# Mapping Interest and Design to Facilitate Creative Process During Mixed-Initiative Information Composition

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In the postmodern age, people interact with information on a daily basis. The process tends to become routinized. Yet, information has the potential to stimulate imagination, and the emergence of new ideas.

We are endeavouring to open the space of everyday experiences with information. People need to create, work with, share, and present collections of information resources. Interactive systems can help them find information and see it in new ways. We are developing a mixed-initiative system, combinFormation, that uses composition for browsing, collecting, and arranging information samples from web pages. The samples act as visual, semiotic, and navigational surrogates for the documents from which they are extracted. The visual forms and meanings of the samples are connected through the composition to create recombinant information. The initiatives are the system's generation of composition, and the user's direct manipulation. The system's generative initiatives -- collecting information samples, and composing them visually -- are conducted iteratively, based on a user model. The system presents the ongoing generation of the composition to the user in an interactive information space. In this space, one of the user's initiatives is to directly manipulate the composition through interactive design operations, which enable samples to be displaced, layered, annotated, and removed. The user can also express positive or negative interest in each sample. Expressions of interest affect the model, creating a feedback loop through the visualization.

Supporting the agent's composition initiative and the user's composition and interest expression initiatives in the same interactive space raises particular interface design problems. This paper describes exploratory interface design research toward methods for giving the user expressive power in partnership with the generative agent. In one design, *The Compound Mappings Interface*, design composition and interest expression operations are mapped in preset pairings. In another design, *The Independent Mappings Interface*, design and interest operations are orthogonalized: that is, any pair can be combined. Independent Mappings are more powerful, but impart greater cognitive load.

To evaluate these interfaces, we develop a new methodology for evaluating the facilitation of creative process by interactive systems. The Csikszentmihalyis have previously validated that *flow* is a measurable constituent of creative process. The new methodology applies aspects of their experience sampling method for measuring *flow*, in the context of using an interactive system. Applying this methodology in an exploratory study, we discover that users are more able to engage in creative process with the Independent Mappings Interface, in spite of its increased cognitive load. In this study, we integrate flow measures with empirical user interaction log data.

Sampling is the extraction of information elements from larger works. Sampling has been used as a source of materials for creative works for almost a century (Lippard 1971). Samples can function simultaneously as visceral representations and semantic and navigational surrogates. Ernst was an early practitioner, in collage (Spies 1988). Sampling is now a staple of pop music and television.

D.J. Spooky uses samples of Martin Luther King and George W. Bush in his album for Adbusters (2003). IBM uses clips of the fighter Mohammed Ali's "I'm the greatest," in its Super Bowl 2004 "Linux: The future is open," advertisement.

Recombinant information is the composition of samples to create a connected whole (Kerne and Sundaram 2003). Recombinant information is a superset of techniques such as collage, montage, detournement, cut and paste, remix, compositing, and hypertext. In each of these forms, juxtaposition of elements creates relationships that are perceived as part of reading. Recombinant information is aesthetic and semiotic. Recombinant information research identifies commonalities and differences in the work of practitioners such as Ernst (Spies 1988), Eisenstein (1942), Stockhausen (1960), Spooky (2003), and MTV. Recombinant information extends Nelson's early notion of compound hypertext, "where materials are viewed and combined with others" (1982). CollageMachine (Kerne 1997), Shredder (Napier 1998), and aesthetic information collage (Fogarty et al 2001) are some prior procedural examples.

## Solving the Large Collections Problem with Sampling and Composition

A *surrogate* is "a replacement for an original item, … which gives some description of the item, and how it can be obtained" (Burke 1999). Examples of surrogates include entries in catalogues, bibliographic citations, search engine result set elements, and bookmarks. Typical applications, such as Google and most digital libraries (e.g. NSDL 2004), present collections of surrogates in the form of a list of textual elements. Such representations exemplify what we call, *the large collections problem*: while long lists are easy for software to generate, they place an undue burden on working memory (Baddeley 1982) in situations where people need *to make connections* between the elements. The problem is exacerbated when scrolling is necessary.

We are developing methods that use sampling and composition to solve the large collections problem. The methods are intended to work for users of the internet as a whole, for users of particular collections, and for presenters of collections. (Different contexts require different feature sets, over a common base of functionality.) This paper focuses on support for PC users engaged in creative ideation tasks (Finke, Ward, Smith 1992), such as writing a technical paper, choosing and developing a thesis topic, creating an interactive poster, or even simply creating a set of related references to share with collaborating colleagues. When engaged in tasks of this sort, users need more than to find particular elements of information. They need to discover new connections between the relevant elements. For this reason, we are interested in information representations and interaction designs that facilitate users' processes of seeing connections between surrogates. We are sampling documents, and extracting images and sharp sentences of text, which act as visual, semiotic, and navigational surrogates for the documents, and the ideas that are represented within them.

To *compose* means "to put together" (Oxford 1992). Composition is the basis of our solution to the large collections problem. Composition uses spatiality and other visual techniques to put together a perspective that connects surrogates. Composition is a means for constructing recombinant information, which promotes thinking about connections among surrogates. These compositions of surrogates can serve as provocative stimuli that enable users to see informative materials in unexpected ways. This will sometimes help stimulate the emergence of new ideas (Finke Ward Smith 1992).

The composition processes we are interested in are semiotic, in that they involve assembling units of meaning. They are visual, as in painting and collage. They are also temporal, involving rhythm, as in time based media such as music and film.

