CritiSearch: A Design Proposition to Enhance Immediate Personal Control Over Inquiry

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ABSTRACT

Online search systems are rooted in a particular question-and-answer design. But is that the entirety of the best design for inquiry? CritiSearch allows users to directly manage hits returned by a search engine to indicate their own informational needs. Rather than developing a new query to manipulate the search engine, users are put in a position of immediate direct control by up-voting and down-voting hits. They thus may mark the screen, staying closer to their own line of thought. This small change to the experience signifies a larger issue of power and control over the information environment and moves inquiry back towards the foundational HCI principle that how we arrange the world is an extension of our intelligence. A two-week study of 10 graduate students using CritiSearch and/or other search engines of their choice to conduct their own (scholarly) research begins the exploration of usability within this design space.

Author Keywords

Query ideation; creativity; search; arrangements; user power and control.

CSS Concepts

• **Human-centered computing~Human computer interaction (HCI)**; *Haptic devices*; User studies; Please use the 2012 Classifiers and see this link to embed them in the text: https://dl.acm.org/ccs/ccs_flat.cfm

INTRODUCTION

One of the foundational principles in human-computer interaction is that users need to be able to arrange their computing environments to suit their needs, just as we arrange the physical environments around us as an extension of our intelligence [16]. We see this power in the very idea of the Graphical User Interface. Yet when we think about search technologies such as Google and Bing!, we see that, despite their convenience, they fail to explore the parameters of direct control by users. Search outcomes are offered as an entirety, arranged as a whole by the search engine. The basic mechanism for users to change content is to formulate a new query, which requires not only thinking about what is desired but also how to exclude that which is extra. This works well when the search engine's judgments are helpful, but can distract the user and disrupt their own line of thought. It also puts the user in a passive, "one-down" position with respect to the larger computing system. It is as if these search engines are saying, "Stop what you are doing and accommodate *my* method of understanding." Even the recent addition in Google of suggested completions for search terms and "People also ask" questions keeps the search engine in charge of options and arrangements. The search offers more but it is always on *its* terms. Changing content requires the user to wrestle with the system.

Our design response to this is CritiSearch ("C/S"). C/S reframes searching tasks beyond informational needs towards a creative dialog between user and tool. The act, on the part of the user, of making a simple, direct decision about results ("hits") creates a light-weight structure that marks and clears away distraction. C/S shifts the focus of the task from the search engine's arrangement to the user's arrangement.

We report on an initial probe of the usability of this approach over a two-week period of time for 10 graduate students in the tradition of research-through-design [9, 30, 31]. C/S is a design proposition. The goal of this study was to investigate simple usability and establish that the larger claims associated with the system have enough plausibility to deserve further exploration.

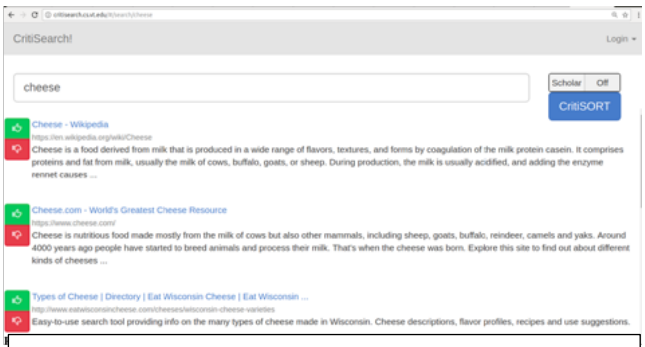

Figure 1: CritiSearch interface. Results can be marked as up- or down-voted and re-arranged to show choices.

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Motivational Examples

Two examples illustrate some of the underlying motivation for the design exploration embodied in C/S. The first emphasizes *paralysis*. In the context of a different project, we observed 8th grade students (13-14-year olds) brought to a standstill by their attempts to do "research" on literature in their English language class. In particular, when researching John Hersey's Hiroshima, a typical 8th grade assignment in the United States, many stared at the screen, unable to decide what action to take. When they did click through on hits, the hits were often not substantive ones, but simply copies or summaries of the book. It seemed to their teacher that their paralysis and poor judgment was caused by difficulty remembering what exactly they were doing in the face of distracting responses.

In general, college-educated adults have many sophisticated strategies for handling search engines. Yet adults are not immune to paralysis or simply giving up. *Discovery* remains challenging. Suppose you have reason to look up "interpersonal psychology" on a search engine. Most people will probably receive hits featuring a definition from Psychology Today, and related hits. The searcher might puzzle over whether this was what they were looking for but there is little or no hint that the term "interpersonal psychology" has a number of definitions, ranging from the simple idea that interpersonal interaction and beliefs are a part of psychology, to sets of complex and contradictory theories with intellectual traditions. Somewhere on the third screen this author finds a reference to Harry Stack Sullivan and, also, the Five Factor Model of personality which a person educated in the area might recognize as historically relevant. On the fourth screen are images of books, the first of which, Horowitz and Strack's (2010) Handbook of Interpersonal Psychology [10], happens to represent a modern scientific take, developing and changing Harry Stack Sullivan's ideas. On the fifth page, there is a link to a Google books page from Horowitz and Strack that situates the field from the point of view of more modern psychology. Reading that page, we find that there are few if any search terms that would differentiate between these overlapping approaches. In fact, almost the only way to arrive at this understanding of the field via a search engine is by already knowing to formulate a search that uses the names of key modern players. If you have succeeded in finding the information you originally sought, the state of mind that brought you to the search is utterly lost. This example does not show inevitable outcomes of such a search---there are many paths and, as mentioned above, college-educated adults have many strategies for searching. But it illustrates a kind of sub-optimal interactional process.

