouped through overlapping, creating stacks. This method emphasizes collective grouping over individual item visibility.

 **(c) Lines:** Items arranged in a line pattern are placed continuously adjacent to usually forming vertical or horizontal lines (or columns/rows). This pattern, which was found in 36 images, often includes multiple columns or rows, each serving as a distinct spatial grouping of items. The space between these lines is greater than the space between items within each line, visually distinguishing one line from another.

 **(d) Circular:** Items arranged in a circular pattern are positioned around a central point, either along the circumference or within the circle itself. This arrangement can consist of a single circle or multiple concentric rings, with the distances between items varying to allow for both uniform and irregular spacing. This pattern was observed in 13 images.

 **(e) Hierarchies:** In this pattern, data items are organized into multiple levels of superiority or subordination, representing ranked relationships. This structure typically indicates a chain of command or a sequence of importance, with each level distinctly higher or lower than others. We observed 13 examples of hierarchical patterns. The observed maximum height of these hierarchical patterns was not more than 3. This may indicate that arranging thoughts into more than 3 levels of a hierarchy is unusual. Items organized within multiple hierarchies as observed in one example are referred to as a forest.

 **(f) Grid:** A grid pattern refers to the spatial organization of items into visibly distinct rows and columns, forming a tabular layout. This arrangement may include blank spaces, resulting in an incomplete grid. The distance between adjacent items in either a row or column is equal, creating a uniform structure. This equal spacing helps to differentiate a grid from a line pattern, where the spacing is unequal. This pattern was observed in 67 images.

 **(g) Graph:** Items are connected together using directed and/or undirected links to form networks. We observed Graph patterns in 14 images. Labels on links are sometimes used to explain the semantics of the relationships between items.

 **(h) Matrix:** In spatial organization, a matrix refers to a tabular arrangement where items are systematically placed in a grid of rows and columns. Each cell within this grid can act as a cluster, allowing for a specific subgroup of items to be organized according to a desired configuration. This pattern was observed in 11 images.

4.2 Attributes

We use the term *Attributes* to refer to the additional visual characteristics used to differentiate elements within spatial organizations. These features are critical for identifying and interpreting

Fig. 3. Attributes. a) color; b) size; c) rotation; d) shape; Augmentations. e) text; f) diagrammatic; g) pictorial; h) voting.

various patterns. These attributes related directly to Bertin's visual variables [17] size, shape, color, value, orientation, and texture. However, position is not included because it is used up in the basic spatial arrangement and value and texture tend to be used as variations in color in our examples.
(a) Color: Color is a prominent attribute used for visual differentiation such as depicting different organizational levels in a hierarchy (e.g. Fig. 3(a)), appearing in 73% of observed instances (225 cases). Color variations were noted in the sticky notes, diagrammatic augmentations, and textual labels. Despite its frequent use, there were occasions when the choice of color seemed arbitrary.
(b) Size: Variations in size were utilized to emphasize different informational elements or fitting the information into the note (Fig. 3(b)). This attribute was noted in 17% of instances (53 cases).
(c) Rotation: Altering the orientation of elements, notably by rotating them away from the typical 90-degree alignment, made them stand out within the arrangement (Fig. 3(c)). This method was particularly useful for labeling purposes, recorded in 5% of the cases (15 instances).
(d) Shape: Different shapes were employed less frequently but served as an effective means of differentiation (Fig. 3(d)). This pattern was observed in 4% of cases (13 instances).

Overall, these attributes are seldom used in isolation. We often observed combinations of color, size, and rotation, particularly in the labeling of clusters or the designation of top-level notes in hierarchies. This synergy of attributes enhances the clarity and utility of spatial organizations.

4.3 Augmentations

We called additional objects added to the content and the structure of the spatial patterns, *augmentations*. These augmentations are used for semantic purposes, clarifying the structure and/or adding more information about individual items in the configuration.
(e) Text Augmentation: Text augmentations are words or sentences, typically handwritten, placed on the surfaces surrounding items often on whiteboards or large sheets of paper. These augmentations serve to provide additional information, functioning as labels or data items or more lengthy explanations. (Fig. 3(e)) (110, 35%).
(f) Diagrammatic Augmentation: This is the addition of different types of lines, to provide additional aspects of a diagram among the arrangement of items. These augmented elements help the viewer to recognize the pattern itself and sometimes indicate the relationships between the

items. For example, a line drawn around each group of sticky notes in the Clustering pattern, helps the viewer easily recognize whether two sticky notes belong to the same category or not (Fig. 3(f)) (78, 27%).

(g) Pictorial Augmentation: Pictures are often use in the arrangement of items. Pictures could be photos, or hand drawn. Pictures were used as augmentation as stand alone items in the organizational pattern, or as an addition to an individual or a group of items to provide more information (Fig. 3(g)) (32, 10%).

