# Distil: Supporting Dynamic Sensemaking

**Leave Authors Anonymous**
for Submission
City, Country
e-mail address

**Leave Authors Anonymous**
for Submission
City, Country
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**Leave Authors Anonymous**
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e-mail address

## ABSTRACT
Online information is the modern tool of choice for individuals trying to learn and make decisions around complex subjects, but it is becoming increasingly challenging for them to make sense of it. The complex and messy process of sensemaking requires users to constantly adjust the way they organize, perceive, and collect information as they learn from online sources. In this paper, we introduce Distil, a new tool for saving, annotating and organizing information collected from the web during sensemaking. Distil embraces the dynamic nature of the sensemaking process, allowing for users to adjust their behaviors and organization naturally as they collect and learn more about a topic. We utilize a user study to first inform the design of the Distil system, and then demonstrate through two scenarios the value of the Distil system.

### ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces

### Author Keywords
sensemaking; complex search; active reading; annotation

## INTRODUCTION
People are increasingly using the internet to make sense of unfamiliar domains for their own personal goals. With the ever increasing breadth, depth and diversity of online information sources, individuals are using the internet for a wide range of research tasks, such as understanding medical diagnosis, performing in depth product comparisons, or creating an itinerary for an upcoming trip [4]. This process of information foraging and active reading often involves collecting snippets of information [26, 28] from different sources for later use in comparison and summarization. As individuals begin to "make sense" [11, 29] of the information they've collected, they start to form a structure of the space either mentally, or depending on the complexity of the task, externally.

A key challenge when trying to make sense of an unfamiliar domain is that people don't know what they don't know. This results in the process of coming to understand an information space being messy, requiring frequent refactoring, throwing out old or irrelevant information, making decisions, and distilling often verbose content into a more consumable form [29]. When people begin this process, they often have a novice understanding of the information space and the value of individual pieces of information is highly uncertain. For example, if someone is planning a vacation to an unfamiliar destination, they may not know what the good locations to visit are, or even the types of locations they should visit (beaches versus museums, etc.). If they come across a list of possible attractions, they may be uncertain on how to evaluate it until they know more, so might save the entire list or just a link back to the list for later. As they move to knowing what they don't know, their sensemaking needs change: when collecting and organizing new information, they can be more discerning about what they collect, and the specifics become much more important (i.e. what time a train arrives, how long it takes to walk to the attraction, how much it costs). However, at any point in the process they might come across new information, e.g., that Barcelona actually has excellent wineries, and may need to add or refactor their organization accordingly, possibly triggering additional searching.

Despite these varying user needs at different points of the sensemaking process, the tools available for individuals to capture and distill content tend to be fixed and constant. For example, the most common way of capturing content is copying and pasting text into a notepad for later review – similar to what one would do on paper. Later, once users have collected content, they have to manually organize, structure, and distill the content they've collected – an often laborious process. If this structure changes as they learn more about the space, it is often costly to do so. To counter these challenges, we introduce Distil, a set of tools for dynamic sensemaking. Distil is composed of two parts: a flexible capture tool, and a dynamic organization and structuring interface. The capture tool allows the user to quickly transition from a low cost, low specificity interaction, to a higher cost, high specificity interaction. This information is then persisted into the organizational interface where users can refine what they've collected and pull out the most important pieces as they learn about the topic. As their mental structure evolves, users can quickly re-formulate and adjust their structure to accommodate both the new data they've collected, as well as existing information.

## RELATED WORK
In modern times, a large number of sensemaking tasks occur in an online setting, from shopping for a camera, to researching a

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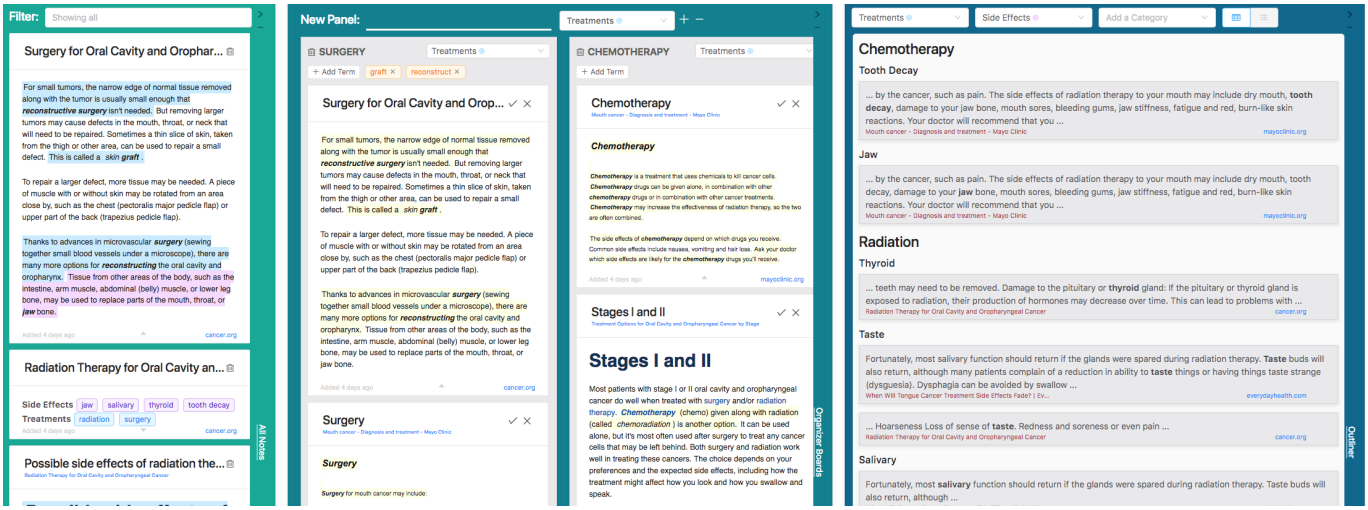


**Figure 1. Distil's organizer interface: The left most portion contains the raw notes collected from webpages, highlighted according to which "smart" panels they match. The central portion shows the "smart" panels the user has generated, along with any matching notes sorted inside of them. The right most portion is the outliner tool, where two categories have been put into a hierarchy to generate an outline from the note text**

medical issue [9, 18, 24]. By leveraging the abilities of digital systems to quickly process large amounts of information and offer streamlined, context aware interactions that support a user's cognitive challenges [7, 20], specialized digital sensemaking tools have begun to offer the potential to augment and simplify this process. As a result, there has been a large body of work that has looked at understanding and supporting the sensemaking process online, either by improving the foraging process of finding and collecting information, or the integration process of organizing and synthesizing the information collected [6, 23, 28, 34].

