Happy Puzzles: Puzzle Games for Visualization Task Abstraction

S. Rajendran[1], M. Tuscher[1], A. Arleo[4,1], D. Archambault[3], S. Miksch[1], T. von Landesberger[2], and V. Filipov[1]

[1]TU Wien, Austria, [2]University of Cologne, Germany, [3]Newcastle University, UK, [4]TU Eindhoven, the Netherlands

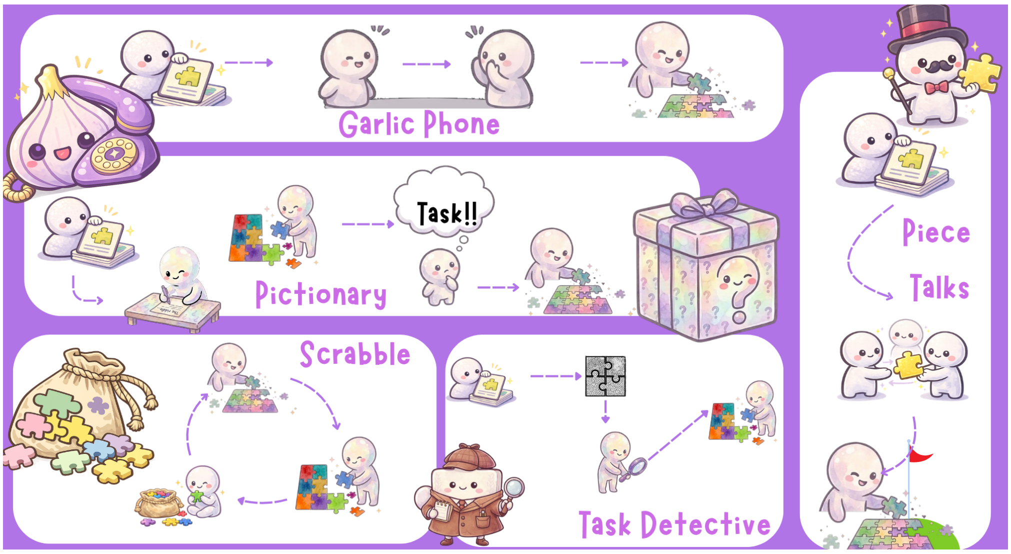

Figure 1: "*Happy Puzzles*": *Game Modalities*

Abstract

Task abstraction is fundamental in visualization research. It aids in describing and reasoning about analytical goals. While existing approaches provide rich and well-established frameworks, they are primarily text-based and challenging to engage with in practice. In this work, we explore a complementary, game-based approach to task abstraction using a puzzle metaphor to represent and construct analytical tasks. We design a set of interactive games in which participants construct and reconstruct tasks using these pieces, encouraging hands-on engagement and reflection. By framing task abstraction as an interactive and playful activity, our approach aims to support accessibility and foster a deeper understanding of visualization tasks while remaining grounded in established theory. Printable parts of the game as well as instructions are available through OSF.

1. Introduction

Visualizations are designed to support user tasks (i.e., goals and actions that users perform when analyzing data through visual representations). In visualization research, a task generally refers to a unit of analytical activity that a user performs to answer a question or obtain insights from data (e.g., *identify your house based on an aerial image in Google Earth* [Rot13]). Tasks may include actions such as identifying patterns, comparing values, tracking changes, or discovering relationships within a dataset. Clearly defining tasks enables researchers to determine which interaction techniques are most effective, which visualization methods are appropriate for a specific use case, and what types of analytical reasoning a visualization should support. Because tasks can be described at different levels of specificity, visualization research has introduced the concept of task abstraction, representing analytical goals independently of particular datasets, visual encodings, and/or application domains. Task abstractions are central for visualization since they reveal commonalities and differences across domains, enabling more consistent design decisions and transferable insights.