(h) Voting: This attribute can be seen where artifacts, usually small circles, are placed on items in order to display preferences of the team members. Fig. 3 (h) shows an example of voting. Each colored dot, can present a particular participant's preference or priority about an item (16, 5%).

4.4 Gestalt Principles

We observed some instances of gestalt principles as techniques that people used to define their desired spatial organization.

Proximity: In most of the spatial organization patterns we observed how people took advantage of adjacency between items or groups of items to show relationship. For example, the closeness of the data items and the space between the groups of data items indicates the clustering pattern. Similarly, in some examples, the space between lines, indicates the pattern and In Grid pattern, the distance between adjacent items is equal, creating a uniform structure. This equal spacing helps to differentiate a grid from a line pattern, where the spacing is unequal. For a visual representation of these observations, see Fig. 4.

Similarity: we also observed how people picked similar items in terms of color, shape and size for similar data items for examples labels of a cluster, roots of a hierarchy, etc. We also observed similarity in augmentation where the used same font color for text (labels) and similar arrows. For example Fig. 3 (f), the red arrows and black arrows represents two semantically different types of arrows.

Figure/Ground: The figure/ground principle in design refers to the way in which objects (the figure) are perceived against a background (the ground), influencing the visual hierarchies and readability of a space. Maps and templates such as the Business Model Canvas were employed to structure the placement of items. These predefined backgrounds help in organizing thoughts and data items (as figures) effectively, ensuring that each element is distinctly recognized against a structured ground. Further details and examples of these practices are elaborated upon in Section (4.5).

4.5 External Influences on Spatial Organization

We noted indications of how certain factors such as the architecture, the materials and templates influence spatial organization patterns.

Architecture and Materials The surface that the data items were placed on influenced the spatial organization pattern. Firstly, *the available space*, either constrains or enhances the potential for spatial organization of data items. We saw small surfaces such as a notebook and large spaces like perpendicular walls. Given the size of pages in a notebook, we only observed spread and line pattern. However, large surfaces such as perpendicular walls in Fig. 5 (c) allows for having forest or as in Fig. 5 (d) having large hierarchical structure with 10 children at the second level and about 80 leaves.

Second, spatial organization pattern and technique depends on the surface characteristics and the available materials and the organizational options they can support. We observed use of various materials in our samples. Beside sticky notes, markers, strings, tapes and large papers and even Lego were used. For example, in instances where the items were placed on walls, we did not see