When collecting information during the information foraging [28] and active reading [26] processes, reducing the time and effort to select and capture relevant information is crucial to supporting comparison, cross referencing and structuring. [1, 20, 32]. Otherwise, individuals may not capture information in the first place [25, 33, 15]. A number of improvements have focused on increasing the speed and accuracy of these selections, such as bezel gestures [8], autocomplete [35], and using the structure of the information to be copied [3, 16, 31]. Researchers have also recently explored the value of reducing the accuracy of selections, supporting fuzziness or uncertainty of text selection as a means of reducing the cognitive costs of deciding where the selection bounds should start and end [7, 13]. We build on these methods, but instead of introducing or using a single selection method, we explore the idea that different methods may be more useful at different stages of the sensemaking process or with different methods of organization. For example, uncertain or fuzzy selection may be more valuable earlier on to reduce cognitive costs, or if organization tools provide help in narrowing down their overly broad context.

The information extracted is then reorganized by individuals into a more meaningful format and structure. A number of tools have used novel visualizations and metaphors for assisting users with structuring information, such as WebBook and WebForager [5] which utilize a book metaphor for managing pages, Elastic Windows [17], and Webcutter [22] which presents URL collections in a tree, star and fisheye. Others have focused on allowing for quick, efficient navigation of large collections, such as Sensemaker [2] and Scatter/Gather [10]. Improvements to the process of collecting pieces of information from pages and organizing it into collections have also been made including Hunter Gatherer [36], Dontcheva et al.'s extraction and organizational tool suite [12], Hearst et al.'s triage tool [14], and Clipper [19, 20].

However, sensemaking is, by and large, a dynamic process, where an individual's understanding, needs and confidence are constantly changing. This process isn't just a linear workflow of finding and extracting information, forming this into a schema, and discovering knowledge gaps requiring additional information [21, 11, 29]. Rather, it's a cycle, where a user is constantly reevaluating the information they have to determine its usefulness, if the structure they've formulated is representative of the information, and what else they need to learn to formulate a complete understanding of a topic.

In this paper, we explore how to incorporate this dynamic, cyclical nature of sensemaking into a support tool in order to improve user's flexibility and reduce the cognitive load during sensemaking. Rather than requiring fixed information schemas, information capturing tools, or the inability to quickly reuse or throw out older information, we focus on enabling a cyclical and elastic sensemaking process through the use of flexible foraging tools and a dynamic presentation of stored information. Previous work suggests a strong connection between uncertainty and the cognitive processes and constraints underlying the dynamic sensemaking process [7, 20]. Understanding how this uncertainty in different stages of the process affects users' use of different tools and collected information is a first step to properly supporting it.

## UNDERSTANDING ANNOTATION

In order to understand the impact of the dynamic sensemaking process on how users save and organize information, we ran a qualitative think-aloud study. We focused specifically on the interaction of the user's current phase in sensemaking and what tools they utilized, when they saved information, what information they saved, how much information was saved, and how that information would be later utilized either externally or during a later point in the process.

In the study, participants were instructed to perform three complex sensemaking tasks while collecting information and ultimately creating a document for each that they could hand off to a friend to share the findings from the task. While generating this artifact, we prompted individuals to speak aloud about their thought process, with occasional prompts asking them to clarify an activity or to explain an action that was not spoken aloud. Participants utilized a Microsoft Surface Hub to search and record the information they found during their searching process. We chose this device due to its closeness to paper annotation, while still allowing for easy searching and quick copying of information to the note-taking workspace.

We recruited 13 participants through a local behavioral research participant pool. Participants ranged in age from 20 to 44, with approximately half of them reporting as students. 5 of the participants identified as male and 8 identified as female. Prior to the study, participants were required to submit four potential search tasks they were interested in performing. Along with the name of the tasks, individuals also rated each task across four scales: their knowledge of the topic, the importance of the topic, the expected research time to learn about the topic, and the estimated number of web pages they would have to visit to fulfill their information need. From these searches, participants worked on three of them: two from their suggestions, and one that was provided by the researchers. When choosing the two searches provided by the participants, we tried to pick one task where the individual listed minimal knowledge of the topic and a long expected research time, and another where the individual listed a moderate amount of knowledge of the topic and a short expected research time. Some participant-provided tasks included learning about social media monetization, car shopping, and planning a wedding. The tasks provided by the researchers were designed to be tasks where individuals were expected to have no knowledge. These included how to start beekeeping, planning a vacation to Thailand, and understanding the sport of curling.

### Capturing Information

When observing how individuals were capturing information, users tended to use general methods of annotation (large screenshots, entire articles) early in the sensemaking process and for topics with which they're generally unfamiliar. They then tended to use more focused annotation methods (highlighting, notes on specific subtopics) once they gained command or had prior knowledge of the topic. This aligns with previous work in active reading and selection, suggesting fuzzy selection can be beneficial for uncertain selection [7]. 11 of 13 participants used multiple annotation methods during their session, and all 13 of these participants used larger selection methods for unfamiliar topics and smaller, more specific methods for familiar ones. Below, we discuss the different annotation methods, ordered from broadest information captured to most detailed.