Task Taxonomies. Andrienko & Andrienko [AAG03] provide a re-

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view of exploratory tasks in spatio-temporal visualization. Brehmer & Munzner [BM13] introduce a typology describing tasks according to the **why**, **how**, and **what**, allowing them to be characterized across different levels of abstraction. Roth [Rot13] proposes a taxonomy of interaction primitives for geovisualization, emphasizing the role of interaction operations in analytic reasoning. In addition to these, many domain-specific task taxonomies exist to address the unique analytical requirements of particular data structures and application areas. Prior work introduces taxonomies for various graph analysis scenarios (i.e., multivariate, dynamic, and temporal networks, and group-level structures) [PPS14, APS13, KKC15, SSK14]. A comprehensive meta survey by Filipov et al. [FAM23] emphasizes the diversity of task taxonomies in the networks across the literature. Similar domain-oriented taxonomies exist for cartograms [NK15], multidimensional projection analysis [ELCF15], biological pathway visualization [MMF17], and volume data [LBLS15]. Pandey et al. [PSS*21] present a collection of tree visualization tasks for design and evaluation and highlight the breadth of task formulations across literature. Collectively, related work demonstrates the importance of task abstraction in visualization research. However, several challenges emerge: (i) task taxonomy frameworks are text-heavy and challenging to internalize, requiring significant interpretation before they can be applied in practice, and (ii) task taxonomies present extensive collections of task definitions that are hard to navigate. As a result, while taxonomies provide valuable conceptual guidance, they may be difficult to integrate directly into design processes or educational settings.

Visualization Games. To address these challenges, game-based activities explore methods to engage users with complex concepts in visualization [SBK*25]. **Serious games** [NM14, CBM*12, BHC*16] are designed for these specific purposes and applied to learning and skill acquisition across a range of domains. In visualization, game-based mechanisms have been used to assess visualization literacy [BRBF14]. Constructive approaches, such as building visual representations from discrete tokens [HCT*14, PDBE*25], further demonstrate that assembling representational components can itself support analytic reasoning. These collectively show that framing analytical activities in a playful, hands-on setting can lower barriers to engagement and support reflection.

Contribution. Building on this, we propose a playful, game-based approach "*Happy Puzzles*" to exploring task abstraction through a puzzle metaphor. Participants engage with visualization tasks by assembling puzzle pieces that represent core dimensions of task abstraction, such as actions, data, features, space, and time. An interactive, game-based setting enables users to construct and communicate tasks, shifting the focus from interpreting text-heavy taxonomies to engaging with their underlying concepts. This approach serves two purposes: (i) it provides a unifying representation that distills and connects ideas from prior task taxonomies; and (ii) it creates a playful environment in which users can practice, explore, and reflect on analytical reasoning. By translating textual task descriptions into manipulable puzzle components, we aim to make task abstraction more accessible, intuitive, and engaging, while remaining grounded in established visualization research.

2. Task Design Space Using Puzzle Pieces

To structure our game, we represent tasks as an arrangement of puzzle pieces encoding key dimensions commonly found in visualization tasks. Drawing on prior frameworks [Mun14, TS20, APS13, FAM23], we identify five core components captured by these pieces: **actions** (the analytical objective), **data** and **features** (what is being analyzed), and **contextual dimensions** such as **space** and **time**. Within the game, participants construct tasks by assembling these pieces into meaningful configurations, forming sequences that reflect the structure of an analytical objective. Each piece is designed with simple input and output "ports" that allow them to interlock, enabling users to iteratively build, modify, and interpret tasks in a hands-on and intuitive way (see Figure 2). In contrast to traditional text-heavy task abstractions, the puzzle game provides a visual and flexible alternative for specifying tasks while remaining grounded in established task abstraction approaches [BM13, TS20].

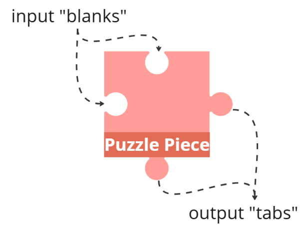


Figure 2: *The input ("blanks") and output ("tabs") ports of a puzzle piece are used to connect it to other pieces. These enable mapping relationships and dependencies for task abstraction.*

2.1. Puzzle Pieces

We define the puzzle piece dimensions and differences as follows:


Action: typically expressed using action-oriented terms (e.g., "identify", "trace", "compare"), this piece defines the task objective (*how*), such as identifying key influencers, tracing biological pathways, or comparing spatio-temporal patterns.