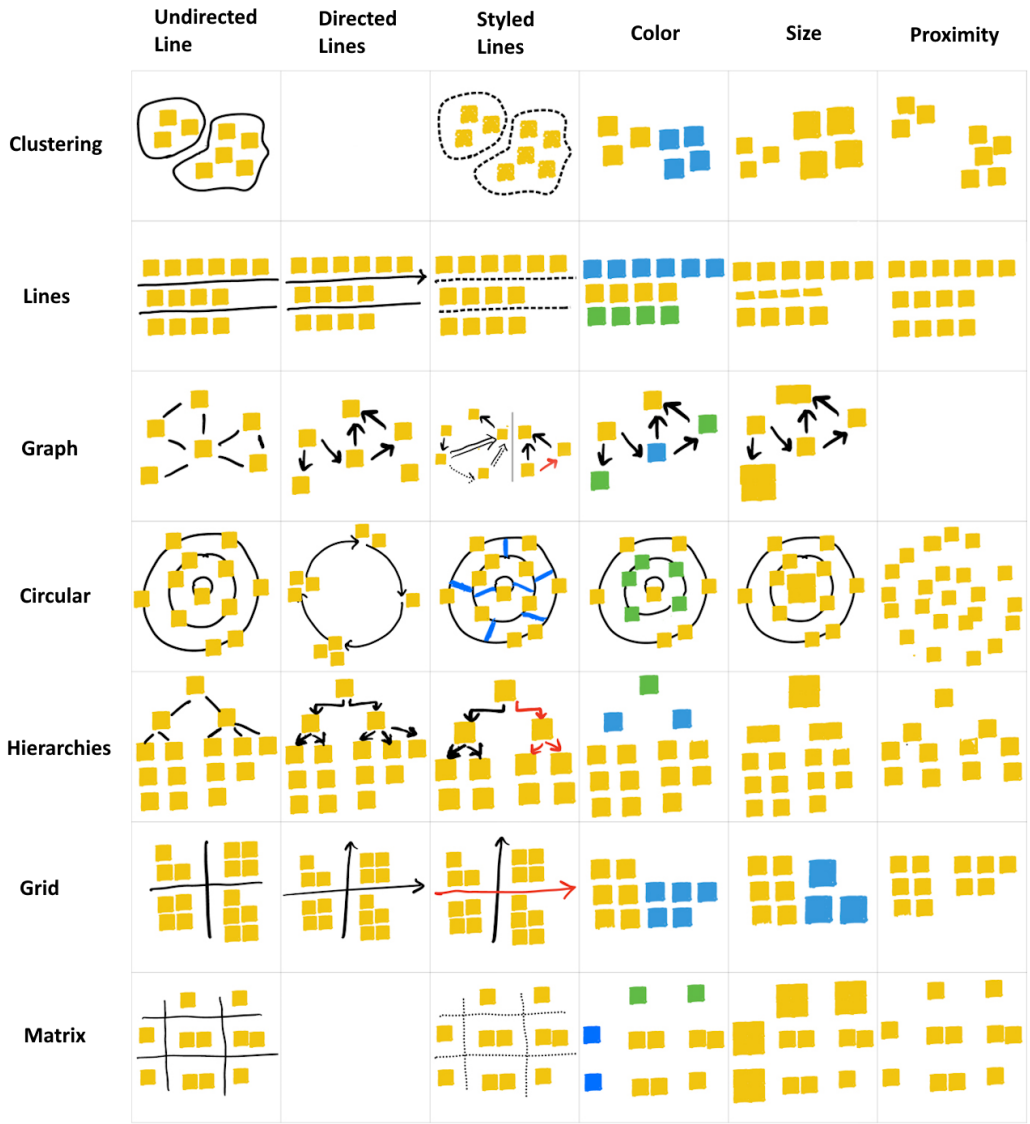

Fig. 4. Overview of Visual Characteristics by Spatial Organization Patterns. Rows indicate specific spatial organization patterns while columns represent the visual characteristics applied within these patterns for enhanced data interpretation and analysis.

diagrammatic augmentation with markers, but we saw use of strings or tapes. It is possible that this constraint influenced the lines pattern, because it is easier to make a straight line with tapes rather than any other curved diagrammatic augmentation. Similarly, the composition of the background can also influence the spatial pattern. For example, as shown in Fig. 5 (a) and (b), the placement of cork boards may have guided the horizontal and vertical arrangement of items.

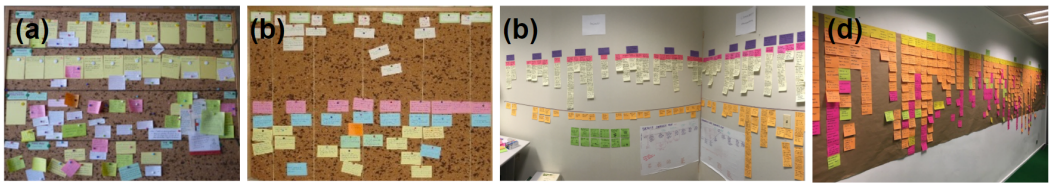

Fig. 5. Examples that shows how the material affected organization. In both instances bulletin boards are used which does not allow for marker augmentations. The placement of boards in (a) and (b) influenced a horizontal and vertical configuration respectively. Perpendicular and large walls allowed for large hierarchies in (c) and (d).

Templates: We saw many examples of using templates in our sample. Templates are a particular model for arranging data items on the surface. An example of a template is the well-known business model canvas [56]. In terms of spatial thinking process, using templates means people, chose the spatial pattern before placing the items. In our sample, we observed two types of templates. The printed out templates, where the items are arranged on a large paper that has printed structure (Example: Fig. 6 (a)). Second, the templates that were made with diagrammatic augmentations or tapes (example: Fig. 6 (b) to guide the spatial thinking. Templates also can be considered as a

Fig. 6. Two examples of using templates. (a) use of printed-out pre-designed template. (b) use of diagrammatic augmentation to form a template

staring point in the spatial thinking process as it guides the structure and helps with generating ideas and thoughts. On the other hand, using templates limits the spatial thinking process to what is available on the template and we observed many instances that due to lack of space people had to go over their space limits (e.g. Fig. 6 (a)).

4.6 Techniques in Spatial Organization

In this section, we describe *how* people show their organizational patterns. Attributes and augmentations, as described in sections 4.2 and 4.3 can be used to clarify the basic spatial organization and provide extra information. In what follows, we will report our observations regarding the way people took advantage of the attributes, augmentations and different ways of combining them with the spatial patterns to enrich the organization of information in a given space. Figure 4 shows a summary of these techniques in spatial organization. There is a row for each spatial pattern and there are columns 3 augmentations (directed, undirected and styled lines), 2 attributes (color and size) plus proximity.