#### *Screenshots*

Participants wanted to save the entire web page or store the link somewhere when they felt the need to preserve the context of information. This typically occurred early on in the sensemaking process when participants were still exploring what sources were actually useful for them. 5 out of 13 participants indicated that they would want to bookmark, locally save, or capture the link in some way, often times to preserve a large amount of information and the context of specific pieces of information they thought were useful. One participant, when given a house shopping task, indicated that she'd bookmark the page with the map before screenshotting or making written notes because she liked the interactivity of the map (P5).

#### *Clipping*

Clipping was often used for dense, relevant information and pictures that participants wanted to return to, or spend more time reading. When participants were scanning articles for their searches, they often clipped paragraphs of information, summaries of webpages (such as housing details on a Craigslist page or a key paragraph for understanding a research topic), or images like how to braid a fishtail braid. We found that users who chose not to clip often felt confident that their information could be remembered without any significant context. For example, we asked one participant, who was looking up the curling system, whether or not she wanted to clip the information from the Wikipedia article she was reading. She noted that because she most likely wasn't going to review it again, she did not want to clip (P10). Conversely, another participant researching game engines clipped an entire Wikipedia article for his research, indicating that he'd want to read it multiple times (P11).

#### *Markup (Highlighting, Underlining, Circling)*

Our participants used markup as a method to quickly scan through already collected information and markup key phrases and pieces of information. At least 2 participants indicated that they used their highlights in artifacts as a means of wayfinding. One participant indicated that the different colors of her highlights help her remember what she's already read (P11), while another participant expressed that his highlighted information in an article would be enough to remind him where he was (P13). Markup was also used to indicate important information, and used to call out key terms, information that was unfamiliar to the participant, or as a visual method to outline longer articles.

#### *Written Notes*

We found that most participants used note-taking as the quickest way to capture information and thoughts, and found it the easiest method in the context of the study. Often, this was a way to combine some prior knowledge on the participant with the information they were reading or to significantly reduce the amount of content. participants described note-taking as "quicker" or "faster." One participant noted, "The benefit of notes that are quicker and less commitment unlike Google

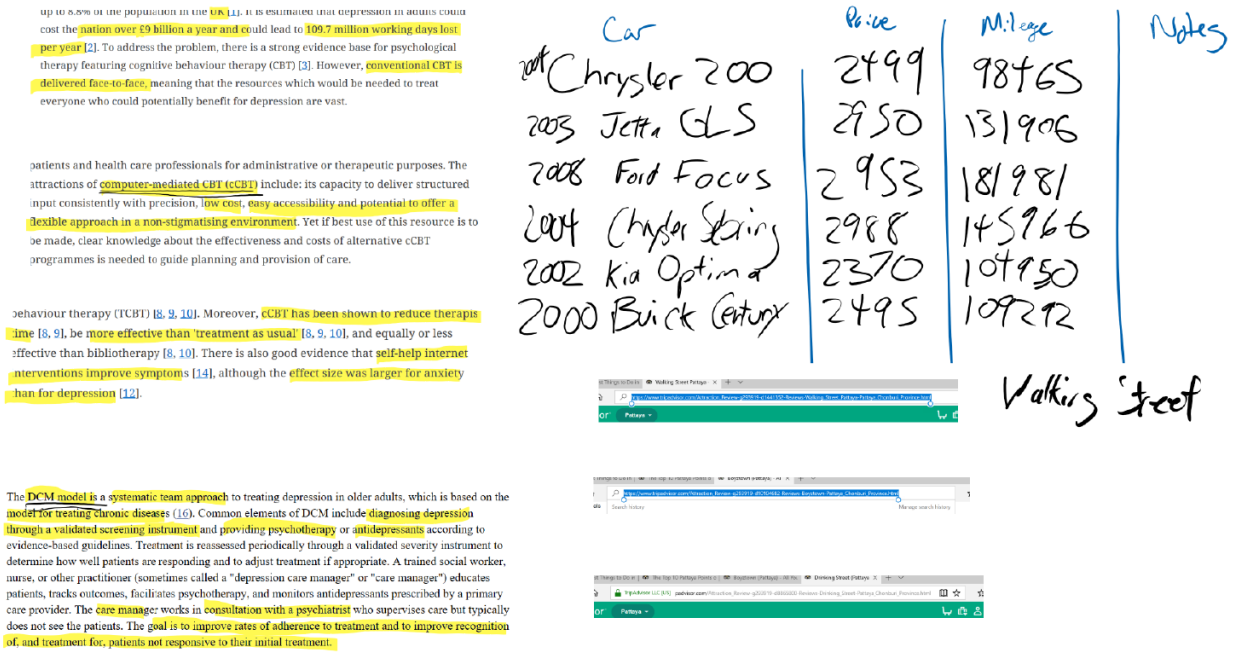


**Figure 2. Example artifacts participants generated from searching**

Docs for things like 'planning a ski trip'." Another participant described their opinion of note-taking as "My first pass would be to get as many notes as possible without thinking how it's categorized" (P7).

### The Role of Artifacts

While our initial analysis focused on annotation, which we define as the interaction method by which the user extracts potentially useful information, we also studied the form in which the results of their research was retained. We found that participants consistently varied the types of content that they created to retain, to analyze, and to share with others based on the goal of the search conducted. We refer to this type of content as an "artifact" of the search.

In conducting the study, we provided participants with tools that allowed them to annotate and preserve information in a variety of ways, including bookmarking links, saving complete web pages, taking complete screenshots of the entire screen or a portion of it, highlighting text, and taking written notes. Of our thirteen participants, eleven created two or more artifacts (across their three searches) of differing types during their session (See Figure 2). In our analysis of participant artifacts, we found that types of artifacts correlated strongly with types of task goals and with the participant's familiarity with the topic being explored.