Data: represents the data and context through which the analytical objective is carried out. Its properties (i.e, structure, associations, or attributes) shape how patterns and relationships emerge and are interpreted (*what*).


Time: represents the temporal characteristics of the data that govern the analytical tasks, focusing on aspects such as temporal trends, periodic patterns, or event-driven changes (*when*) to support identifying patterns, anomalies, and change over time.


Space: represents either a geographical context (e.g., city growth) or an abstract spatial structure (e.g., embeddings). It captures spatial relationships such as distance, regional influence, and clustering, supporting analyses of *where* patterns occur.


Feature: includes any attributes of the data (e.g., category, influence score, strength of interaction) that are relevant to the analytical task (*what*). Feature pieces can also be linked to spatial or temporal dimensions (e.g., location-based features or time-dependent behaviors).

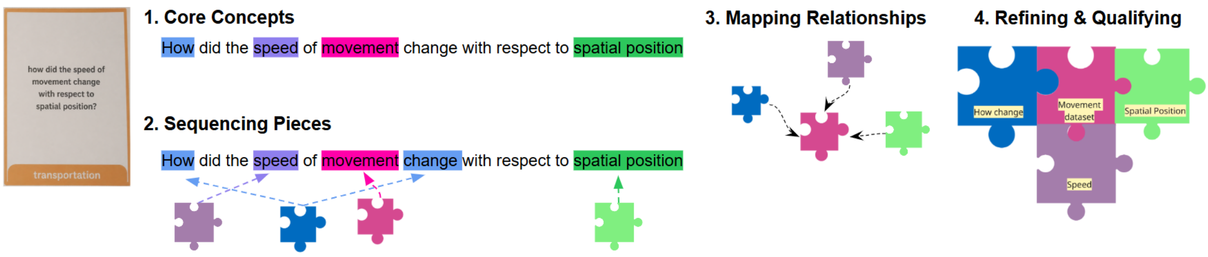
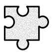


Figure 3: *Left: Task card containing the task description and contextual label (i.e., transportation). Right: Illustration of the steps in the construction process using the puzzle metaphor:* ***(1)*** *Tasks are decomposed into core dimensions, which are highlighted;* ***(2)****: Each component of the task is mapped to a puzzle piece. Blue for actions, pink for data-related components, green for space, and purple for features;* ***(3)****: Relationships between pieces are established to reflect dependencies and context; and* ***(4)****: Puzzle pieces are refined with annotations to specify details.*

 **Wild Card Piece:** functions similarly to a "wild card", helping users to represent phenomena or dimensions that fall outside our predefined categories, such as action, data, feature, space, and time. For example, complex or domain-specific concepts (e.g., information diffusion) can be expressed using the wild card piece along with annotations when they cannot be easily decomposed into existing components. The wild card piece may also be used flexibly in place of other dimensions when needed, supporting adaptability in task construction (*what*).

2.2. Construction of the Puzzle Pieces

Each task is represented through an arrangement of puzzle pieces, where each piece serves as a visual reference to a task dimension. These pieces are annotated to convey the context of the task. We illustrate the construction process of our approach in Figure 3. To construct a task's puzzle representation, we first identify the core components by extracting key verbs and nouns from the task, we highlight these dimensions using consistent color coding (see Figure 3). As most tasks identified (see supplementary material) require domain context, each task card includes a contextual label (e.g., transportation) to anchor the task. When additional specificity is required, the puzzle pieces can be labeled (e.g., specifying extremes such as maxima or minima, or temporal granularity). This modular and compositional approach allows tasks to be translated into concise visual structures.

3. Happy Puzzles: Modalities

We propose a set of games built around our puzzle task abstraction, accompanied by descriptions, rules, mechanics, and learning objectives. The games were chosen based on playability and their compatibility with the puzzle pieces and tested through a trial run, but are not limited to this set; one game was further deployed in a bachelor-level educational setting (for results see supplementary material). Game rules and mechanics will be presented to players prior to play.