4.6.1 Using Color as a Technique. Color is the most used attribute as the distinctive colors of sticky notes can easily convey structure [54]. In examples showing the Lines pattern, people used different colors for each row, column, or the assigned labels to them. In some examples of the Hierarchical pattern, often each level is associated with a vivid color. In Grid-based examples, when there are several sticky notes in each cell of the grid, each group of sticky notes within a cell is frequently associated with a color (Fig. 7 (a)). Similarly, in the Clustering pattern, some examples show color-coded clusters in which sticky notes from the same cluster have similar colors (e.g. Fig. 7(b)). Most of the Clustering patterns that are also coded with the color attribute, utilize a different color of sticky notes to show labels associated with each cluster (e.g. Fig. 7 (c)).

Colors were also used in combination with text and diagrammatic augmentation. People used different colored pens and markers to draw and write on sticky notes and whiteboards. Sometimes use of different colors for different textual elements clearly emphasizes the organization pattern (7 (d)).

Fig. 7. Examples of using colors in combination with: (a) Grids; (b) Clusters; (c) Labels in clusters; (d) Text augmentation

4.6.2 Using Size as a Technique. Similar to Color, different Sizes of sticky notes were used to help viewers to distinguish the levels of a hierarchy and usually these two attributes were utilized together in a single hierarchy. The biggest size of sticky note was chosen for the root or the top level in the hierarchy. We often observed the use of a larger sticky note when apparently the text inside it could not fit into a normal size of sticky note; however, from our examples it could easily be observed that the normal square size of sticky note was the most commonly used. Also in Column examples, occasionally the label at the head of each column exceeded the dimensions of the items it categorized. Furthermore, observations indicated that individuals designated a larger sticky note as the primary element and associated it with smaller sticky notes through partial overlap (e.g. Fig. 3 (d)).

4.6.3 Using Attributes and Association as Techniques. In our examples of sticky note organization, certain sticky notes of differing shapes were overlapped with others to indicate association. Smaller sticky notes were similarly linked through overlapping. When variations in shape or size were not employed, association and differentiation were achieved by positioning the notes at distinct angular orientations (Fig. 8). Printed pictures were partially overlapping with the sticky notes to show association.

4.6.4 Diagrammatic Augmentation. Diagrammatic augmentation was often used to clarify the structure of the patterns. A line around each cluster in clustering examples, (e.g. Fig. 7 c)), grid outlines in Grid pattern (example: Fig. 1 (b), lines between rows and columns in Lines pattern, concentric circle outlines in Circular pattern (e.g. Fig. 1 (g)), directed or undirected links between items in Hierarchies and Graph patterns. We noted different line types including undirected lines and arcs, directed lines (both one-way and two-way) and a variety of line styles such as wavy lines, colored lines, various dotted lines which are referred to in Fig. 4 as 'styled lines'. In some instance

Fig. 8. Examples of association: in these examples, some data items were associated with other data items using overlapping technique. Note that these associated items have different attributes such as size, shape or rotation.

these distinct link styles were strategically employed to signify different types of associations between items. For instance, in one example, dotted lines, double lines (a dotted line parallel to a solid line), triple lines were used to show different relations between some clusters. Other uses of diagrammatic augmentation were also observed. For instance, a line was drawn to act as a timeline and clusters of sticky notes were placed with respect to this timeline.

4.7 Spread to Organized Spectrum

We examined the spatial organization patterns from the perspective of different levels of complexity - specifically from simple to the considerably complex (see Fig. 9). In this spectrum we categorize these patterns starting from simple dispersion, through lines and various types of clustering to grids, hierarchy and patterns that are more structured and complex. In the spectrum from spread to organized patterns (Fig. 9), we classified observed spatial arrangements based on their organizational complexity. The 'spread' pattern demonstrates a dispersal of ideas across a surface without obvious structure. Following this, we identified numerous instances of clustering, where ideas were aggregated to form coherent groups. While, the methodology for creating these clusters varied as some individuals encircled groups of sticky notes, others organized them into Lines such as in rows or columns, grids, or stacks, effectively distinguishing similar data elements. Note that, arranging items in lines or piles can depict an order among data items, providing a structured sequence that is not inherently present when items are simply enclosed in a cluster, whether by proximity or with an encircling line.

At a more advanced organizational tier, we discern 'Matrix' and 'Hierarchy' structures, providing additional insights into the relationships among grouped items. The hierarchical arrangement illustrates parent-child linkages, whereas the Matrix pattern reveals how clustered items align with dual categorizations. Even a basic graph, lacking directed and labeled edges, can imply hierarchical connections. However, in certain cases, the presence of directionality and labels provides further clarity on the relationships, with graphs of clusters elucidating a superior degree of organizational sophistication.

As we explore the progression from simple to complex organizational forms, our analysis delves further into nested patterns, which shows relationships between groups of items and the concept of layers of information. These structuring techniques showcase a multidimensional approach to the spatial organization of sticky notes, illustrating the depth and complexity with which individuals can arrange their data.

