

The Impact of Users' Cognitive Style on Their Navigational Behaviors in Web Searching

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Abstract *User-Web interactions have emerged as an important area of research in the field of information science. In this study, we investigate the effects of users' cognitive styles on their Web navigational styles and information processing strategies. We report results from the analyses of 594 minutes recorded Web search sessions of 18 participants engaged in 54 scenario-based search tasks. We use questionnaires, cognitive style test, Web session logs and think-aloud as the data collection instruments. We classify users' cognitive styles as verbalisers and imagers based on Riding's (1991) Cognitive Style Analysis test. Two classifications of navigational styles and three categories of information processing strategies are identified. Our study findings show that there exist relationships between users' cognitive style, and their navigational styles and information processing strategies. Verbal users seem to display sporadic navigational styles, and adopt a scanning strategy to understand the content of the search result page, while imagery users follow a structured navigational style and reading approach. We develop a matrix and a model that depicts the relationships between users' cognitive styles, and their navigational style and information processing strategies. We discuss how the findings from this study could help search engine designers to provide an adaptive navigation support to users.*

Keywords Web Searching, Navigational Style, Information Processing Strategy, User Cognitive Style.

1 Introduction

User-Web interactions have emerged as an important area of research in the field of information science. As new technology emerges, different information systems have been developed for improving Web searching and information retrieval. However, Web users often report difficulties in Web searching. Search effectiveness may

be affected by many factors specific to topics and task, of which a user's cognitive style - an individual's preferred and habitual approach to organizing, perceiving, remembering, and representing information [26], have been found to be influential in affecting searching [9, 17]. This has motivated further investigations and more researchers are now exploring the Web search behavior from a user's perspective. Earlier, the information systems and the intermediaries, who manage them were concerned about information use from the system's perspective; they have focused on designing questions, searching strategies or queries that best match the system's representation of texts rather than responding to users' problems when retrieving the information [18].

In order to investigate users' issues and problems in retrieving information from the Web, it is imperative to understand users' Web navigations, information searching and retrieving processes, and cognitive factors, such as users' cognitive styles that influence these processes. This study first investigates users' cognitive styles, Web search navigations and information processing strategies, and then reports on the relationships between these components. We define Web searching as "all-users activities during the logging on/logging off period" on Web or information system [28], and cognitive style as an individual's preferred and habitual approach to organize and represent information [26]. There is no such thing as bad or good cognitive style, but an individual with a certain cognitive style tends to find certain tasks easier than others.

2 Related Studies

The study of how users navigate the Web, and the impact of their user characteristics, such as cognitive style, on the Web search behavior is a significant contemporary topic. Different authors refer to cognitive style with different terms, such as field-dependent/independent [30], holists-serialist [21], and wholist-analytic/verbal-imagery [25]. Field-dependence-independence describes the degree to which an individual's perception or comprehension of information is affected by the surrounding fields [30]. Riding and Cheema [25] grouped the cognitive

dimensions into two principal cognitive dimensions: the Wholist-Analytic and the Verbal-Imagery style dimensions. The *Wholist-Analytic* (WA) dimension of cognitive style describes the habitual way in which people think about, view and structure information in wholes or parts. This affects the way they learn and organize information. The *Verbal-Imagery* (VI) dimension of cognitive style describes an individual's tendency to process information either in verbal or verbal mode of representation and thinking. It refers to ways in which an individual would represent knowledge in either words (verbal) or mental pictures (images).

A number of tools are available to assess cognitive styles [23, 24, 29]. Riding's [24] *Cognitive Style Analysis* (CSA) test is a computer presented test to measure WA and VI dimensions of cognitive styles [25] by means of a ratio. The CSA comprises of three sub-tests. The first part assesses the VI dimension by presenting series of statements on one at a time to be judged true or false. Half of the statements contain information about conceptual categories, while the other half describes the appearance of items. The computer then records the response time to each of the statements and calculates the VI ratio. A low ratio (below 0.98) corresponds to a verbaliser, a high ratio (1.09 and above) to an imager, while the intermediate position being described as 'Bimodal'[24]. However, many researchers [6, 7] tend to use a dichotomous classification by grouping into two groups: Verbaliser and Imager. The second and third sub-tests assess the WA dimension of cognitive styles by presenting series of geometrical figures and the individual is required to judge the figures. In this paper we use Riding's CSA test to classify participants into verbal or imagery cognitive styles.