Unpacking these interactions more, we see that, although the search process starts similarly to a human question-and-answer process, sometimes the engine produces results that are irrelevant or confusing. This immediate response is not usually a problem for adults. Human interaction is full of irrelevance, confusion and distraction. The problem is that the search process fails to offer the subsequent negotiation for shared meaning that we find in discourse [2-4, 21-23]. Even when offering a simulacrum of adjustment, search engines control the initiative. The user must diagnose what went wrong and reformulate their query. And, unlike in much conversation, the user's purpose is generally not the local interaction—-it is their own thought process.

Search engines enable the successful use of the internet. They do a tremendous amount of work behind the scenes to gather, sort, and select information. Users would not want to see these complex processes in detail in an everyday way and indeed the internet was not widely usable before meta-engines were available. C/S builds on the useful work already done by search engines, but takes their responses as a starting point for user action. At the extreme, the C/S approach advances an alternative idea of what an ideal computational world should resemble: user empowerment vs. "computer intelligence."

PRIOR WORK

Arranging Worlds

The idea that "the ways that we arrange the world around us is an extension of our intelligence" is a foundational concept in human computer interaction [6, 20]. Sometimes these arrangements are routine, akin to putting our keys in the same place every night. But often they are in response to particular creative needs. The important tie between environmental arrangements and thought is manifest in many visual design techniques such as affinity diagrams [13]. "Hits" can be viewed not only as a way to get someplace else, but also as the material products of searches. As such, they can be a resource in developing and organizing ideas.

The long-term, higher level design implications of the work transcend the issues of search, exploring the design space between computer-controlled and human-run socio-technical arrangements or, as Suchman calls them, "reconfigurations" [24]. This work thus pushes on questions of values and culture in the design of computing systems and what user dispositions are assumed and reinforced by the computer system; this reflects Tatar's call for computer systems to "reflect our better natures" [25]. Here, the matter at stake is user agency, the extent to which the computer helps the user clarify their own thoughts in their own terms rather than demanding that the user divine the search engine's operations or respond to its structures. There is nothing wrong with developing a better understanding of how search engines work, but understanding search engines is a separate and complex process, reflecting as these engines do both process-based necessities and the confluence of the thoughts of others as reflected in their search patterns and detectible behaviors.

There has been work on the role of arrangements and curation in support of creativity. Webb et al. look at curation as the process of searching the Internet and digital repositories, collecting information, organizing that

information in meaningful ways, reflecting on collected information, and interpreting that information to form new understanding [29]. This and related work focus on more public, shared curation: for example, curation for innovation, entrepreneurship, and education as well as for popular consumption (e.g. Pintrest or Spotify) [5, 28]. But people also curate for themselves. We focus on personal, ephemeral curation for "current purposes" [2,3].

Searching

There is quite a lot of research on how people search for information. Much research consists of laboratory studies that divide (1) users into "domain experts and novices" and/or "search experts and novices", (2) searches into categories like "keyword", and (3) goals into categories such as "Perfect Catch, Lobster Trapping, or Drift Netting" [19]. "Information scent" is a particularly important model of how people track down information by approximation [17]. These works elaborate the many different behaviors that can be described as search. They engender respect for the expertise and complexity involved.

"Informational need" is the term of art used to describe what motivates particular searches. It implies and usually indicates a process in which the user has a known and fixed purpose. Considerable literature illuminates the cognitive processes that enable users to engage in search from this perspective.

Yet Wacholder points out that these various foci can be reduced to a rather simple diagram that becomes slightly elaborated in different settings. Wacholder's survey of the literature advances six models [28]. Google is modeled as query formation ("QF") followed by a response. Other models elaborate and investigate this process, attempting at their best to explicate the relationship between the human processes and the (invisible) behind-the-scenes machinations of the search engine. The overarching cognitive task during interaction is somewhat simple. The user has to remember a clearly formulated goal and make tactical moves towards that goal.

From our point of view, the important piece of this is that all approaches begin with some idea of turning an "informational need" into a query. Almost all this work also assumes informational needs are static and that iterations on query formation are in service of that static condition. They do not really consider the relationship between the two.

But there are at least two perspectives that challenge this assumption. First, one of our foci, is that many kinds of search are side-effects of larger thought processes that require intense focus. The search can easily distract from the nascent formulation of ideas.