3.1. Game Materials

For the workshop, we will provide all of the necessary materials. Game sheets explaining the rules and mechanics of the games, as well as task cards for self-printing. All materials can be found in our supplementary material.

- ☐ Puzzle pieces representing the core concepts (action, data, feature, space, time, wild)
- ☐ Task cards with collected analytical tasks
- ☐ Timer or stopwatch (for turn limits, depending on difficulty)
- ☐ Annotation materials (post-its, colored pens, or stickers)
- ☐ Containers or boxes for organizing the puzzle pieces

3.2. Difficulty Settings

Before starting to play a game, the players have to agree on a difficulty level. In most of our proposed games, varying difficulty levels can be achieved through the following options:

- Setting time limits (easier modes do not have a time limit)
- Varying the number of drawn pieces (depending on the game mode, it is easier to start with more or fewer pieces)
- Agreeing upon if the shape of the pieces has to fit, or be ignored
- Choosing between tasks from task cards or making up their own tasks (the latter one might be easier in most cases)
- Include or exclude wild card pieces (easier modes include them)

3.3. Pictionary (3+ players)

Description: A derivative of "pictionary", where players alternate between constructing puzzle representations of tasks and reconstructing tasks from existing puzzle arrangements. The goal is to successfully convey a task through multiple rounds of construction and reconstruction, ideally reproducing the same task at the end as it was initially drawn.

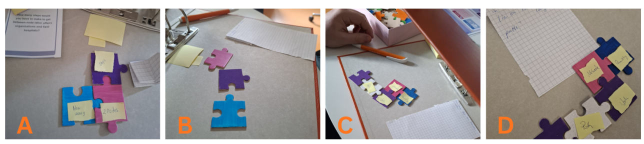


Figure 4: *Pictionary gameplay (for an even number of players): A) Player 1 builds from a random task card → B) Player 2 writes the interpreted task → C) Player 3 builds from that description → D) Player 4 writes the new interpretation.*

Rules:

- No talking is allowed during the game.
- Each player must ensure the next player starts from scratch by folding the paper or dismantling the puzzle and removing the annotations so that previous constructions are hidden.
- Only one solution per round is allowed; players must pass a single construction or task to the next participant, without including alternative interpretations.
- Time limit: 5 min (optional, depending on difficulty).

Mechanics: *(Uneven number of players)*: A player (P1) draws a task from the card deck (or makes up their own task). P1 writes it on a sheet of paper, folds it, and puts it in the box with the puzzle pieces. P1 passes the box to the next player (P2). P2 constructs the task written on the sheet using the box of pieces and annotates the pieces with post-it notes, folds the sheet so the task is not visible to the next player (P3), and passes both the box and the folded paper to P3. P3 only sees the constructed puzzle pieces, not the task, and reconstructs the task using the puzzle pieces with annotations, writes it down on the paper, then destroys the puzzle arrangement, removes the annotations, puts the puzzle pieces back into the box so the next player does not see which pieces were used before, and passes the materials to the next player (P4). P4 only sees the task written on the paper and must construct the puzzle pieces with annotations, then folds the paper so the next player cannot see the task, only the arrangement. This process continues until all players have participated. At the end, the paper is unfolded, and all the tasks are compared with the original to observe changes or consistencies across rounds (see Figure 4).

(Even number of players): In this case, P1 writes the task on the sheet of paper and folds it, so it is not visible to the next player, and also constructs the puzzle arrangement with annotations. The next player only sees the arrangement. The rest remains the same.

(For simultaneous play): Each participant receives a sheet and a box of puzzle pieces and independently constructs their task or draws a task from the "hat". After completing the initial construction, boxes and sheets are passed to the next player for guessing or reconstruction (alternating every step). This cycle continues until each player gets their original box back. At the end, each player can see how their original task changed at each step.

Goal: See how tasks change over time and how people understand them. Compare which tasks worked better than others and discuss why that might be.