We found that tasks with the goal of making an important decision with many known personal constraints, such as price while shopping, or location when apartment hunting, resulted in the creation of a structured artifact such as a spreadsheet, chart, outline, or list. Both participants that were directed to search for a new car ultimately created an artifact that represented information about candidate vehicles in a tabular format. One participant specifically cited the cost of planning a wedding as a reason why she might use a spreadsheet to compare options she discovered, stating that "Weddings could [cost] thousands" (P2). She also noted that "the table is really easy to see after I do my research." Another participant who was directed to search for a new apartment created a list of apartments that unified key features like rent amount, bus route to a common destination, and available amenities.

Additionally, when participants were asked to explore a general research topic with which they were familiar, they were far more likely to ignore the need for context, seeing it as unnecessary clutter, and compose their artifact of specific freeform notes, key terms, and small or specific images. For example, a participant who was a graduate student in materials sciences was asked to explore a topic related to his primary research. His artifact included portions of screenshotted subtopic articles and highlighted unfamiliar terms and no context-providing content. Similarly, a participant who already had some familiarity with figure skating stored text snippets, made brief written notes, and saved videos about particular types of jumps rather than figure skating generally. In some cases, participants who were asked to research a topic with which they were especially familiar even demonstrated an awareness of the type of artifact they planned to create before embarking on the task (e.g. a crochet enthusiast who described the use of an elaborate disk-based filing system that leveraged the hierarchical nature of disk storage to categorize and organize her images and notes).

In contrast, participants who were researching a very unfamiliar topic (like learning about brain chemistry or learning

| *Study Finding* | *Design Need* | *Distil Features* |
|---|---|---|
| Early and late stage sensemaking require different levels of note taking context | A set of flexible capture tools to support both stages | Screenshot and Clipping tools for early, Highlighter for late |
| Participants early on in the process often wanted to read and process their notes again | A way to allow for efficient reorganization of notes based on changing schema | Distil dynamically updates when new information is incorporated or the structure is changed |
| Learning and decision making tasks have different final artifact styles | Multiple structures for presenting collected information | Organizer features a table view and a document view that can be quickly toggled between |

**Table 1. The design of the Distil system and how it was informed by the user study**

how to perform a specific type of hair braid) were more likely to create less structured artifacts like written notes, diagrams, highlighted text, and partial screenshots. All participants were asked to perform at least one task of this variety, and in all cases, they produced an unstructured artifact to retain their findings. When asked why they recorded information in their chosen unstructured format, most participants indicated that they were retaining some amount of greater context in memory rather than in the artifact. One participant who was researching how to ski commented: "I called out what NOT to do, not HOW you do it. That's what I want to remember" (P8). A participant researching the history of urban legends created an artifact that combined a screenshot of a Wikipedia article with highlighted text on one subtopic and free-form written notes on another (P11). Aside from the organization of the information, similar to the findings from capturing information, the need for additional context was higher in the case of unfamiliar topics. In seven of the artifacts produced by participants, they created an artifact that explicitly provides additional context in the form of either an outline, lists of links to complete articles, or screenshots of overview content.

Lastly, we examined was how participants might share the information they had accumulated during the task with a friend, colleague, or family member. Most indicated that they would send general artifacts like links, summarizing screenshots, and structured text like an outline rather than more specific ones like highlighted text and written notes. One participant explained this as: "If the information was something specific that seemed like only one person would know then I would keep the source from it. Otherwise, some notes feel like a fact that everyone knows" (P7). Of the nine participants who were explicitly asked how they'd share their information with a friend, seven indicated that they would use a more general artifact.

Across these two larger findings, there appeared to be a strong relationship between the participant's prior knowledge of the space, the stage of the sensemaking process they were in, and the types of activities they were performing. This connects with the previous work looking at uncertainty in complex search [7, 20], where the large amount of uncertainty early on in the process causes individuals to put off organization and more specific selection until the value of the collected information has been solidified. In our system, we aim to support this transition by allowing users to easily refine and adjust the information they collect as they progress through their sensemaking task.

## SYSTEM DESIGN

The Distil system is composed of two novel components that together allow users to more flexibly capture and structure information they collect during the sensemaking process: a capture tool and an organizational interface. These components work in concert to allow users to quickly and effortlessly collect information from web pages, and then transition that into a more meaningful and compact form. In this section, we provide a high level overview of the interactions, and discuss the specific design decisions, informed by the previous study, that enable fluid interaction.

### Flexible Selection

The annotation process begins with the user selecting and saving potentially useful information from relevant pages. Based on our design study, we developed three different interactions users can use (See Figure 3), each corresponding to a level of specificity, and with a corresponding cognitive cost required to initiate:

*Screenshot*: Users can initiate a screenshot of the main part of the page by double tapping the escape key.

*Clip*: Users can clip a specific part of a webpage by drawing a boundary box around the content they wish to save (with the normal select tool switching to this mode after 70 vertical pixels).

*Highlight*: Finally, users can use the standard browser selection tool to select text, where they can then subsequently save that specific text they've selected.

The screenshot tool is the least specific interaction, and will capture the middle 90% of the display area of the current web page (in order to prevent selection of menus or footers on a page). User's aren't selecting specific content on the page to save, rather they are providing a simple signal to indicate that the information shown could be potentially useful. Instead of requiring the user to make a complex movement utilizing their mouse, a simple double tap allows them to indicate interest without the high cognitive cost of selection. This aligns with our understanding of the early sensemaking


**Figure 3. The different selection tools available to users in Distil**

process – a user might be able to discern that something is interesting or potentially important, however they might not know how to segment the information, or know what they want to keep about a topic or throw out. For example, if the user was learning about a new sport, such as curling, they might come across a page detailing the rules of the game. While the rules could be significant, the user at this point in their search might not know which ones are the most important to pay attention to as a beginner. Therefore, they will probably want to revisit these rules once they learn more of the basics of the game, and rather than trying to select parts of the rules to save, they can just quickly save all the info present on their screen.

