Retzzles: Towards Supporting Retention Using Puzzle Interactions and Abstract Symbols

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Figure 1: We present our touchscreen puzzle prototype *Retzzles*. By allowing users to focus on solving puzzles first, we facilitate engagement that aids in better information retention.

ABSTRACT

While map-based sources may provide upfront content, their current form is not always the most effective way for users to retain information. To help in this, augmentation techniques have shown great potential in helping users retain various forms of information. In this paper, we explore touchscreen visual elements, such as puzzle pieces and abstract symbols, in helping users become more engaged toward improved information retention. We investigate whether these elements aid in retaining information and increasing engagement compared to standard map-based formats alone. To achieve this, we present *Retzzles*, where users can solve puzzles and interact with abstract symbols that display key location information as an alternative to the map format. To evaluate this, we did a between-subject study with a sample of $n = 16$. Our initial findings indicate our approach improved mean scores on textual and spatial recall but not for visual recall, subject to further investigation. Our findings contribute to discussions on using interactive touchscreens in similar learning scenarios involving memory retention.

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CCS CONCEPTS

• **Human-centered computing** → **Touch screens**; • **Applied computing** → **Interactive learning environments**.

KEYWORDS

retention, touchscreen interfaces, interactive maps

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1 BACKGROUND AND RELATED WORK

Maps have been essential tools for human beings since ancient times, serving various purposes such as communication, navigation, and exploration. Throughout history, they played an essential role for multiple purposes, from military and political strategies to trade and commerce. Remembering information is crucial for our survival [4, 6], and maps have always played a central role in this fundamental task as external memory and spatial reference devices. The evolution of technology has expanded the range of maps to encompass various forms, such as cartographic maps, satellite images, terrain models, oblique 3D views, photo-realistic 3D city models, and street-level photography [3]. Each map type has unique benefits, depending on its intended use. For instance, cartographic maps help illustrate land features and political boundaries. At the same time, satellite images provide a detailed view of a location's geography. Terrain models can support planned hiking trails or other outdoor activities. In contrast, oblique 3D views and photo-realistic 3D city models offer a realistic location perspective, thereby enhancing our visual understanding of the environment."

Although map-based sources can be helpful for quickly presenting information on a display, they are not in the most effective format for users to remember information over the long term. While maps can help convey spatial relationships and locations, they need to balance having enough context without being too overwhelming at the same time. This is where interactive screens such as touchscreen displays have merit over traditional maps. They allow users to interact with the content in various ways. To validate this, we explore the effectiveness of interactive touchscreen, specifically the use of visual elements in presenting more engaging information for its users. By using jigsaw puzzle pieces and abstract symbols, we aim to provide the user with a more immersed and personal experience.

In prior works, studies have used jigsaw puzzles as an excellent way to keep the brain active and potentially reduce the risk of Alzheimer's disease [2]. Additionally, users follow their path in the puzzle-solving process, which ultimately becomes a somewhat personalised experience. Moreover, puzzles are inherently fun and have been found to help make learning enjoyable for students, as they provide a unique and engaging way of presenting information [11]. On the other hand, abstract symbols serve us as Points of Interest (POI), which reflect a constant location and information (e.g., a name and address) [19]. Additionally, prior research confirms that every educational environment needs to provide a surface for the construction and manipulation of symbols [16]. Puzzles have already been considered as alternative means of providing information. In one prior work on sensory puzzles, a specific puzzle piece represented a portion of music. It provided a tangible experience representing the content of the puzzle [12]. Another approach that was tested was to include rubber-cast shapes attached to surfaces, which, when moved, generate sounds

Large displays and touchscreen interfaces provided alternative interfaces without the disadvantages of immersive headsets. In these interactive displays, we have seen information presented in different ways, such as (i) gesture-based direct manipulation through the use of controllers [1] or (ii) sensors [20]; (iii) vision-based immersive effects expanding screens to 3d viewing experiences [17]; or (iv) touch-enabled interactions with visual elements projected in a screen [8]. In the latter, playful interactions have been inspired, such as tangible interactive parts [18], draggable puzzle pieces and codeblocks [7, 15] and many others. In this research, we pay special attention to using puzzle pieces in touch screen displays as digital augmentation as a potential alternative to conventional text-based information sources applied in engagement and information retention.