Additionally, more recently, some literature has explored the idea of search itself as a creative process. Teevan et al.'s work on orienteering comes very close [26], envisioning search as a process that prioritizes *reframing*, *refactoring* and *restructuring*. Teevan et al. build on a seminal example of white-water navigation offered by Lucy Suchman as a description of the situated and contingent nature of human behavior. The white-water analogy argues that people have plans in a general sense, but that particular actions, such as dipping a paddle in the water, are dictated by complex situations in the moment. Teevan et al.'s model is that people can get close to the thing they are looking for often with little difficulty, that is, they have a general plan, but the local moves to narrow in on results require and promote the reframing, refactoring and structuring.

The opportunity we see is to support both of these more complex conceptions, by not distracting and by promoting reframing, refactoring and structuring *at a level closer to the micro-structure of cognition*. Particular arrangements and choices are motivated by both the high-level contexts and purposes of the search and the immediate opportunities for action represented by the hits.

There has been surprisingly little research at this micro-level. One partial exception is Thudt et al.'s [27] examination of how people search for physical books in book stores and libraries. Drawing upon interviews, they report that people look for books with contingent micro-strategies - querying (e.g. ask a librarian or bookstore employee or even use an on-line search tool), linking (following citation links or seeing what books are on adjacent shelves), scanning or skimming, and various kinds of assessments. Building on the work of Bates, they further describe this as a creative learning process with ideation playing a large role in both the searching process and the framing and re-framing of results [1]. These behaviors are by-and-large still quite high-level compared to our focus but they document the utility of known arrangements of goods and ideas.

C/S: IMPLEMENTATION AND DESIGN

C/S is an online search interface that allows users to make active judgments about hits rather than having to reformulate their query to accommodate the search engine's more general algorithms. The primary features that allow this are the upvoting and downvoting buttons which let users mark hits and the CritiSort button which moves upvoted hits to the top and downvoted hits to the bottom. Figure 1 (on the first page) illustrates the deliberate simplicity of the interface which augments rather than replaces other search activities. Any selection may be changed at any time by multiple clicks.

C/S is designed to promote user control by addressing five major constraints on interface behavior and challenges to human capacity:

1. Iterative query refinement is the primary recourse available to a user when a query returns unsatisfactory results. But query formulation is complex.
2. The user is unable to leave traces that clarify their own intended meaning with respect to the search.
3. Infelicitous hits on the result page remain distractions on the screen.

4. Users cannot keep track of hits relevant to their purposes, especially while navigating off the search result page to view a hit and coming back to the result page.
5. Users must treat the hits returned by the search engine at either the individual level or as a single, pre-ordained collective.
6. Displaying results by pages limits the user's understanding of the range of hits. We might call this "page-induced blindness."

C/S response:

- C/S enlarges the user's ability to respond to hits produced by a search engine. Instead of just being able to reformulate better search terms, which requires the user to understand why the current search terms have not worked, the user may simply select and mark the hits that seem relevant.
- This marking allows users to drill down on what they wanted the search to produce, helping them to retain a focus on their own purposes in creating the search.
- The user may also mark hits that definitely did not work and re-sort to make the useful hits more visually prominent while moving the irrelevant hits out of the way.
- By choosing hits, users create tentative organizational propositions, treating the search results as a potential collective that constitutes meaning.
- When users return to a page of hits after clicking through on a particular one, the state of the page reflects the organizational work they have already done.
- C/S displays results in an "infinite" scroll to prevent "page-induced blindness."

In these ways, C/S allows users to track their own intentions and judgments, engaging processes of arrangement and curation, integrated into the search itself.

Additionally, C/S passively allows the user to notice how many irrelevant hits arise. It opens up the possibility that the user may wish to better understand how search engines work, without demanding that the user bend his/her own mind to thinking like a search engine in the moment.

The Implementation

C/S is a web-based application written in JavaScript. The front end uses AngularJS and the server side is written in Node.js. A "Model View Controller" architecture separates the view from the model. The view consists of the front-end interface which is rendered on the client side. The model consists of the query submitted by a user along with the corresponding result set. In addition, user actions that are performed on the C/S interface are also logged as Events in a MySQL database. An ORM (Object Relationship Model) is used to connect the server-side model to the database. The controller is responsible for rendering the appropriate view. The controller is integrated on the client side.

On entering a query on the search interface, the query is sent to the server. On the server side, the server code checks if the incoming query is a standard query or a scholar query. In case of a regular query, an API call is made to the a Node.js module* to search and scrape the search engine. The API makes a call to the search engine and returns the result list in a JSON format, which is formatted on the server side and sent to the client for further manipulation. In case of a scholar query, C/S also uses a MySQL database for logging purposes. Logging is done to capture screen events, including both user actions and attendant updates from the search engine.

CritiSearch Study

C/S was initially designed for 8th grade students (13-14 years old), based on the observation that they were often brought to a standstill while searching, despite considerable training and experience. However, this is a difficult population to study because they do not engage in a lot of searching in a classroom context and such searches are conducted only at specified points in the curriculum that may not recur for another year. Additionally, Kim et. al. [11] observed that search performance is affected when the search tasks are imposed by the researcher rather than motivated by the user. 8th grade students may not be as motivated as parents and teachers would like, but most would be significantly less motivated in a laboratory context than a classroom context.