Clipping is a slightly more specific interaction, requiring the user to draw a box around any content they want to save. Distil uniquely combines this interaction with the standard browser text selection interaction: if the selected text exceeds 70 vertical pixels, the text selection tool switches into a boundary selection tool. This removes an extra step for clipping interface that would normally be required. The clipping tool is for the middle of the sensemaking process, where the user can confidently discern groups of useful information, such as a paragraph about the symptoms of a medical disease they are researching, or pictures and details of an apartment they might be considering. The clipping tool allows them to provide a more specific selection that will require less future processing and understanding.

Finally, the highlighting interaction, which is based on the existing browser text selection interaction, is the most specific tool and requires the largest cost. As noted in previous work [7], specific text selection requires the user to make a judgment about what and how much content to save – in other words, they have to know exactly what information is important to make a meaningful selection. We propose this as a late stage sensemaking tool – once a user has a complete understanding of what information is useful, they will want to only save the important pieces, and not keep unnecessary information that could clutter their set of information.

This set of annotation interactions feed into the Distil organizational interface, where users can further filter and organize the content into a more meaningful and compact structure. Regardless of the selection interaction, Distil saves the HTML

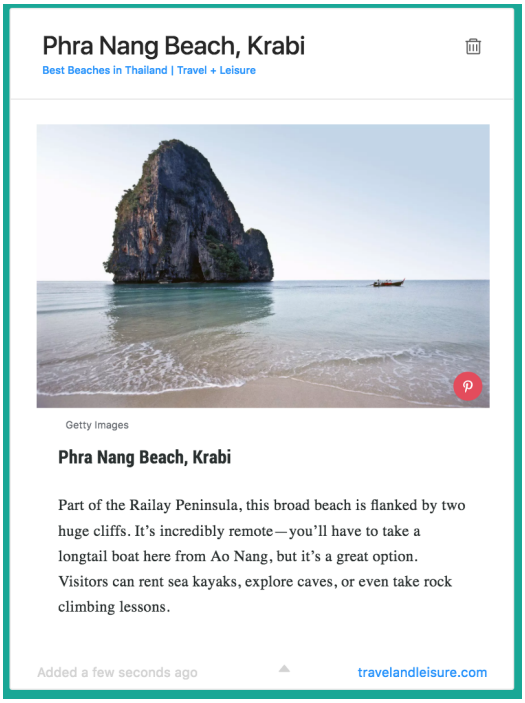


**Figure 4. An example clipped note in the Distil interface which retains the original formatting**

and CSS of the content selected. When this information is displayed in the organizational interface, it maintains the appearance of the original page, while allowing for a number of convenient features, such as further selection, content scaling with text reflow, enhanced context and in-text links to additional information (See Figure 4).

### Transforming Annotations

The organizational interface consists of three components, which are used in series: a Pinterest-esque board to view all of the notes a user has collected, a set of smart panels (similar to Hearst et al.'s interface [14]) where a user can categorize their notes, and finally an outline tool where a user can generate a document or table from their notes (See Figure 1). Information in this interface flows from left to right – the notes in their

raw form are then grouped into simple categories, which can then be used to form an outline. The design of the interface borrows heavily from the suggestions of [20], where users can delay structuring very late into their process – no structure information is collected when saving information, and the structures created are easily adjusted and reformulated.

### Smart Panels

Once a user has collected a sufficient amount of information and they want to start organizing, they can open up Distil's organizational interface. This begins as a blank canvas, with their notes appearing on the left (See Figure 4). Users first start by sorting information into panels which correspond to clusters of items in their corpus of notes they are interested in, such as a place they might want to visit on vacation, or a symptom of a disease they are researching. These panels can be generated in two different ways: by either entering the name manually, or selecting a word in their note text and creating it from there. When a panel is created, it will automatically find any notes referencing the terms in its name and put them into the panel. This is accomplished by performing a search on an inverted index of the note text, similar to how a "smart folder" found in interfaces such as iTunes and the OS X Finder work. The sentences containing those terms are highlighted in the note on the left, as well as in the note in the panel, and the matching term is bolded.

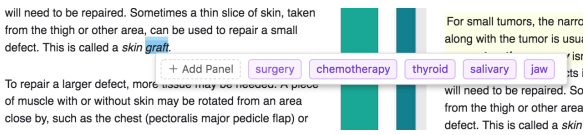


**Figure 5. Toolbar for adding search terms**

While the name of the panel might match a large portion of the desired notes, the name might be abstract, and other terms might also match into that category. For example, a restaurant panel might also want to contain mentions of food, steak, tapas, etc. Users can add additional search terms to their panels by either manually adding the term, or by selecting a relevant word from their set of notes and adding that as a term (See Figure 5). In order to simplify this process, we suggest the top 5 existing panels that a term would most likely match by computing similarity of the word selected against each panel's name using GLOVE and then ranking the results.

As the user continues in this process and starts to generate a number of panels, they might realize that these panels could be grouped together into a hierarchy. For example, if researching a camera, you might have a set of panels for the different camera models, and another for the different features. For a vacation planning task, there might be a set of panels for destinations, and another for different activities. Users can group these panels into a category, and assign each category a color. The highlighted terms and sentences that correspond to panels in that category are then highlighted in that color, giving users the ability to quickly glance at a note and understand the type of content it is talking about. Users can also collapse the notes on the left, and see a summary of the note through the panels and categories that match the note.