Puzzles, by definition, are fun and have been observed to help make learning enjoyable for students [9, 13]. Existing frameworks and research support that activities where people "learn by doing" along with social interaction supports cognitive development which then helps users learn in general [14]. Specifically, the use of jigsaw elements which is one of the most common puzzle games has been observed to help students acquire a deeper understanding of certain concepts and terminologies [10] in the broader context of learning. In summary, this research presents preliminary findings and provokes insightful discussion on the following targeted contributions:

- **Artifact**: We present the prototype *Retzzles*, an interactive touchscreen interface that allows users to solve puzzles towards supporting information retention.
- **Empirical**: We present early-stage findings of a user study between two conditions (map vs puzzle) on evaluating visual, spatial and textual recall.

2 RETZZLES: DESIGN AND IMPLEMENTATION

We designed our interaction following some benchmarks in the literature on the context of learning and tourist information systems. This section discusses the design and concept behind our prototype entitled *Retzzles*. Drawing on the theory of constructivism, we recognize that individuals actively construct knowledge and create their experiences [5]. While the end goal of the puzzle for everyone will be the same, the path toward achieving a solution will be unique for each user. As the puzzle is being built, the user is piecing together the knowledge as long as they play the game. With *Retzzles*, users are building the puzzle, which represents a tourist destination map, so the final map is the same for everyone, but the story is personal. On this map, we put information about the city's essential points of interest (POI). We are trying to pique the users' curiosity to make them interact and learn.

In *Retzzles*, users can move the puzzle pieces and put them in the correct spot. Some POIs contain specific information about a tourist site. Users may uncover the map/picture of a particular POI they want to read more about. As the user solves the puzzle, POIs become revealed when the suitable puzzles are pieced together. These buttons are clickable once the whole puzzle is complete, and they provide the user with information about the touristic location they are placed at on the map. We used Unity to build this prototype. Jigsaw puzzles were created using GIMP and its