Most search engines today provide multiple navigation tools to allow users to structure their navigation strategies with multiple approaches. For example, Google provide different search features and tools, such as maps, image, and video; users can use these tools to search information. However, studies have reported users getting lost or disoriented while navigating on the Web. Chen and Macredie [4] reported users confronting "disorientation problem", "lost in hyperspace", and "mismatching" while navigating on the Web. They also reported a user's preference, such as his or her cognitive style, having significant effects on his or her navigation. Field-Dependent students preferred guided navigation (linear), while Field-Independent learners preferred freedom of navigation.

Kim [14] investigated how users' emotion control and search tasks interact and influence the Web search behavior and performance among experienced Web users. The study findings indicated that users tended to use more navigation tools in a general search task that required them to find a few pieces of information on a

broad topic than in a specific task that required locating one specific piece of information that was known to exist on the Web.

From a user study exploring the relationships between Web users' searching behavior and their cognitive style, Kinley, Tjondronegoro and Partridge [17] presented a conceptual model of Web searching and cognitive styles. The model presented based on the preliminary findings, revealed relationships between different stages of Web searching and cognitive factors. Among the cognitive factors, the cognitive style of a user was found to have a greater impact. As the authors reported, the study results and the model presented are in its "infancy" as the findings were based on a small scale population sample.

2.1 Limitations of the Current Studies

The studies discussed in the previous section provide valuable insights into cognitive styles and Web searching research, in particular Web navigations. They are the bases on which this study is founded upon. However, their findings on Web navigations were based on a low level variables, such as either the number of clicks on navigational buttons [14, 15], or the counts of visits to web pages [10], which do not implicitly represent a user's navigation patterns. There exist limited empirical studies that have looked into the relationships between users' cognitive styles, and their navigational and information processing strategies. In fact, there is no empirical study conducted on investigating the effects of users' cognitive styles on their information processing strategies. To the best of our knowledge, this study is the first work exploring this area of investigation.

In this study we first look into how users search the Web and then investigate the effects of their cognitive styles on their Web navigations and information processing strategies. Investigation into users' navigational style and information processing strategies, and their cognitive styles, will provide rich data about user-Web interactions.

3 Research Aims and Questions

Users' navigational style and information processing strategies are important elements of Web search behavior because they are the path towards successful Web searching. They are like tools that can add extra leverage in searching and retrieving the required information.

Studies show that a user possesses unique characteristics [25, 26, 30]. Among these characteristics, cognitive style is one of the most important user factors that affects Web searching and information search performance [7, 14, 19].

This study aims to investigate the effects of users' cognitive styles on their Web navigations and information processing strategies. The findings in this study will help search engine designers to provide an adaptive navigation support to users. The fundamental research question underpinning this research is:

What are the relationships between users' cognitive styles, and their Web search navigations and information processing strategies?

4 Methodology

4.1 Study Participants

A total of 18 volunteers (8 male and 10 female), comprising of 8 postgraduate research students, 2 academics and 8 professional staff from the Queensland University of Technology participated in the study. The participants' age was between 20 years and 56 years old. They regularly engage and search the Web for information in the course of their academic, personal or administrative activities.

4.2 Search Tasks

We developed three search tasks, outlined in Table 1, based on Borlund and Ingwersen's [2] concept of "simulated work task situation" or scenarios. The search tasks were designed to ensure that these tasks are as close as possible to the real world situations. The simulated work task situation provides each searcher with the context, which ensures "a degree of freedom" to react in relation to his or her interpretation of the given situation [2]. This approach has been used by several researchers in information seeking studies [examples include: 1, 13].

The search tasks were also designed with different levels of difficulty and complexity, and a diverse area of topics. Task 1 presented the least complexity, which required using basic searching skills. Task 2 was more complex and required a higher level of search experience than for task 1. Task 3 was more complex compared to task 2 and required participants to use a more advanced level of search terms and presented relatively more abstract scenarios compared to task 1 and task 2. Although many studies [examples include: 6, 10, 13] show task type as an influential factor in Web searching, it is not a controlled variable in this study. We aim to investigate the effects of task complexity and difficulty on Web search behavior in future.