### Outliner

Finally, once a user has a sufficient set of categories, they can use the outliner to generate an overview of the information space. The outliner allows users to specify a hierarchy of their categories, and then see their notes organized based on that hierarchy. For example, when shopping, they could compare the models of the items they are shopping for, versus the features they have. The outliner finds overlapping mentions from the previous defined categories, and will show the portion of the note that contains that mention. Based on our empirical study we developed two views for this information: a dense, table-like structure preferred for decision making tasks and a sparse, nested document structure used for more free-form tasks. In the table view, the top two levels of the hierarchy defined by the user are converted into the rows and columns of the table. The notes that overlap those two dimensions are collapsed into a cell – allowing the user to get a quick overview of "coverage" for their collection of notes. A user can hover over a cell to see the specific text from their notes that match the row and column. For example, a user researching cancer treatments might have one category for treatments and another for side effects. In their table, they can then see what treatments are associated with which side effects, and where they might need to do additional research. In the document view, headings are generated based on the category hierarchy, and the notes that match the above headings are shown in the body text of the document.

The unique piece of this interface is how it responds dynamically to changes in the user's growing collection of notes and mental model. If a user adds a note to Distil, the panels and outline will automatically adjust to incorporate the information from that note: any parts of the note that match an existing panel will be highlighted, extracted, and then included in the panel and outline interfaces. The reverse will also occur if a note is deleted. When a user adjusts the panels, for example if they discover a new side effect that they hadn't encountered before, the outline will also adjust to incorporate that new information. Additionally, a user can swiftly move panels from one category to another, allowing them to reorganize the information they've found into a new structure, and explore different table and document structures in a similar way as they can explore pivot tables in a spreadsheet. With this dynamic updating, Distil reduces the amount of manual labor an individual has to perform when modifying synthesized data, providing a powerful alternative to traditional tools.

## IMPLEMENTATION

Distil is implemented as an extension for Google's Chrome browser, enabling it to run automatically on any web page without additional interaction from the user. When a selection event is recognized by the extension, the user is presented with a toolbar indicating they can save their selection as a note. These notes are persisted to the organizer interface, which is accessed through the extension's icon in the browser. The application is written in Javascript using Facebook's React library for interface rendering, and Google's Firebase database service for data persistence.

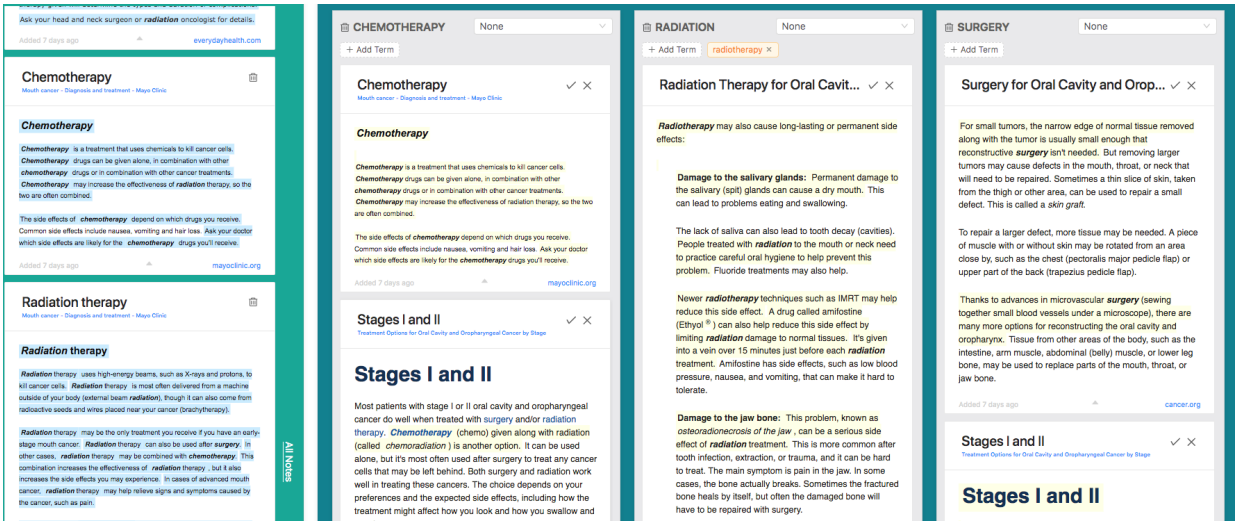


**Figure 6. Dan's collection of treatment panels**

## DISTIL IN ACTION

Below we discuss two scenarios demonstrating the value of Distil for different types of complex searches, and how its features support the fluid and dynamic nature of the sensemaking process.

### Scenario 1: Understanding Treatment Options

In this first scenario, we demonstrate how Distil allows a user to iteratively build up a understanding of a complex topic, and then utilize that for further research. Our user, Dan, was recently diagnosed with squamous cell carcinoma, a type of oral cancer. There are a number of treatment options his doctor is considering, and he wants to understand what those are, and what the side-effects of the treatments might be. He decides to use Distil to help him with his research, and begins by collecting information from a number of cancer support websites, such as cancer.org, mayoclinic.org, and cancercenter.com.

After collecting a number of clips he begins to make three different panels for treatments: surgery, radiation, and chemotherapy, based on his previous knowledge and what he's gained from reading (See Figure 6). Distil automatically highlights the parts from each note that mention one of the three types of treatments, and pulls in the corresponding notes into the appropriate panels. Noticing in one of his notes that "radiotherapy" wasn't matched for radiation, he adds that as a term to his radiation panel. He then begins to browse his collection of notes for the different side effects.