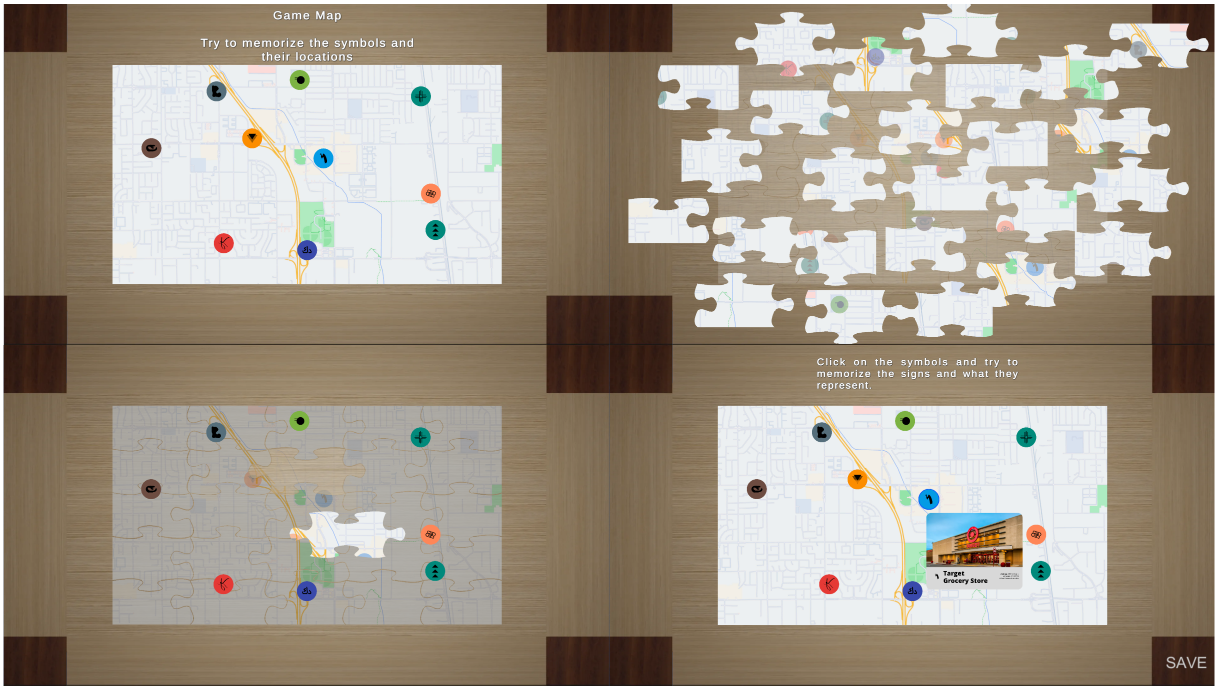

Figure 2: Different Views of Retzzles. Top Left: Map Condition. Top right: Puzzle Condition. Bottom Left: One piece left. Bottom Right: Point of Interest opened.

pattern feature "jigsaw". In this specific map, we identified ten abstract symbols to use as buttons that do not correlate with the information they provide. The symbols were created in Canva, and the map was created using Snazzy Maps. We augmented this map by adding buttons on the location of the places. The puzzles are all organized into one empty parent game object. Each piece is assigned with the `DragObject` script, allowing it to be moved and dragged anywhere on the screen. This script explains how the puzzle pieces snap into the correct position. Because our pieces are treated as sprites in Unity, we used `PolygonCollider2D` to handle the physical collisions. The collider's shape is defined by a `freeform` edge made of line segments, which is easily adjustable to cover any shape, in our case, any jigsaw puzzle.

We have added some automated mechanisms to log data within the prototype for more efficient data collection. We are tracking the amounts of moves/clicks for each puzzle piece, activating information points / POIs, the time needed to solve the puzzle, open and read the information points, and many others. To top it off, we are also tracking and saving every movement of each piece. In future work, we would like to visualise how users moved the pieces and see if there is a way similarity between users.

3 USER STUDY

We conducted a between-subject study design to validate our hypothesis with $n = 16$ participants recruited through convenience sampling. Our participants are unfamiliar with or have not learned any information about the touristic place that is the subject of the map in the prototype. Generally, our study involved three major phases: 1) Orientation and Informed Consent, 2) Interaction Task and 3) Wrapping Up. In 1) The moderator of the study provides a brief introduction to the experiment and the prototype *Retzzles*. Afterwards the user is invited to read and sign the consent form. At the beginning of 2) the moderator explains the task in more detail. We used two conditions, namely (1) Map condition and (2) Puzzle Condition. Symbols and information used between both conditions are the same. However, the interaction is different as the former had touch-screen map interactions while the latter required puzzle assembly before unlocking the same touch-screen map interactions. As part of the study, they were subjected to different questionnaires to measure variables such as visual, spatial and textual recall. For this study, we proposed the following hypothesis: H_0: Puzzle interactions aid in improved visual, spatial and textual recall of map information.

3.1 Task Protocol

For both conditions, the task of our participants is to memorize as much information as possible after interacting with the prototype. First, they were given a module that taught them how to use the prototype. Then when they are ready, they proceed to the actual task based on their assigned condition (see Figure 2). Throughout the prototype, they will encounter icons with abstract symbols representing key Points of Interest (POI) in the map. Second, depending on their assigned condition, they will have 6 minutes to use the prototype and remember as much information as possible. Participants can finish before this time limit. For (a), they will interact with a map instead without needing to assemble the puzzles. Here, the POIs are already clickable. In (b), they will have to solve the jigsaw puzzle of a map before interacting with the POIs and reviewing the information provided.

3.2 Evaluation Metrics

We evaluated users on several variables, including visual, spatial, and textual recall, and also measured their subjective cognitive load using the NASA-TLX scale. To test visual recall, participants were presented with a map containing 20 abstract symbols (ten correct and ten incorrect) and asked to identify the correct symbols. Spatial recall was assessed by asking users to remember the positions of the abstract symbols on the map and to place them in their correct locations on a separate blank map. Finally, for textual recall, users were shown ten symbols on the map and asked to provide information about each symbol, including its name and category. For example, they might provide the name "Costco" and the category "grocery store". This information was obtained by clicking on a point of interest before the task.