4.3 Data Collection

Riding's [24] CSA test was used to classify participants into verbal or imagery cognitive styles. The CSA test indicates the position of an individual on the

Task 1: You have recently moved to Austin, Texas, USA and would like to know the relevant laws passed by the Texas state government regarding child safety while travelling in vehicles. Identify three such rules.

Task 2: You, with your two friends, are planning a trek for one week in Solukhumbu in Nepal. The trekking will occur next month. You are told that tourists trekking in the place may get high-altitude illness. You decide that you should know more about the place, and symptoms, seriousness and preventions of high-altitude sickness.

Task 3: There has been talk of the Bermuda Triangle mystery for the last three decades or so. You are curious about the mystery and want to know more about it. So, you want to search any incidents, people's views and any other relevant information (literature, images and videos) about it.

Table 1: Search Tasks

VI fundamental style dimensions by means of a ratio, which describes an individual's tendency to process information either in words (verbal) or mental pictures and thinking (images). We use a dichotomous classification; a low ratio (below 1.03) on the VI scale corresponds to a verbaliser, while a high ratio (1.03 and above) to an imager. Although there has been a few studies questioning its reliability and validity [20, 22], the CSA test was chosen in this research because of the following points, (1) the CSA test is relatively new compared to Embedded Figure Test [29] or Verbaliser-Visualiser Questionnaire [23]; (2) the CSA test has been shown to have good reliability and validity, and a good number of studies have used the test [examples includes: 6, 7, 8]; and (3) CSA test is a computer administered test which often makes it more attractive to participants and also makes data collection easier for researchers.

Participants' cognitive thinking was collected through a think-aloud method. Think-aloud method is used for investigating a user's cognitive process, which requires the participant to verbalize as he or she performs specified search tasks. We investigate users' interactions and their navigational styles with the Web search systems by investigating their Web search sessions. We use a monitoring program to record Web search sessions and think-aloud protocols.

4.4 Procedure

Participants' demographic information were collected using a pre-experiment questionnaire. Following the cognitive style test, the participants were then invited to participate in the Web searching experiment; they were assigned three sets of search tasks, outlined in Table 1. Although the participants were never stopped while performing their search tasks, it was recommended that

they spend between 10 and 15 minutes on each search task.

Participants were asked to talk aloud while they were performing the search tasks. They received the following instructions.

You are required to verbalize orally your thoughts, motivations, actions, and reasons while conducting a Web search. This will enable the researcher to understand your cognitive thinking.

Their Web interactions, including think-aloud and Web search logs, were captured using a monitoring program.

4.5 Data Analysis

The captured user-Web interactions for each participant were played and replayed several times to create participant observation memos with search logs, session length, and think-aloud stamps. The total session length was 594 minutes. Important search behavior then emerged from the search logs were coded for qualitative analysis using elements of content analysis [11, 27] and protocol analysis [5] within a constructivist grounded theory approach [3].

5 Results

The participants' demographic information indicated that they had a minimum of 3 years Web search experience and were skilled with at least basic searching skills. Although participants' demographic information contributed significantly to this study, participants were not differentiated by their demographic data as it is not a controlled variable in this study. In this study we focus on participants' cognitive styles and its impact on how they navigate the Web and process information.

5.1 Cognitive Style

Based on the VI ratio, we classify participants into two groups: *verbalisers* and *imagers*. Participants scoring below 1.03 on the VI scale were classified as *verbalisers* and those scoring 1.03 or above as *imagers*. Out of 18, 10 participants were classified as having a verbal cognitive style while, 8 participants were imagery users.

5.2 Web Search Patterns

Based on the findings that emerged from the qualitative analysis, two types of Web search patterns were identified for the study: *Web Navigational Styles* (NS), based on how users navigate during Web searching, and *Information Processing Strategies* (IPS), based on how they view and process search results or retrieved result pages.

Web Navigational Styles

To investigate the participants' navigational style, we classify navigational styles into two categories: sporadic and structured navigations that bear some similarities to those suggested in previous studies [10, 12].

Sporadic navigational style refers to those behaviors in which users performed an unstructured navigation during Web searching. They visited numerous links and pages, switching between browser tabs and windows, and were thereby characterized by a shorter duration between any two consecutive nodes. They opened many pages simultaneously and quickly scanned each of these pages. They tended to navigate back and forward more often. Users formulated queries, read first few lines, navigated back to the search result page, and then reformulated the query; they seemed to repeat the same procedure again.