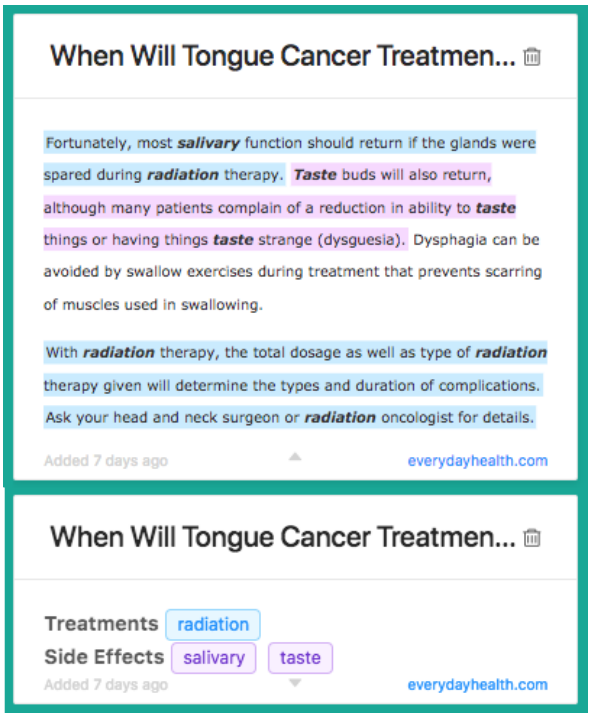


**Figure 7. A collapsed vs uncollapsed note**

As he encounters each side effect, he adds a panel for it using the term selection toolbar. For each note, once he feels like he's pulled out all the useful information from it, he uses the collapse feature of Distil to reduce the content of the note to only the panels and categories it matches (See Figure 7). This provides him with a way to understand which of the notes he's fully processed, and which ones he still needs to read or perform additional work on. Working his way through his list of notes, he adds a number of panels including nausea, soreness and thyroid. For each of these panels, any note that mentions one of these side effects, regardless of the treatment options it's associated with, is included in the panel. Finally, once hes worked his way through all of his notes, he uses the outliner tool to compare the different treatment options with the side effects. Using the table view, he's able to gain a quick understanding of which treatment options have the most side effects, as well as where he might be missing information (See Figure 8). Noticing that chemotherapy doesn't have a lot of information, he decides to do some additional research on that topic. After searching for "chemotherapy oral cancer", he

learns that it actually isn't a common treatment path, rather surgery and radiation therapy are often the treatments given to newly diagnosed patients.

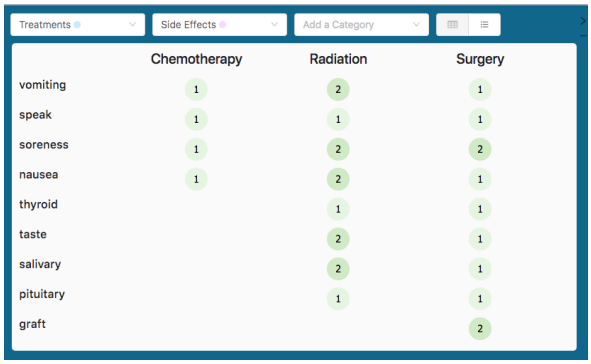


**Figure 8. Dan's outliner table comparing treatment options with side-effects**

### Scenario 2: Trip Planning

In this second scenario, we show how Distil dynamically reacts to new information captured by a user, and supports efficient extension and refactoring of an existing structure. We explore this in the context of a travel task, where our user, Mary, is planning a week long vacation to Barcelona, Spain and the surrounding areas. Using Distil, Mary has already collected a number of notes from various travel websites, and has started to develop an organization for her notes. She has two different categories of information: places, for the different surrounding towns, and activities that she might be interested in doing. At this point, she's created a document in the outliner where she's nested the different activities under each possible place she might visit.

Reading through her list of notes, she comes across a note about Catalunya Vineyards, and realizes that she doesn't have an activity about wine despite its popularity in the region. Using the toolbar for creating panels, she creates a new one about wine and includes both "wine" and "vineyards" as terms in that panel. The wine panel immediately pulls in any other mentions of wine from her set of notes, and the outliner updates to include "wine" as an activity nested under Catalunya (See Figure 9). Looking at the wine panel, she realizes that most of her other places don't appear to mention wine as an activity. Wondering if there are some other places that might include some type of wine activity, she search for webpages about "winery around barcelona". From this search she is able to find that there are a number of excellent wineries, and she clips a few notes about them.

Back in the organizer interface, these newly added clips are automatically associated with the "wine" panels and the "barcelona" panels, since they match both terms. Her outline has updated as well to include the excepts from these notes (See Figure 10). Looking at one promising winery, she comes across the place Maresme, somewhere she hasn't seen before. She adds another panel to her "places" category, and again her outline and panels are updated to incorporate that new information. Because the note about Maresme also mentioned

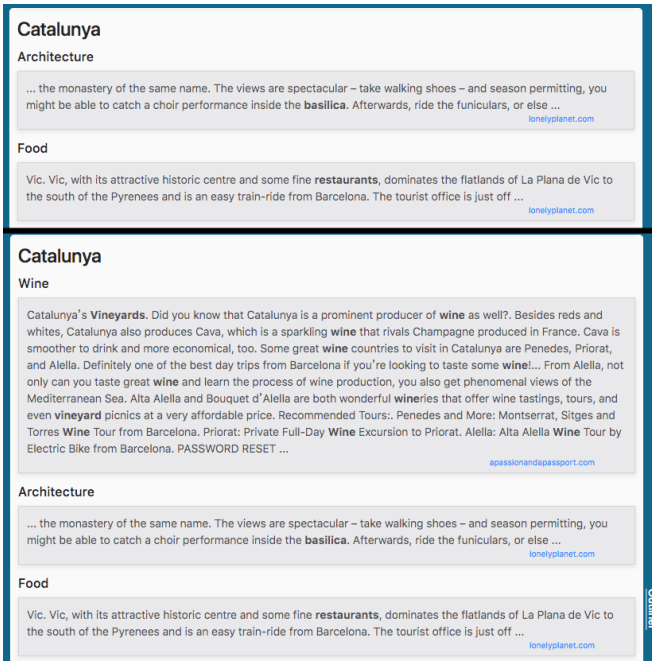


**Figure 9. Mary's change in her document outline after she added the "wine" panel**

beaches, her outline includes the two activities of wine and beach for the location. This "pivoting" between sources and interests types during foraging is a common pattern Distil aims to address.