For this initial study, we therefore looked at a different population, graduate students trying to formulate their own relationship to the literature in an area. They are engaged in a creative task of selection and synthesis that often requires tremendous intellectual focus. In moments of intense concentration, they cannot afford distraction. The disadvantage of this population is that they have already developed many strategies and habits for handling the complexities of search engines. Therefore, it is noteworthy if they find C/S usable and useful at all.

The local research question is whether a focus on the manipulation of hits can be useful for adult users conducting searches that are motivated by their own needs, that is "in the wild." The desire to examine real searches suggested a longitudinal approach, leading to a two-week design. Yet, because C/S offers only a small subset of the facilities of other search engines, we could not ask a graduate student population to confine their searches to C/S but instead opted to record user actions in C/S and/or other search engine/s of their choice. Thus, the data allow us to compare their choices in particular instances. This work addresses the following more specific research questions:

1. What purposes and attitudes does this sample bring to their search tasks?
2. What types of searches does this sample conduct?

3. When do users choose to use C/S vs. other search engines?

4. What patterns of use do they show while using C/S that arrange and curate the information?

Study Design and Methodological Approach

We conducted a longitudinal user study from July 2017 to August 2017 to evaluate how users work with C/S and other search engines while conducting scholarly search tasks. The methodological approach was multi-pronged, involving general questionnaire data, behavioral data (logging and screen capture), and interpretive data from interviews and reflections gathered via ecologically momentary assessment [22] after search sessions. Analysis of data was conducted via reducing screen capture and logging data to action transcripts that were integrated with participant comments to form a picture of each session. These were examined qualitatively using a critical incident approach [7] to tie together search behavior, intent, and evaluation by the user.

The study was conducted in the [anonymized] Department of Computer Science. An initial session was scheduled with the participants. Each session lasted 20-30 minutes. Each session started with an institutionally-approved informed consent procedure in which the goals of the project were explained to the participant. Users answered an initial questionnaire assessing search preferences and attitudes. A short semi-structured interview probed for more understanding of their background and overall research goals. This was followed by a demonstration of how to use C/S, stressing the different features that it provides for managing search. The final part of the session focused on setup and installation of software to record the search sessions that the participants would be performing.

We used the software Screen Recorder Pro 4 to record users' screens when they would be conducting online search for research related articles. Users were responsible for recording each search session. When a video was submitted, the user was asked to reflect on the session by answering three questions about the search. Screen recordings and assessments were shared with the researcher using a Google Drive folder. Assessment for the study was supported by questionnaires and log file analysis.

Data

Data were drawn from the initial questionnaire, one-on-one interviews, logging/screen capture, and post-search-session questionnaires.

Initial questionnaire. The initial questionnaire asked eight questions focused on prior preferences, practices and attitudes towards search engines. Some of these were open-ended and some Likert-scale ratings.

One-on-One interviews. During the initial introduction sessions, we conducted one-on-one interviews with each of the participants asking (1) What is your area of research? and (2) What are your overall research objectives for the next two weeks?

Logging and Screen Capture Data. Use of C/S was automatically logged. Data about other search engines was captured when users turned on a screen recorder and subsequently submitted the recording.

Post-session(s) Questionnaire. At the end of each session that a user would record and upload, we would ask them (1) what their research objective had been, (2) what plan they started with and (3) what made them satisfied or not with the session.

Limitations of the Study

The intent of this study was to investigate C/S as a probe that enhances direct hit-level manipulation in search. It was not intended to show that the need for such agency dominates search tasks even for graduate students or that C/S, a small project, could compete with or outdo Google Search or Semantic Scholar.

C/S currently works only for text-based results. It filters out other types of hits including audio, video, and news which are common on most search engines today. The C/S interface also fails to provide some advanced features supported by scholarly search interfaces such as "searching by author" or searching within a specific date range.

We asked participants to record their own sessions, which suggests that the data-set of search activities may be incomplete even for this small set of users over the short duration of the study.

RESULTS

Participants

Eleven graduate students were recruited at [anonymized] University. One participant dropped out of the study after the initial session, so results from ten are offered. The participants came from diverse disciplinary areas including physics, mathematics, architecture, chemistry, psychology, urban affairs and planning, biology, and engineering education. Three males and seven females participated.

Overall Use

58 sessions were recorded from the ten users during the two week study. C/S was used during 27 sessions, while other search engines were used during 31 sessions. Other search engines mainly included Google, Google Scholar and [anonymized] Library search. C/S was used exclusively on 12 occasions while it was used in combination with other engines on 15. The median number of sessions was 4. User 4 recorded the maximum number of sessions (10) closely followed by User 3 (9). Overall there was great variability in the duration of each session. The average length of session was 41.6 minutes. The maximum length of a session was 2 hours and 57 minutes and the minimum duration of a session was 1 minute and 57 seconds.

We report on five aspects of discovery: pre-existing user dispositions, characterization of the search tasks, choice of search engines, and arrangements and curations in C/S.