Users with sporadic navigational styles also took some time to decide on search terms to be used, and links and pages to be visited or clicked. They tended to view only the first few search result pages and seldom clicked on the 'Next' button of the search results page. They also tended to visit the homepage more frequently and used the 'back' button more often, which is an indication that they felt uncertain about their searching. Users of this kind were found to be unorganized. Palmquist and Kim [19] relate frequent usage of embedded links to a 'passive' way of navigation and use of Home button as an indication of 'getting lost' that is, stopping whatever they have been doing and starting over again. As per Palmquist and Kim's interpretation, this indicated that sporadic users get lost more frequently than the rest.

Structured navigation style is associated with relatively a lesser use of links of the site visited, longer periods between any two nodes and low homepage use. Users preferred to use multi windows to navigate and manage information; they used separate windows to manage links/pages of similar topics. Participant 7 pointed out:

"I like to have a few windows opened at the same time and look for different subjects. So in one window will be looking for hotels, food, etc and other one will look up activities."

Users seemed to feel confident about their searching performance. They focused on a fewer pages and read carefully in detail. They spent relatively a longer duration on each page they visited. They performed one thing at a time, spent adequate time on a single task and navigated cautiously from one page/search to another.

Information Processing Strategies

Information processing strategies refer to approaches adopted by users to view, select and process information during Web searching. Based on the study findings and our previous study results [16], three information

processing strategies are identified: Scanning, Reading, and Mixed strategies.

Scanning refers to examining hastily, where a user makes a sweeping search for a piece of information. Users formulated and reformulated their queries more often, clicked several links, opened numerous result pages and scanned them quickly. The time span between any two consecutive nodes was relatively shorter. Users were also found switching between subject topics, and between browser tabs and windows. For instance, the first thing Participant 1 did with the results from his first query was to quickly scan the search result descriptions, and then he formulated his query without opening or reading the result pages. Users were found scanning result pages for general information without a clearly defined goal.

Reading refers to a comprehensive viewing, examining and understanding the information on a page. Users visited relatively a lesser number of pages in a given duration and spent relatively a longer time on a page. Users were found reading pages in details and spent enough time to understand the content of a page. They often opened links and pages in the same window, which indicated that they preferred to read a single page and accomplish one task at a given time. For an example, Participant 14 was cautious about what she was searching for. She opened one page at a time and based on the information retrieved with the preceding query, she reformulated her query carefully. For instance, having found the general information, i.e. a map on Solukhumbu, she then searched for other information on accommodation.

A *mixed* strategy of information processing involves both scanning and reading. During the experiment, it was observed that some participants adopted both scanning and reading in parallel to process information. At a certain point of their searching and examination, users started and stopped scanning, and then switched to reading. Few users were found scanning and reading result pages either at the same time in multiple windows or at different stages of their searching. Initially, Participant 8 formulated and reformulated his queries several times. Most of the time the user followed repetitive search behavior- formulating a query, scanning the search result descriptions, and reformulating the query without opening any retrieved result pages. However, at a certain point he was found reading a result page in detail for more than 3 minutes. There were a handful of users who processed information by both scanning and reading.

5.3 Impact of Cognitive Styles

Previous section has demonstrated that Web users use different navigational styles and processing strategies to search and access information. Next we investigate the

relationships between verbal and imagery users, and their Web search behavior in relation to the two Web patterns identified earlier. We report our findings on how users with different cognitive styles, i.e. verbalisers and imagers, navigate the Web and process information.

Web Navigational Styles

Verbalisers: We observed that in general, verbal users seemed to exhibit sporadic navigational styles. They tended to open many links and pages, and used 'back' and 'homepage' buttons more frequently. They were found to be impatient with their search as they frequently scanned the result pages, which seemed to make them confused. They also reported more dissatisfaction with their search results (Participant 2 and Participant 9) and some users displayed frustration with the search (Participant 3 and Participant 9). While searching a map on Solukhumbu in Nepal, Participant 9 pointed out, "I should be looking for Nepal map. I am not very happy with that [retrieved page]".

Verbal users tended to use multiple navigational features, such as clicks, back button, home button, and history. In general they seemed to employ trial and error strategies to find the needed information.