3.4. Garlic Phone (4+ players)

Description: A game mode based on "gartic phone", but instead of whispering sentences around, we whisper tasks. The goal of the game and the most fun part is: "how far or how close can you get the final task to the original?".

Rules:

- The first player can look at the task card, but cannot reveal it to other players.
- The task must be communicated verbally in a single pass; repeating or restating the task is not allowed.
- Communication should be discreet (e.g., whispered) and passed sequentially from one player to the next.
- Players must listen carefully, asking questions is not allowed.
- The last player must build the puzzle before seeing the original.
- Time limit: 8 min (optional, depending on difficulty).

Figure 5: *Garlic Phone gameplay: A) a player with the task card (randomly picked) → B) and C) whispering the task to the next players sequentially → D) a side-by-side comparison between first player's and last player's puzzle construction.*

Mechanics: One player secretly picks a task card from the deck and creates an arrangement of puzzle pieces for that task. That player cannot show the puzzle arrangement to anyone else, they must whisper the task to the next player. That player then whispers it to the next, and so on until the end of the chain is reached. The last player must construct an arrangement of puzzle pieces based on what they heard. At the end, the original and the result are compared, and everyone tries to figure out what was lost, misunderstood, and changed along the way (see Figure 5).

Goal: Learn how tasks can be misunderstood or simplified. Help players see how these puzzle pieces are parts of a larger task (i.e., tasks can be broken down and decomposed into the dimensions we have).

3.5. Task Detective (1+ players)

Description: A game mode where one player encodes a task using only wild card pieces and secretly defines their meaning. The goal is to see how other players interpret and reconstruct the task, and how closely their solutions match the original intent.

Rules:

- First player must use only the wild card puzzle pieces.
- Players cannot ask questions to the first player.
- Time limit: 4 min (can be changed depending on difficulty).

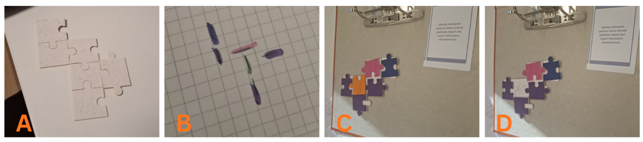


Figure 6: *Task Detective gameplay: A) Completed puzzle with wildcard pieces → B) The first player records a memory of their ar-rangement → C) The detectives (other players) examine the pieces and task, then reconstruct with core dimensional pieces → D) Final arrangements are compared with the first player's version.*

Mechanics: In this game, the first player draws a task card at random and constructs a representation of the task using only wild card pieces within the time limit. The player privately annotates the meaning of the pieces on a sheet of paper as the ground truth.

The first player can also rotate the arrangement to make it more difficult to identify the correct pieces. The remaining players are then shown the task card and the constructed wild card representation, but not the annotation. Based on this, the players must interpret and reconstruct how the task could be expressed, choosing the correctly colored pieces and their positions. At the end of the round, all players reveal their constructions alongside the original annotation, allowing the group to compare how interpretations align, diverge, or evolve across participants (see Figure 6).

Goal: To examine how people interpret and reconstruct task dimensions and their relationships using flexible puzzle pieces.

3.6. Piece Talks (3+ players)

Description: Piece Talks is a multiplayer game centered on collecting the necessary puzzle pieces to complete a chosen task. Players draw pieces from a shared pool and negotiate with others through trading, offering, or withholding pieces to obtain what they need.

Rules:

- Players can refuse the task construction, but with a valid reason.
- Exchanges are only allowed between two players at a time.
- All exchanges must be mutually agreed upon.
- Players can simply offer puzzle pieces.
- Players can hoard pieces.
- Time limit: 5 min (depending on the chosen difficulty).