Pre-existing Participant Interests, Practices and Dispositions

Table 1 shows participant gender, discipline, preferred search engine and the research areas that they were interested in pursuing. Nine out of ten users indicated that they used search engines to find research related articles more than once a day. One of the questions in the questionnaire asked the users to rate how successful they felt when searching for research related articles online. Overwhelmingly they reported feelings of success. Only one user reported feeling unsuccessful while two others reported feeling neutral. At the same time, when asked how *frustrated* they felt while performing online search, six users reported feeling neutral, one felt frustrated, and one felt very frustrated.

Users also reported noteworthy problems in response to the question "What were the most common/recurring problems that you encounter while performing search tasks?" User 7 indicated that she "had to reformulate the query every time to filter out the irrelevant content." User 10 responded:

> Not realizing that my search terms overlap with another field that the results get confused with or not being specific enough. For biology searches, particularly finding the results I am interested in for a particular model organism rather than others (i.e. in human rather than in mouse or in fruit fly or yeast).

User 9 answered "Same articles appearing in the search bar. User 6 found "keywords related search is not very efficient." User 2 indicated "Not enough articles, not enough relevance." Some other problems included "not being able to search by a target area/region" or "difficulty finding papers by a specific author."

Unsurprisingly for the population, most participants reported success and positivity associated with searching and search engines. Digital literacy of this kind might even be thought to be an implicit selection criteria to be graduate student. More surprisingly, *not all did*.

#	GENDER	DISCIPLINE	PREFERED SEARCH ENGINE	RESEARCH TOPIC / AREA OF STUDY
1	Female (27)	Mathematics	Google Scholar	Math education (literature review for enquiry oriented learning, abstract algebra, learning and teaching, students and teachers, attitudes towards math education)
2	Female (37)	Architecture	Google Scholar / web of science	Building simulation and architectural design; computational fluid dynamics
3	Female (24)	Psychology (industrial organization)	No preference	Emotion regulation / resource depletion / prejudice / authoritarianism / egalitarianism
4	Female (24)	Biology	Google Scholar	Cell biology; toxicology.
5	Female (27)	Urban affairs and planning	Google Scholar	Food; agriculture and nutrition economics; policy planning.
6	Male (27)	Biology	Google Scholar	Cell biology; cancer biology; chromesone evolution.
7	Female (25)	Chemistry	Google Scholar	Parallel algorithms for electronic structure theory. Quantum chemistry
8	Male	Engineering Education	Google Scholar / library	Discipline based engineering education; academic engagement
9	Male	Human Development	Google Scholar / library	Grandparenthood outcomes and impact lit review
10	Female	Physics	Google Scholar	Condensed matter

Table 1: Participants and research areas in which they actively seek information

Characterization of Interactive Inquiry

Drawing upon critical incident theory [7], we identified the kinds of categories and behaviors relevant to inquiry from the post-session data. For example, consider:

> In this search, I was starting an investigation into a particular microscopy method that I think would be useful to localization single virus particles. I don't remember a lot about this search specifically, but I do recall the sorting option being very helpful. I didn't have as structured of a plan because I was mainly interested in what papers were out there and how the technique has been used for virus. If any frustration was had, it was in regards to the limited results issue that we have discussed. - User 4, Session 5

Three codes were assigned to this description: *specific content, vague sources,* and *exploratory*. The code *specific content* was assigned because the user mentioned an "investigation into a particular microscopy technique...." *Vague sources* refer to the fact that there was not any particular body of work, conference or author that the user was interested in. Finally, we assigned the code *exploratory* because the user mentioned that she was interested in "what papers were out there." A similar coding procedure was employed for all sessions. The following list of characterizations were generated:

1. clear, searching over a broad area
2. clear, but not very well defined.
3. searching for specific content
4. searching for an answer
5. exploratory
6. vague sources
7. specific parameters to narrow search
8. investigation with clear goal

After initial coding, the codes were reviewed again to search for common patterns across categories. During this re-evaluation, we investigated common underlying meaning across all the codes or a group of codes. Three higher level codes emerged: needle-in-the-haystack, gathering, and exploration.

1. **Needle in a haystack** In this category, a user has a specific target that requires filtering through many distractions. For example, he/she could be looking for a specific answer or a paper or a reference within the literature. The sources for the answer are not very well-defined. The target is met when a specific answer is found. Below are some examples:

> I needed the formulation and procedure to compute integration by Runge-Kutta 4th order method. I easily found that in a paper. - User 6

> I was interested in the size of respiratory droplets reported in the literature. I am doing a study where I will need to mimic respiratory droplets and was unsure what the range or average size was. This was a simple search with a clear goal. - User 4

2. **Gathering** In this category, the overall search target is well-defined but does not involve one specific answer. An aggregation or collection of documents may meet the information goal of the user. The inquiry is exploratory but the goal is "gathering". For example:

> I wanted more literature on autocorrelation exponents in relation to my research project. I found a couple of papers and went over them. Noted a few important points." - User 6