Imagers: In general, imagery users appeared to follow structured navigational strategies while searching information on the Web. They concentrated on a single page and visited relatively a lesser links but they ensured to read them in details. Users seemed to be more organized with their Web searching and followed step-by-step navigations. For instance, Participant 14, who is an imager, followed systematic Web navigations.

"This person trekked to Sagarmatha National Park. I don't know what it [the park] is and I have no idea about this place. I need to go back and have a better understanding of Solukhumbu, geographical part of it and understand map of it." (Participant 14)

Having found the map of Nepal with Solukumbu district and having a better understanding of Solukhumbu, the user then searched for other information.

"Let me have a look on the Map of Nepal. This one [map] has the map of Solukhumbu. Sagarmatha National Park [map] in Solukhumbu has blue area [shaded with blue color] showing me where Solukhumbu is. That is very good. So I have now a better understanding of Solukhumbu. Solukhumbu district is a part of Sagarmatha zone. I have now a better understanding of what that area is. Next, I need to search where to stay". (Participant 14)

Information Processing Strategies

Verbalisers: Although there were a few verbalisers who adopted reading approaches, in general they seemed to prefer scanning to process information. They scanned through the search result descriptions and result pages to see if they contain the required information or not. For instance, Participant 1 formulated and reformulated his

queries more often, opened several result pages and scanned them quickly. This behavior was repeated several times throughout the entire searching.

Imagers: On the contrary, imagery users tended to prefer reading; they were found reading result pages in detail and spent an adequate amount of time to understand the content of the pages. They visited relatively a lesser number of pages in a given duration and spent relatively a longer time on a page. Participant 4 with imagery cognitive style opened the first result page in the same window and spent more than 3 minutes reading the page in detail. Throughout the search tasks, the participant was found reading carefully and spent sufficient time (approximately 3 minutes) on each result page she opened. In fact, she spent more than 10 minutes on the first two queries. It was also observed that most of the time she opened the result page in the same window, which indicated that she preferred to read one page at a time.

6 Discussion and Implications

We reported results from the analyses of 594 minutes recorded Web search sessions of 18 participants engaged in 54 scenario-based search tasks. The captured Web search interactions and think-aloud exercises provided excellent data into users' Web search behavior; users adopted different navigational styles and information processing strategies. Our study found significant associations between users' cognitive styles, and their navigational style and information processing strategies. Users with sporadic navigational styles tended to navigate the Web in a non-linear mode. They tended to visit their homepage more frequently and used the 'back' button more often. They were unable to reconstruct their navigation paths and therefore were prone to get stuck. On the contrary, structured navigators followed a linear navigation. They followed defined steps and retrieved information more effectively than others. They focused on a fewer pages, spent adequate time and cautiously navigated from one page/search to another.

We also observed that as participants progress with their searching, they tended to try various alternatives on a trial and error basis. Participant 16 initially displayed a structured navigational style, but towards the end of the task 3, his navigational style changed to sporadic style, where he clicked the 'Next' button several times without a proper examination of the search results. In fact, he navigated till page 6 of the Google image search result, which is worth noting because this was the first of such kind observed in our experiment. As he navigated hastily while performing search task 3, the participant only scanned the result pages, whereas he spent a sufficient time on reading the pages while performing task 1 and task 2.

To give a clear overview of our study findings, we developed a matrix and a model that depicts the relationships between users' cognitive style, and their navigational style and information processing strategies. Figure 1 summarizes the attributes of the two classifications of navigational styles and three categories of information processing strategies that emerged during the data analyses. The dashed line between the imagery user and sporadic navigations indicates relatively a fewer number of imagery users displaying sporadic navigations, which needs to be reconfirmed in future studies. Table 2 illustrates a