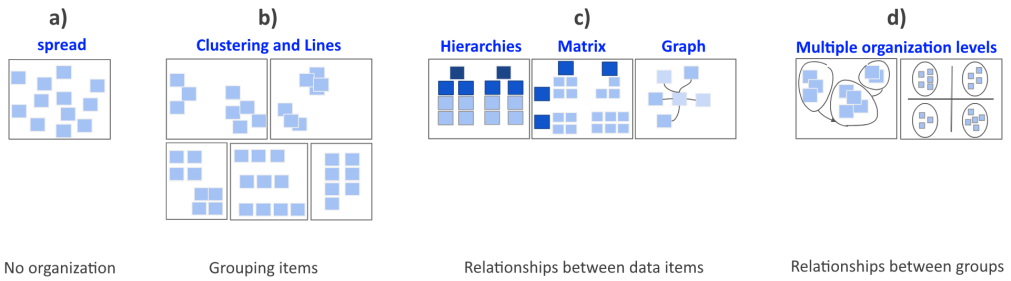

Fig. 9. From spread to organization spectrum: a) item dispersion without structure, b) structure into grouping c) structure with respect to more than one criteria d) multi-dimensional structure

4.7.1 Nested Patterns. Nested patterns, or patterns within patterns, refer to a complex organizational strategy where multiple levels of structure are employed simultaneously. In most of our nested pattern examples, clustering was the primary observed pattern. The items within each cluster were organized according to another pattern, such as simply spread, lines, or grids. This introduces a secondary level of structure that enhances organization and can aid in the identification and analysis of relationships within the data.

Moreover, these initial clusters can themselves be grouped or arranged following another overarching pattern, creating additional tiers of organization. For example, the clusters might be arranged in a larger clustering structure or matrix, introducing a macro-level pattern that contextualizes the micro-level arrangements within each cluster.

As shown in Fig. 10 (a) and (c), the internal organization of stickies within the clusters depicts a grid layout while in (b) no internal organization can be seen. Clusters in (b) and (c) are organized in a 2 by 2 grid and rows respectively, depicting an external organization while (a) does not show such an organization.

It is important to note that not all spatial organization patterns facilitate both levels of organization. For example, the organization within columns or rows in the Lines pattern is inherently fixed, with only one method for aligning sticky notes in a linear format. Conversely, while the organization of columns allows for variability, our observations revealed that columns or rows were consistently aligned in parallel, with their headers positioned at uniform heights or alignments.

Fig. 10. Examples of Nested patterns and information Levels: (a) the internal organization of clusters is *Grid*; (b)no internal organization within clusters, but the clusters are organized within a grid (c) the internal organization within the clusters is grid but the clusters are organized in Lines. (d) the clusters were created first and then some of the clusters were grouped together (for example the clusters in bottom right) to form a bigger cluster

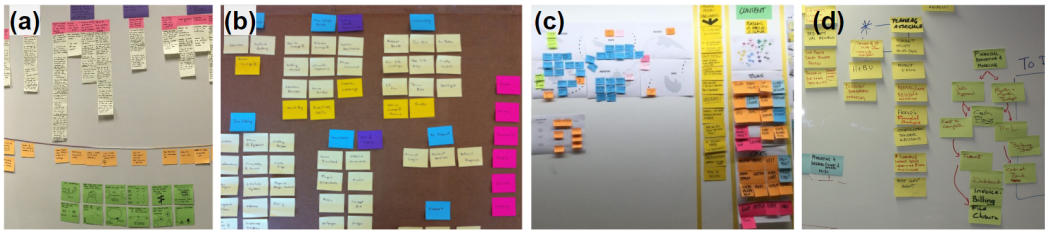

Fig. 11. Examples of multiple patterns: in (a), (b) and (c) the primary patterns are *hierarchy* and *Grid* and the *Lines* pattern is secondary; d) Without dominance, *graph* and *Grid* are present

4.7.2 Multiple Patterns. We observed multiple instances where more than one spatial organization pattern was present. In these cases, we identified either a primary dominant pattern that encompassed most of the data items alongside a secondary pattern or no single dominant pattern among the multiple spatial organizations. In Fig. 11, parts (a), (b), and (c) show the Line pattern as secondary to the dominant hierarchy and grid patterns. However, in part (d), both the graph and grid patterns exhibit the same level of dominance.

4.7.3 Layers of Organization, Information Hierarchy. We observed several examples of how people demonstrated a hierarchy of spatial organization. In such examples, we can see that information is organized at multiple layers. For example, Fig. 10 (d) indicates after creating the clusters, some of the clusters were picked to be grouped to form another level of clustering pattern.