> The goal was to see if a precise distinction could be made between Inquiry-based learning (IBL) and inquiry-oriented instruction (IOI). I was also generally seeing what had been written about IOI as I was reviewing material for a lit review partially based on inquiry oriented instruction. I was just browsing to see if there was a clear distinction to be drawn or if there were any salient points I should be sure to bring up during the lit review, though I didn't really find anything I didn't already know." - User 1

3. **Exploration** In this category, a user is primarily interested in finding out "What's out there?" There are usually starting points, but the target is not very well-defined and may become more clear along the way. For example:

> Look for the classic literature on racial discrimination and the study of racial prejudice in psychology. I wanted, and looked for the most cited articles and ones that looked relevant. - User 3

> I was looking for articles that describe qualitative processes for system dynamics modeling - User 8

> in the recording 1, I started looking for resources to start a section of my review that I am not very familiar with, so I generally searched on Google about this to find some general and background info that will be useful as I delve into more specifics about the topic in context of what I will be writing on - User 10

Noticing Aspects of Inquiry

There are, naturally, similarities between these categories and others in the search literature. Rosenfeld and Morville [19] use fishing metaphors to describe a user's information needs. The category "Perfect Catch" is very similar to "Needle in a Haystack" in the sense that the user is looking for a single answer. Their "Lobster Trapping" is similar to "Exploratory" in terms of vaguely defined information needs and scope.

But there are differences between their categorizations and ours. Terms like "Perfect Catch" do not include the importance of exclusion in the process that we try to capture in "Needle in a Haystack." "Lobster trapping" does not call out the disposition toward discovery that we saw in our data. Searchers are already supposed to know what a "lobster" is and how to recognize one when seen, but Exploration-related behaviors go beyond this.

These arguably small differences are worth noting because our categories draw attention to the idea that search is not *just* the connection of a user to a particular object, a lobster as it were. Search may be about making that connection, but it may also be about inquiry---broadening understanding, discovering new connections, or testing approaches.

Hit Evaluation Strategy: C/S v. Other Search Engines

According to Klockner et. al [12], users process hits in two different ways, namely depth-first and breadth-first. In the depth-first approach, a user examines an entry on the search engine result page and decides whether to review it or not. A breadth-first strategy involves reviewing a number of entries on the result page first and then revisiting the promising ones. We call this the "Hit Evaluation Strategy."

The number of instances in which a user used a particular strategy within the session was used to classify sessions as depth-first, breadth-first, or combination. In all, 31 sessions were depth-first and 21 breadth-first. Additionally, some users showed a strong preference. Users 1, 2, 5 and 8 predominantly used the depth-first approach to processing the list of results.

The other six users demonstrated a combination of depth-first and breadth-first hit evaluation strategies across their sessions.

To analyze whether there was a relationship between the choice of search interface and the hit evaluation strategy, we split our data into C/S and Non-C/S usage for all users across all sessions. Each session which involved users working with C/S at least once during the session was referred to as a "C/S session." Note that during these sessions, users may have used other search engines as well. Non-C/S sessions were those in which C/S was not used at all. Table 2 shows a possible relationship between the kind of approach to search and choice of search engine in which depth-first searches appear to be somewhat more likely without C/S and breadth-first, though more rare in general, more likely with C/S.

	Depth-first	Breadth-First
C/S session	11	15
Non-C/S session	20	9

Table 2: Depth vs. Breadth First Searches by C/S Inclusion

This relationship suggests that some users may have a sense that they themselves have different motives for searches at different moments. It also suggests that they sometimes have a need to treat the set of hits as a *set,* that is, as a group that could lend itself to interpretation and diagnosis.

C/S Arrangements and Curations

What did participants do when they did use C/S? We identify four use patterns: marking, grouping, discovery and distraction reduction. The first two are *arrangements* that structure next moves. The other two are something more

than this. We call them *curations* because parts of the result set are used to frame choices.

Marking: This is the simplest use of C/S. User 6 input the query "critical temperature heisenberg anti ferromagnet." He then upvoted the fifth link titled "Critical temperature and the transition from quantum to classical". He scrolled up to view the first five results again and upvoted the third result. The user then scrolled down further to view results between ten and twenty and upvoted the eleventh link titled "Heisenberg antiferromagnet." The user then visited each of the links in a new tab before ending the session.

Similar observations were made with user 8 who upvoted three hits, followed by reviewing each of these hits in turn. A variant on this is that on two separate occasions users 6 and 7 used the upvote button to mark a hit *after* clicking through to reviewing the hits.

In both of these examples, only a small fraction of hits on the screen were deemed relevant.

Grouping: Several users used the sort capability ("CritiSort") as well as the upvoting and downvoting features. The following observation was made with User 4 in session 5 when she was researching a "particular microscopy method that I think would be useful to localization single virus particle." She was interested in finding papers related to this technique and how the technique had been used. During this session, she entered the first query "Raman spectroscopy of viruses." After entering the query, she hovered the mouse over the first five results as if reading the contents in the hits snippets. She upvoted the results 1, 3, 4, 5, and 6. She then downvoted result 8, and scrolled back up to downvote result 2. Next, she sorted the results using CritiSort. After sorting the results, she visited the links that she had upvoted one by one. Thus, she had arranged the screen to structure her actions and preserve her decision making.