Figure 7: *Piece Talks gameplay:* ***draw*** *a task card and pieces from a random heap →* ***trade*** *or hoard them → solve the task through a finished puzzle arrangement.*

Mechanics: Each player draws 12 puzzle pieces from a bag and is assigned (or selects) a task card from the deck. The goal is to assemble their pieces into a configuration that fulfills the assigned task. Players may take additional task cards if they can construct them using their available pieces. The time to construct the puzzle pieces must be within the time limit. To complete tasks, players can exchange puzzle pieces through mutually agreed-upon one-on-one trade. Players may request specific pieces, offer trades, give away, or strategically hoard pieces if they believe others need them. If a player is unable to obtain a needed piece through exchange, they may draw one puzzle piece from the shared pool per attempt. Once a player believes they have successfully constructed a task, they present their puzzle to the group. The construction is accepted only if the majority agrees that it correctly represents the task. Any player may challenge the construction by providing a clear justification for why it does not match the task (see Figure 7).

Goal: Helps to understand how tasks depend on available components, how people justify interpretations of structure, and how different players prioritize task dimensions.

3.7. Puzzle Scrabble (1+ players)

Description: This game explores the task construction, how it might differ across players, and which tasks can be constructed with the puzzle pieces.

Rules:

- Players must decide on the number of pieces and the time limit.
- Players are not allowed to see the other players' puzzle pieces.
- Players may not extend or modify another player's task by just adding one or two additional pieces (e.g., adding a time piece to change "Find the most important nodes in a graph" into "Find the most important nodes in a graph over time").
- Tasks must alternate between horizontal and vertical placement.
- Each task needs to be complete, which means that it needs to include at least one action piece and one data piece.
- Tasks must connect to at least one piece placed by another player.
- Depending on the chosen difficulty, puzzle piece shapes may need to fit exactly or not.
- Each player has only a limited amount of time to come up with a task and place it in the middle (depending on the difficulty).
- Time limit: 3 min (depending on the difficulty)

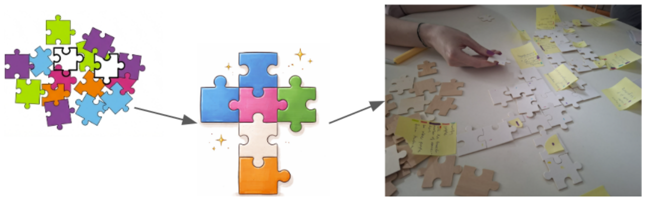


Figure 8: *Puzzle Scrabble gameplay: drawing pieces from a random heap → aligning them horizontally or vertically → progressing to-ward a completed arrangement.*

Mechanics: Each player draws 15 puzzle pieces from the bag and keeps them hidden from other players. The first player attempts to create a task using their pieces. If it is not possible, they draw one additional piece. If still impossible, the turn passes to the next player. If the player successfully forms a task, they place it in the middle and annotate the puzzle pieces with post-its. The next player must use at least one existing puzzle piece, along with its annotated meaning, and may connect as many of their own pieces as they want to form a new task. Players take turns building on the existing chain of tasks (see Figure 8). Each task must be complete (see above) and connected to at least one other puzzle piece. The game ends when one player has no pieces left, when the time limit is reached (e.g., 30 minutes, depending on difficulty), or when no more moves are possible (for example, if the shapes of the remaining pieces prevent further connections).

Goal: The goal is to see which different tasks can be formed by reusing pieces and to figure out different arrangements for tasks.

4. Accessibility and Replayability

Accessibility: Happy Puzzles is designed to engage participants across a range of visualization expertise. Tangible puzzle pieces and visual representations promote collaborative thinking, while game sheets provide step-by-step guidance. The inclusion of a wild card piece allows participants to represent concepts or phenomena that are not captured by existing dimensions. Its modular design supports gradual learning, and the game can be adapted for different group sizes or low-resource settings, such as drawing pieces on paper. Puzzle pieces can also be represented through multimodal cues such as icons, visual elements, and tactile displays. The choice of colors is not fixed and can be adapted to user preferences, including more color-blind friendly palettes or other color variations.

Replayability: The combinatorial nature of the puzzle pieces and task variability make this game replayable. Multiple task cards, gameplay modes, and player-generated tasks create diverse outcomes across sessions. Adjustable difficulty levels and game modes encourage repeated play, allowing participants to explore increasingly complex task constructions and interpretations over time.

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