4 FINDINGS AND DISCUSSION

Descriptive statistics of the data were analysed. To test for normal distribution, we used Shapiro-Wilk since we did a between-subject study design. We found that the variables are normally distributed ($p \geq 0.05$ see Figure 3) except for the visual recall of negative symbols. Based on the participants' mean scores alone, the puzzle condition performed better except for the visual recall ($SR : 70.00, N-TR : 56.3, C-TR : 65.0$, see Table 1). We conducted the Mann-Whitney U test, a form of independent samples t-test, to further test the significance of the different metrics. This allows us to determine whether we will reject or accept our proposed hypothesis. We subjected visual, spatial and textual recall across both conditions. Based on our sample size of 16 participants, we found no significant difference ($p \geq 0.05$) across all variables. Thus, we reject our null hypothesis.

Based on the participants' mean scores in the puzzle condition that were generally higher than the map condition, our sample size may not be enough to arrive at a conclusion. Several factors contributed to the effects on visual recall, such as the colors used in the POI. Several participants shared during the after-test briefing that some were associated with the colors, which were not considered a variable in our study.

Table 1: Overview of Metrics Used. Legend: *Cond*: Condition, *VR*: Visual Recall, *NS-VR*: Negative Symbol Recall, *SR*: Spatial Recall, *N-TR*: Name Textual Recall, *C-Tr*: Category Textual Recall

	cond	VR	NS-VR	SR	N-TR	C-TR
mean	puzzle	▼76.3	▼8.75	▲70.0	▲56.3	▲65.0
	map	81.3	7.50	62.5	53.8	51.3
std dev	puzzle	23.3	9.91	27.8	28.3	12.0
	map	21.0	13.9	24.9	20.7	17.3
Shapiro-Wilk w	puzzle	0.904	0.736	0.900	0.937	0.897
	map	0.863	0.628	0.841	0.941	0.849
Shapiro-Wilk p	puzzle	0.313	0.006	0.287	0.581	0.274
	map	0.128	<.001	0.077	0.622	0.094
Mann-Whitney U	p	**0.668		**0.489	**0.750	
	H_a $\mu_{puzzle} \neq \mu_{map}$,**no sign. diff.					

with abstract symbols can affect users' retention skills. We also plan to integrate a mixed reality approach to explore interaction and direct manipulation differences with the puzzle pieces, focusing on engagement and retention. Our goal is to guide designers in creating engaging interactions in practical fields such as tourism, civics, and digital humanities.

5 CONCLUSION AND FUTURE WORK

In this paper, we explored whether touchscreen visual elements, such as puzzle pieces and abstract symbols, can help users become more engaged towards better retention. We presented our prototype, *Retzzles*, where users solved puzzles and interacted with abstract symbols displaying key information as an alternative to the map format. Results of our between-subject study, involving $n = 16$ participants, showed better mean scores; however, no significant difference between these conditions. We believe we can arrive at better results with a larger sample size and if we consider other variables such as color. We also have a significant amount of interaction data that we have not yet analysed. This will give us exciting insights into how users build customised paths when solving puzzles. We feel the results presented in this study are a step in understanding how touchscreen puzzles and augmented maps

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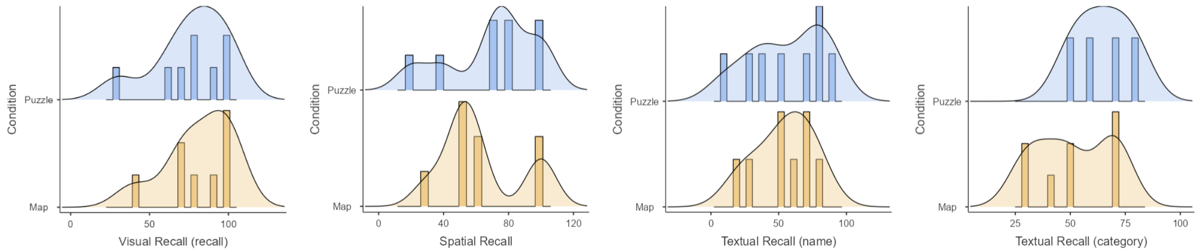

Figure 3: Curve plots showing normal distribution across several variables in our study

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