Please note that while external organization in subsection 4.7.1 also indicates organization of clusters or other organizational elements, the difference is that in external organization, the order of organization is not clear. In other words, we don't know whether the creators decided for a spatial pattern before another. however, in the case of Fig. 10 (d), the spatial layering and visual cues such as grouping of pre-formed categories suggest that the higher-level "clusters of clusters" were added after the individual clusters were created.

Layers of information are also evident in instances where one item is placed atop another, with some overlap suggesting it belongs to a different layer. For example, in Fig. 8 (a) and (b), the smaller items attached to the underlying notes can depict a different layer of information. Similarly, the presence of voting dots placed on top of sticky notes, as shown in Fig. 3 (h), highlights a further layer of information.

4.8 Aspects of Spatial Thinking Process

The images that we collected from the internet mostly shows the outcome of the spatial thinking process; however, the details in some of these images can reveal interesting aspects of the process itself. For example, from some of the samples, one can tell whether diagrammatic augmentation is placed on top of a sticky note or vice versa. From this placement order, one can infer the order in which the information layers were placed.

4.8.1 Making and Breaking Rules. While certain predetermined structural rules were generally followed, in several instances, the specific organizational patterns designated for each instance were not fully adhered to. For example, as shown in Fig. 12 (a), we see an exception to the typical columnar organization of sticky note piles. While most piles are neatly aligned within specific columns, some are positioned between these columns. This placement suggests that these piles may not belong exclusively to one column or the other but could be relevant to both. Similarly, Fig. 12 (b) shows an item is placed outside of a column in a Lines spatial pattern and (c) shows an

arrangement of green items that does not fully follow the circular pattern. The findings indicate that while structured approaches provide a foundational framework for organizing thoughts, the occasional breaking of these rules may reflect adaptive strategies or creative responses to specific contextual needs.

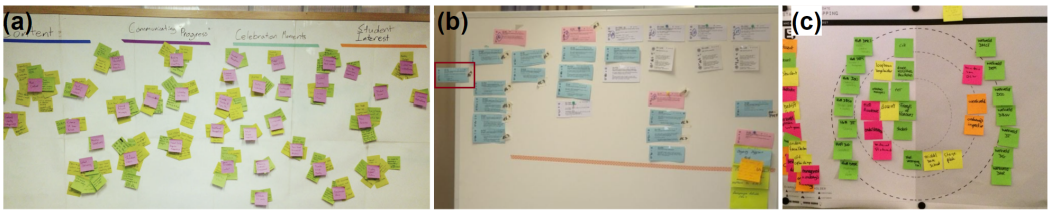

Fig. 12. Examples of making and breaking rules in spatial thinking: (a) Some of the piles are placed in between the columns, breaking the Lines pattern; (b) an item is placed outside of a column; (c) the green items are not fully following the circular pattern

5 Discussion

Our findings resonate with prior work on externalization practices such as those described in Sticky Creativity [33], where sticky notes were primarily analyzed in relation to creative ideation and, to a more limited extent, information management. Similar to their observations, we also found that spatial configurations such as proximity clustering, were central to how participants organized and made sense of information (see Section 4.1). However, whereas their work was grounded in a single professional design company, our study demonstrates that these spatial organization patterns appear across a wider range of problem-solving contexts. Also, our analysis revealed new organizational forms and strategies not captured in their framework. For instance, we reported on how the visual and material attributes of sticky notes such as color, size, and orientation are employed differently across spatial patterns (see Figure 4) along with additional techniques and observations such as the spread-to-organization spectrum (Section 4.7), and the make-and-break rule (4.8).

The spatial patterns and visual techniques we observed offer not only descriptive insights but also design-relevant considerations for future digital systems. HCI has a long tradition of learning from physical practices to inform interaction design; from study of flight strips as cognitive artifacts[48] to collaborative tabletop interfaces [58, 65]. Our findings contribute to this conversation and could inspire more spatially-aware adaptive digital environments. These considerations reflect recurring practices such as selective rule-following, flexible use of templates, and variation in spatial organization practices. Furthermore, while our goal was not to formalize design patterns, we discuss how our findings can offer a foundation for developing spatial design patterns in future work, which could further guide the improvement of digital tools for ideation and spatial thinking. Finally, we discuss the limitations of our study and outline directions for future research.

5.1 Design Considerations

Support Rule-Making and Maintenance through Feedforward Our analysis revealed that users often created and sustained visual rules to structure their spatial layouts; for example, using consistent colors for category labels or aligning items within a grid. These patterns served both cognitive and communicative functions, helping users maintain clarity and coherence across their

workspace. This aligns with Gestalt principles such as proximity, similarity, and continuity, which describe how humans tend to perceive structure and order in visual arrangements [17, 60].