User 3 utilized a similar strategy while conducting a literature review in the area of racial discrimination. She systematically labelled upvotes and downvotes, to a depth of 30 hits, before clicking through on any of them. However, in contrast to user 4, she used the downvote more frequently than the upvote during the session. On her first query, she downvoted six hits before using Critisort to start clicking through. On her second query, she downvoted nine hits and upvoted four hits before sorting.

User 7 used the capabilities of C/S in a similar manner while finding articles related to "Task based parallelism for quantum chemistry." During this session, the user was seen to use upvote/downvote to mark hits. She then sorted the result set into batches, twice. That is, she upvoted/downvoted hits, sorted them, clicked through on them, and then came back for a second round of selection, sorting, and clicking through with the same search. In this case the user also categorized quite a lot of hits, 30.

Grouping actions clearly involve arranging. They may *also* involve curation, but we cannot know this through observational methods. We look to other patterns of behavior for stronger evidence of curation.

Discovery: Some users seemed to use C/S as part of figuring out what was relevant. User 4 entered the query "virus detection in droplets." She proceeded to review the result set, upvoting the seventh link. However, instead of visiting the link, she went back and modified her query to "virus detection." In the result set for the modified query she upvoted the first and second results and visited them.

The fact that she upvoted a hit that she did not visit, modifying her query instead, can be viewed as an act of curation in which she is marking an element that has proved successful and using that marking to prompt further action.

A similar case of curation was observed in user 1, embedded in more complex circumstances. While trying to find a citable definition of "what theory of learning is", the user enters the query "learning theory." After scanning through the list of results the user modified the query to "learning theory mathematics education." The user clicked on a particular hit titled "APOS: A constructivist theory of learning in undergraduate mathematics education research" and then left the C/S interface to read the paper. After reviewing the paper, the user continued modifying her query and scanning through results on C/S. At one point, she saw the link which she had visited and reviewed earlier ("APOS: A constructivist theory of learning in undergraduate mathematics education research"). The user then upvoted this hit, as if to confirm that she had discovered an example on the right track.

User 3 performed two kinds of acts of curation. First, she downvoted a hit, then paused, as if to think about it, and clicked the downvote button again to unmark the hit. Second, later in the session, after performing an upvote on the seventh hit, she scrolled up and upvoted the first two hits. That is to say that hitting "upvote" for the first time prompted the user to reflect on previously encountered hits and take action on them.

Distraction Reduction: User 9 used the downvote capability to downvote a link which was "dead" (no hyperlink). This is a special case of marking where the user utilized the downvote as a reminder to avoid a dead link. More interestingly, Users 1 and 2 each downvoted a hit immediately. In case of User 1, the downvote action on a hit was performed after reviewing the hit "Metacognition in educational theory and practice." During this session, User 1 reported that she wanted to "find a citable definition of what learning theory is." In case of User 2, this interaction was observed in Session 2 where she voted on two hits which she had already encountered during the search process. The user had scrolled over these hits when encountered for the first time. Then the user had modified her query and when she

encountered these hits again, there was an immediate rejection.

DISCUSSION

C/S focuses on hit manipulation rather than search manipulation. Other search engines invite query reformulation as a component of search manipulation but give little attention to the current list of results. C/S gives the user additional control over the current list of results by enabling them to upvote, downvote, and sort. This enhances user agency with respect to the activity.

We have made an initial foray towards an empirical argument for C/S in the tradition of research-through-design [9, 30, 31]. This initial foray is part of iterating towards a design space for both participating and potential users. It is highly significant that even the expert users in the current study report finding searching frustrating and complain about finding the right search terms. People with less expertise, such as 8th grade students, may well be in greater need of enhanced agency, especially agency that makes them think harder about the particulars in front of them.

At minimum, this small initial study showed that the C/S was usable. Additionally, even in this highly sophisticated user group with many behavioral options, it found at least limited use over the two-week period. C/S seemed to be most helpful in exploratory contexts, with a more breadth-first hit evaluation strategy that promoted exploring the breadth as a potential category or set of categories. The significant features of C/S appeared to be used in moments appropriate for particular current purposes.

On Arrangements

We saw two forms of arrangement for the purposes of making sense of and having control of the mini-world of searching: marking and grouping. These are uses of the affordances designed into the interface, but particular arrangements and choices are presumably motivated by both the high-level contexts and purposes of the search and the immediate opportunities for action represented by the hits; it would not be easy to formulate the novel queries that succinctly captured the nascent ideas expressed through these arrangements. We infer that these arrangements and choices reflect ideation, as in Thudt's study of subjects searching for novels to read [27].

Two important aspects of this are that (1) the lack of intrinsic meaning to upvoting and downvoting is a feature that accommodates a wide range of user motivations and goals in a way similar to projective methods, like affinity diagrams [13] and (2) using C/S differs from the filtering and selection features in standard search engines because upvoting, downvoting and sorting preserve elements of the previous search context. Indeed, rather than effectively globally erasing them, C/S deliberately allows an on-going negotiation with them.