## LIMITATIONS AND FUTURE WORK

While Distil is designed as a general purpose sensemaking tool, there are some situations where it provides limited support. Due to its design to work with unstructured text collected from documents, occasionally the smart panels incorrectly categorize a note; for example, if a note or sentence talks about more than one topic in a category, this can lead to information incorrectly matching multiple panels. Additionally, there could be ambiguous terms across notes, for example one note could be talking about Jaguar – a model of car, while another could be referencing the animal. Based on some initial feedback we had from users testing the system, we have a couple of proposed solutions including giving users the ability to manually drag and drop items to and from the smart panels, breaking up larger notes into smaller, more focused ones, and using more advanced text processing and searching (e.g., extending the word vector approaches we use for panels to terms in the panel) to provide better filtering functions. Also, in certain scenarios users might not want a table or document outline for the notes they've collected. For example, in the trip planning scenario, a user might want a map, or a user could want some other graphical representation of their data. Combining the features of Distil with a data visualization tool could provide significant benefit to users working with unstructured text.

Ideally, a long-term deployment study of the Distil system would allow us to collect information about tasks that are completed over several weeks, rather than the shorter ones possible

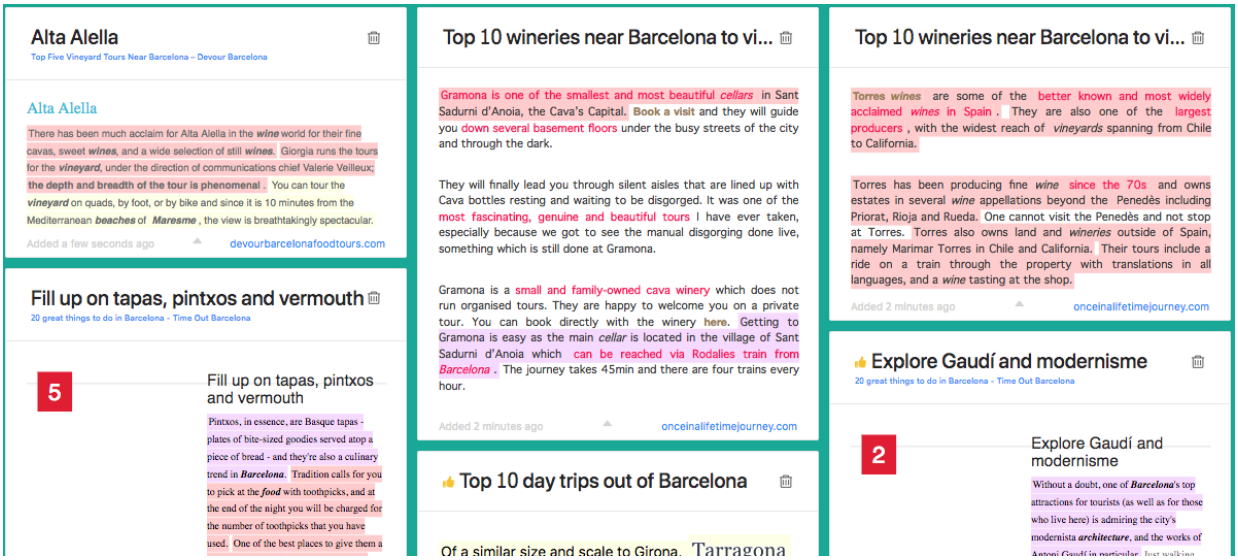


**Figure 10. New wine clips collected, automatically matched to the existing panels**

in a lab study. An analysis of the behavioral data collected from Distil could provide deeper insights into the annotation and synthesis of online information, and what commonalities exists over a large user population. Additionally, given the information structure of Distil compared to traditional forms of synthesis (i.e. a text document), a richer dataset could be generated that would further enable the use of AI and ML techniques for supporting sensemaking.

While Distil does use some basic natural language processing tools to support quick organization, there are a number of opportunities to further expand on these to both decrease the user's mental effort, and ensure summarized information is comprehensive and representative of the data collected. One approach would be automatic panel generation - using an unsupervised clustering algorithm and word embeddings, users could have panels suggested to them based on the data that has been collected. Another could be more structured entity extraction and presentation where Distil could pull out specific entities, such as phone number, addresses, or headings, and utilize those as components for creating even more structured organizations [12, 3]. These would be especially useful in the later stages of the sensemaking process, where a user will more likely want specifics about the topics and items they've focused in on.

Another opportunity could be extending Distil to be a collaborative interface for sensemaking. There have been a number of systems designed to tackle collaboration, such as SearchTogether [27] and Coagmento [30]. However, many of these systems have focused on the foraging portion of sensemaking, rather than the synthesis and decision making based on the information collected / learned. Because of Distil's focus on generating a structure and an artifact, it could offer a unique take on collaborative sensemaking, given right affordances. Additionally, because Distil is built on top of Google's Firebase service, it already has the necessary infrastructure to support real time collaboration.

## CONCLUSION

In this paper, we introduce Distil, a system designed to support users' dynamic needs and changing mental models as they proceed through the sensemaking process. Informed by an empirical study on online annotation, we highlight two areas for focus: flexible selection tools and an interface that support filtering and refactoring of collected information. As demonstrated through two scenarios, Distil gives users the ability to collect a large amount of information and, as they learn about the topic, mold it into an ideal artifact for later reference and sharing.

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