Interactive tools should support users in establishing and maintaining these self-generated spatial rules by offering lightweight, context-aware feedforward which is a concept grounded in HCI literature as a method of guiding users before an action is performed [62]. Rather than enforcing constraints, the system could act as a reflective collaborator, gently surfacing potential inconsistencies that might affect structural clarity. For instance, the system might prompt: "You're choosing a different color for this label. Would you like to indicate a new category, or keep the color consistent with the others?" or "This item appears larger than the others in the same group. Is that intentional?" These reflective, soft prompts share similarities with nudging approaches in interface design, where subtle cues influence behavior without removing user freedom [24]. Such techniques encourage users to reflect on their spatial logic, clarify intentions, and preserve consistency without overriding user agency. By supporting deliberate rule-making and maintenance, systems can enhance pattern recognition, communication, and sense-making.

Support Expressive Rule-Breaking and Creative Deviations While many spatial arrangements adhered to consistent patterns, we also observed frequent and often purposeful departures from established rules. These moments of rule-breaking, such as placing a sticky note between clusters or partially overlapping categories, often served expressive or pragmatic purposes. These deviations often seemed to reflect ambiguous membership, emerging ideas, or the need to adapt an existing structure.

Digital tools should recognize and support these acts of intentional deviation by offering feedforward that invites interpretation rather than correction. The goal is not to enforce structure, but to prompt awareness and offer options. For example, the system might suggest: "You've placed several items outside this frame but near its edge. Would you like to expand the frame, divide the cluster, or leave it as is?" or "This note is positioned between two groups. Does it belong to both?"

These reflective prompts allow users to explore creative possibilities and reframe emerging patterns without feeling constrained. By supporting rule-breaking as a deliberate and valid design choice, systems can foster richer visual expression and cognitive flexibility.

Nested Templates: Supporting Structural Adaptation We observed that people often use a template to scaffold their spatial externalization; for example, grids, labeled frames, or radial arrangements. However, these templates often proved too rigid or shallow to support more complex, nested patterns, leading users to abandon or override the original spatial organization as their ideas developed. While this kind of template is expected and accepted in physical media (e.g., printed calendar), digital tools have the potential to offer greater adaptability and support. Platforms like Miro currently allow users to choose from a variety of templates However, these templates are generally fixed in structure. While users can manually create a pattern or template within another, the system does not facilitate this through simple or guided interactions. This lack of support for composing nested or layered templates limits users' ability to easily represent patterns within patterns, which we observed frequently in real-world visual compositions. Digital tools should support composable, and extensible templates. More importantly, such tools should become spatial-organization–aware: able to detect emerging layout patterns and suggest templates dynamically that align with users' evolving visual logic. Instead of only offering predefined templates at the start, systems could provide context-aware prompts based on both content and layout. For instance: "You're forming a radial layout; want to add more rings as sublevels?" Such prompts could be seen as a natural extension of the lightweight feedforward mechanisms previously discussed and not limited to highlighting rule consistency or deviations, but generalized to support structural evolution.

Spatial view modes The visual forms in our data ranged widely, from minimal spreads to layered grids, radial patterns, and nested hierarchies. While we could not confirm authorship context, this diversity suggests that users bring different organizational styles, cognitive preferences, and potentially roles to their work. One user may prefer tightly clustered items, another linear sequences; some may shift styles as their work progresses. Tools should offer multiple spatial view modes, allowing users to toggle between alternative arrangements that suit their thinking style or task. These modes can be offered as non-destructive overlays, or suggested via feedforward based on layout density, grouping behavior, or role-based signals. Such flexibility not only supports individual agency but also enhances collaborative alignment, letting team members work through spatial perspectives that match their workflow or interpretive needs.

Designing interactive systems that support spatial thinking requires more than static templates or one-size-fits-all features. Our findings point to the need for tools that are sensitive to evolving spatial patterns, capable of distinguishing between structure and ambiguity, and responsive to users' diverse organizational styles and intentions. Such support calls for interaction techniques that are lightweight, context-aware, and reflective rather than corrective. Feedforward, when extended beyond local cues, offers one such technique. It can help systems surface timely prompts that aid in maintaining, adapting, or reinterpreting spatial structures, while preserving user agency. At the same time, not all users may welcome such suggestions; some may find them distracting. We therefore envision them as an optional, configurable layer of support that can be enabled, tuned, or dismissed according to preference. We see promise in further exploring feedforward alongside other interaction techniques to support the layered, dynamic, and expressive nature of spatial thinking.

The types of systems we envision are those that already support visual exploration, such as collaborative whiteboards, large-display ideation spaces, or mixed-reality canvases; examples include tools like Miro and FigJam, which enable freeform spatial arrangement and visual annotation. However, while these platforms allow flexibility and open-ended layout, they often do not explicitly accommodate the kinds of hierarchical nesting, loosely defined groupings, or evolving spatial structures we observed in our analysis. The proposed design considerations act as a design layer on top of existing freeform systems, bridging the gap between rigid templates and unconstrained spatial freedom.