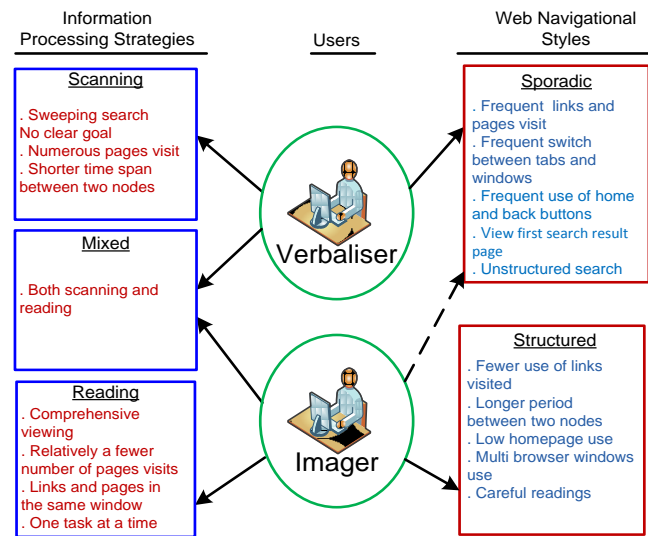


Figure 1: Relationships between users' cognitive style and their information processing strategies and navigational styles

UserID	CS		NS		IPS		
	V	I	SP	ST	S	R	M
1	°			°	°		
2	°		°		°		
3	°		°		°		
5	°			°		°	
7	°			°		°	
8	°		°				°
9	°		°		°		
10	°		°				°
11	°		°		°		
13	°		°				°
4	°			°		°	
6	°			°			°
12	°		°		°		
14	°			°		°	
15	°			°		°	
16	°		°				°
17	°			°		°	
18	°			°		°	

Note: Cognitive Style (CS); Navigational Styles (NS); Information Processing Strategies (IPS); Verbaliser (V); Imager (I); Sporadic (SP); Structured (ST); Scanning (S); Reading (R); Mixed (M).

Table 2: Cognitive Style-Navigational Style – Information Processing Matrix

matrix of cognitive style, navigational style and information processing strategies.

This study has demonstrated that a user's cognitive style plays an important role in Web searching and navigations. Cognitive style affects users' Web search navigations and information processing strategies. The next question we should consider is:

How can we provide adaptive navigation and effective information retrieval?

Search engine designers need to be aware that users differ their cognitive styles, and that a user with a certain cognitive style tends to navigate in a structured manner, while others follow sporadic navigations. Some users find certain search tasks easier, while others experience difficulties. Web search engines can utilize our findings to provide a better search assistance according to users' cognitive styles and their navigational styles. For instance, systems can provide effective browsing tools with an interactive user interface, such as webpage embedded with interactive navigation buttons and links, to users with sporadic navigational styles. Web pages can have advance bookmark features, which enable users to keep a track of their searching and navigations. Similarly, search engine may store in-depth subject contents with diverse topics, so that users with structured navigational styles can explore extra information related to their search task and information need.

7 Limitations

Although this study has successfully illustrated valuable findings into users' cognitive styles, and their Web navigations and information processing strategies, it has some limitations. The study data were collected from a total of 18 end-users participants. Small sampling of participants prevents advance statistical analysis of the data, thus, prevents from illustrating statistical correlation significance. The grounded qualitative analyses would have been boasted had it been supported with statistical methods, such as correlation analysis, factor analysis, and analysis of variance (ANOVA).

As illustrated in Figure 1 by a dashed line between imagery users and sporadic navigations, while most of the imagery users follow structured navigational styles, few of them tended to follow sporadic navigations. There may be other factors, such as query formulation strategies and task complexity, which might have influenced the user's Web navigational style and information processing strategies. Although many studies [6, 10, 13] show task type as an influential factor in Web searching, in this study we have not considered the effects of the task complexity and difficulty on Web navigations and information processing strategies. Further intensive investigations, involving both

qualitative analysis and quantitative statistical analyses with a larger sample population, are needed to reconfirm the findings presented.

8 Conclusion and Future work

The findings reported in this paper provide valuable insights into the Web search behavior of users with different cognitive styles. Users' Web search behavior, in particular, their navigational styles and information processing strategies, appear to be affected by their cognitive styles. Verbal users seem to navigate in a non-linear mode, while, imagery users take a more linear approach. Table 2 and Figure 1 depict the Web search patterns and the relationships between users' cognitive styles, and their Web navigations and information processing strategies.

We aim to conduct similar research in the future with a larger sample population not only to reconfirm the results presented in this study but, also to investigate how users with different cognitive styles formulate their queries, what kinds of results they click, and how they deal with task complexity and its effect on their search. This will contribute to a better understanding of Web search behavior from a user's perspective, which will help search engine designers to provide users a better Web search support.

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