This negotiation partakes at once of the kind of give-and-take that verbal discussion has in the course of clarifying meaning and the importance of being able to arrange our physical environment in ways influenced by sensoria in the moment [8, 23, 24].

On Curations

We saw two forms of behavior that appeared to be more creative: discovery and distraction reduction. Webb et al. argue that curation, along with reflection and interpretation play key roles in learning, creativity, and problem solving [29]. They look at curation as a phenomenon of persistent annotation. In contrast, C/S creates ephemeral curation. The creation of meaning is contingent on the immediate context of the inquiry.

The examples showing "discovery" note that upvoted results were not necessarily visited. The juxtaposition of the visited and not-visited websites suggests that marking created or proposed new categories. Many interpretations that could be made from this juxtaposition of visited and not-visited: emergent new categories, contrast and comparison, meta-suggestion for revised search, etc. All of these are in service of potential ideation as well as the accumulation of facts. Importantly, these categories are tacit, at least initially, as in affinity diagrams.

Ephemerality

Arrangements and curations raise the issue of ephemerality in the relationship between search and the larger activity that brought the user to the search. When libraries were based on card catalogues, searchers would make notes on paper. Systematic searchers would carefully annotate them; compulsive systematic searchers would make many card notes and keep them in order. Early work in hypertext analyzed these cards for their information, but it found that ephemerality was also a resource for users [14, 15]. The average seeker would have some cards with just the call number and probably the title—-these were ephemera. These notes served to move the investigation along in response to the current purpose. Sometimes they rendered the more systematic effort irrelevant. (In some cases, ephemera might have been kept—-the physicality of the card might have found later use in recovering momentary thoughts about the state of the discovery process.)

C/S allows the user to see elements together in their visual field in such a way as to create an opportunity for the negotiation of meaning. It shows the new opportunity in the context of the on-going action. C/S allows the external representation of what would otherwise just be a memory.

Negotiation

The interaction in all four categories of C/S usage can be seen as a negotiation with the system. It suggests that some advanced form of C/S would use AI to "learn" from the *marking, grouping, discovery* and *distraction reduction* patterns of interaction, but that is not what we focus upon. The user's arrangement of hits is not talking to the system, but to the user him/herself — the system is giving-in a bit,

by presenting its space not as a fixed entirety but as partly amenable to user action.

What is "Searching" Anyway?

The term searching encompasses many things. Most centrally, it implies that there is something specific to find. But we have identified a recurring opportunity for users to "see" as much as they search. Along with a few others, we suggest that there is important room in the concept of searching for creative action. We draw attention to the moments before and around Teevan et al.'s concept of reframing [26]. Even before reframing, users interacting with the upvote/downvote/sorting elements of C/S (as well as the elimination of ads and other distractions) see a new construct that is jointly produced by C/S and the user. "Seeing" (as opposed to being shown) implies action on the part of the user.

Understanding that the use of C/S creates "seeing" enters into the realm of critical design by contrasting it with standard search tools. It points out the appropriation of user agency by standard search tools. The reflective user might note that using C/S not only facilitates "drift netting", but that Google and Bing, for instance, have "colonized" the idea of information as something that is theirs and knowable more by them than by the user. Thinking about C/S makes it more obvious that standard approaches to search offer no way of knowing why something is displayed or prioritized.

CONCLUSION

This is an empirical paper, but the arguments for the exploration presented here are not simply empirical. C/S is a small design change that represents an important change in perspective about ownership and control.

The effort to understand another person is arguably worthwhile but the effort to understand the search engine in that moment of the inquiry is a distraction. One might reasonably point out that other people can be distracting too. But usually we don't involve distracting people in our most focused and intense moments of discovery. One might also assume that the search engine's responses *should* distract because they are superior to formulation by an individual human. That might sometimes be true, but the assumption definitely puts human endeavor in a passive position. It is also fraught, since search engines embody and sometimes codify human bias in undetectable ways.

The different patterns observed and different cases for which users would employ a typical search engine or C/S demonstrates that users are at some level aware that they are motivated to engage in "search" for different reasons. This reflects an opportunity in design of search tools more broadly. Right now, search is commonly approached as an efficiency problem, but inquiry is far more than that.

It is important to note that all users of the internet have a stake in how searching works, who owns it, and who is in a position to assess and even challenge it. As Alan Kay, the first person to conceptualize portable computers, is credited with saying, "A change in perspective is worth 80 I.Q. points".

Various patterns of inquiry suggest that the metaphor of the search engine does not completely capture user goals in all cases. Moreover, existing interfaces *structure* and may *pre-ordain* user understanding of the possibilities of inquiry, undermining user agency in discovering new connections, and limiting discovery as a creative process of questioning and renegotiating these connections. Even in situations where the metaphor of a goal-driven search does not serve the intentions of the user, users still turn to search engines for want of an interface that better corresponds to their needs and motivations. C/S changes perspective. It deserves exploration as do other systems in this design space.

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