5.2 Design Pattern Perspective

In architecture and urban planning, design patterns, as introduced by Christopher Alexander in his influential work *A Pattern Language: Towns, Buildings, Construction* [8], refer to recurring solutions to common design problems encountered in a given context. These patterns are derived from empirical observations of successful built environments and are adaptable guidelines, not prescriptive rules. Alexander's earlier works, such as *The Timeless Way of Building* [7], laid the theoretical groundwork for his exploration of design patterns, emphasizing understanding natural patterns as a basis for architectural design.

The Gang of Four's (GoF) software design patterns [34] were inspired by Alexander's book [8], adapting its concept of patterns as solutions to contextual problems into the realm of software engineering. They introduced software design patterns that aim to solve common software design challenges by providing generalized, adaptable solutions. Each design pattern is a blueprint or a "micro-architecture" that can have different realizations which means it can be implemented in multiple ways and adapted as needed by specific contexts.

Both categories of patterns designed and optimized aimed at solving recurring problems. These patterns emerged organically through practical experience, observation, and systematic documentation of recurring problems and effective solutions. While the specific processes and contexts

differ between the two fields, the underlying principles of problem-solving and knowledge sharing have driven the evolution and adoption of design patterns in both disciplines.

Our work lays a foundation for developing spatial thinking *design* patterns. We have reported our observed spatial patterns as well as nuances of how people make use of space. Future research could extend these findings to create design patterns that help people in their spatial thinking process. In crafting such patterns, we can bring aspects learnt from developing software engineering and architectural patterns. Notably, environmental factors and material availability influence architectural patterns [8], while the problem domain and technical limitations affect software design patterns. Therefore, in the development of spatial thinking patterns, the *context*, a broad term encompassing multiple dimensions, should be meticulously considered.

It is important to acknowledge that our exploration of spatial thinking patterns does not take into account cultural influences, which can shape how design patterns are perceived and utilized across different societies [55]. Recognizing the cultural dimensions could enrich our understanding and applicability of these patterns in diverse settings. Moreover, unlike software engineering, where design patterns are often prescribed for specific scenarios, our approach in identifying spatial thinking patterns is descriptive rather than prescriptive. We aim to illustrate how people have organized their spatial environments, offering insights and inspirations rather than strict frameworks. This approach highlights the diversity of potential applications and adaptations, underscoring the expansive design space and the varied ways people engage with and think about their surroundings

5.3 Limitation and Future Work

By collecting images shared online, we focused on the residue of spatial thinking. It allowed us to examine naturally occurring instances of spatial organization and to avoid the distortions that can arise when people are aware of being studied [5, 57]. However, this unobtrusive strategy also introduced a limitation: we were unable to observe the temporal and cognitive dynamics through which spatial organization evolved. Future studies could benefit from observational studies and interviews. These approaches would offer valuable insights into people's intentions, decision making processes and making and breaking rules over time that could inform designing of digital spatial thinking tools. Additionally, our dataset is limited by the lack of contextual metadata associated with the images. While we aimed for diversity in sources such as Pinterest, Medium, Twitter, and personal blogs, we often could not determine where the images were taken (e.g., studio, workplace, classroom), who created them, when they were created, how long the sessions lasted, or what the original purpose of the arrangement was. Our focus on sticky notes excluded other forms of physical spatial thinking which may follow different spatial logic or support different cognitive processes Future studies could expand this scope to examine how different physical media afford distinct patterns of spatial organization and sensemaking.

6 Conclusion

In this paper, we have explored the diverse spatial organization patterns individuals employ to externalize and structure their thoughts. Through a visual analysis of over 300 images of sticky note arrangements, we identified recurring spatial configurations such as grids, clusters, etc as well as hybrid forms that combine these structures. Our analysis also uncovered key visual techniques people use to make meaning through spatial arrangements, such as color coding, size variation, drawing lines and arrows, and selectively breaking spatial rules. These practices suggest that individuals are not merely arranging items, but actively manipulating visual logic to support cognitive tasks like categorization, and prioritization.

To support spatial thinking meaningfully, digital tools must go beyond offering flexibility in layout. They should enable users to move fluidly between structured organization and improvisational exploration, allowing ideas to take form without being confined by rigid systems. Such tools should also support the ability to layer and nest information hierarchically or relationally, without flattening the visual or conceptual complexity that often emerges in physical arrangements. Additionally, they must make room for users to break away from pre-defined templates and redefine spatial logic as their thinking evolves.

Acknowledgments

We thank the reviewers for their constructive comments. We also thank and acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC) [RGPIN-2019-07192], the Canada Research Chair in Data Visualization [CRC-2019-0036]

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Received 2025-07-25; accepted 2025-10-17