## Mixed-Initiatives

Horvitz uses the term “mixed-initiative” to describe systems whose goal is for the user and a software agent to interact like associates, while engaging in fluid collaboration (1999). In our mixed-initiative system, combinFormation (Interface Ecology Lab 2004), composition is concurrently a generative algorithmic process that a the agent executes, and a process of manipulation that the user engages in (figure 1). The interactive representational paradigm that we are developing integrates these two modalities in a single space.

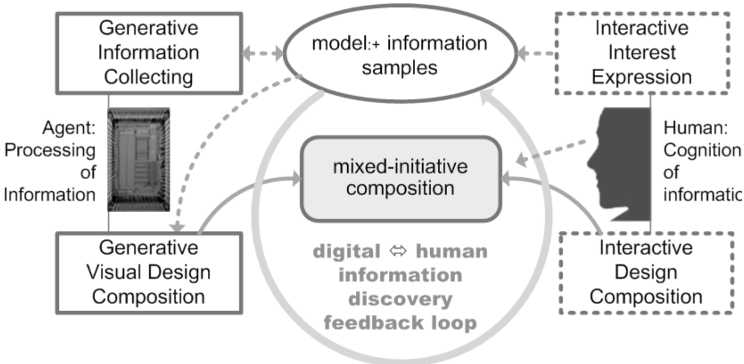


Figure 1: Mixed-initiatives: the agent engages in generative information collecting and visual composition. The user engages in interest expression and composes design. State flows through the model.

We are developing a software tool for browsing and collecting that generates a manipulable composition of web page samples, in an information space. To start a typical session (Interface Ecology Lab 2004), the user launches the program with a set of seeds, in the form of web addresses, any of which may be a search engine or digital library query. A session may also be launched with an empty space, which is a target for drag and drop by the user, or with an information space from a past session, which was saved to disk, and perhaps published on the web.

The program's generative engine collects information by retrieving and sampling HTML documents from the web addresses, selectively crawling links, and dynamically creating hypermedia. It displays a composition of these samples, instead of whole pages or thumbnails. The generative process is temporal and continuous. It is adaptive (Brusilovsky 1996) in that the evolving set of information samples is collected procedurally, based on a model of information relationships and user interests.

The model is also used as the basis for generative visual composition of a subset of the collected information samples. When the program is in generative mode ("record"), the agent adds a new element to the visual space periodically (depending on the speed control; default is one per second). In generative composition, the agent begins by setting the size of the new element, based on the model of its relevance, so the new element's size is in proportion to the relevance of others in the visual space. Next, the element is placed so it covers up other elements of least relevance. As the space fills, the agent will periodically and concurrently remove the least relevant element.

A number of techniques are employed to create a sense of recombinant information. Compositing is used to create a sense of connection between elements. Text elements are stroked, to enable parts of elements that would otherwise be covered to show through. Images may be treated with a radial alpha gradient, so that the element is translucent at its fringe, and opaque in the center. The user can engage in the same operations through interactive controls that are enabled through interaction, on mouse over, at the border of the element.

Two modes of expression by the user – design composition and interest expression – constitute the user's initiatives. As in prior spatial hypertext systems (Bernstein 2003, Marshall et al 1994, Shipman 2001), the user can affect the position, coloring, size, and font of elements within the space through direct manipulation. The user can also express interest in information samples within the space to affect the model. This interaction constitutes providing relevance feedback (Rocchio 1971). Through this feedback loop, the system is adaptable. The builders of other systems (McNee et al 2003) have found it difficult to get users to provide relevance feedback. We hypothesize that this problem can be alleviated by defining the interface in terms of interest expression, which corresponds to the user experience, rather than relevance feedback, which corresponds to the IR system model.

## Sharing Control of the Information Space

This section describes affordances for sharing control of the information space. Like the generative methods described above, these interaction design techniques are used with both the Independent Mappings and Compound Mappings interfaces.

Enabling the mixed-initiatives of the user and the generative composition agent in a shared space creates particular interaction design problems. We want the agent to respect the user’s intentions, which develop through the experience. One example occurs when the user activates information elements (via mouse over selection). In order to avoid disrupting interaction, the system must avoid placing a new sample over the user’s activated element, even if this would otherwise have been the area of least relevance. Another example is that during a drag operation, the user is looking for a new location for an element in the visual composition. If the composition is meanwhile changing, the user may be disturbed. Thus, the agent automatically pauses the generative process of adding new surrogates to the composition during grab and drag direct manipulations.

### Controlling the Flow of Generation

Tape recorder metaphor controls (figure 6, bottom right) allow the user to pause the generation of visual composition; later, play can be continued. Thus, the user can express interest and compose design concurrently with the system's generative composition of information samples, or pause and play generation to take turns. A slider affects the rate. Dyadic undo enables the user to undo the agent's actions, as well as her own. Thus, if the agent removes a desired element, the user can use undo to restore it. The number of undoable operations is constrained only by memory; we used 64 during the user study.

**Cool and Hot Design Spaces**

Integral to the act of creating a visual composition is the ability to sort and organize its constituent elements. To facilitate the composition process in the information space, some users have requested that we secure part of the space for their exclusive use. In naming the areas of the partitioned design space, we considered new media theory. To McLuhan, a hot medium, such as film, saturates its audience with information (1994). A cool one, such as the novel, leaves more of the sense of view forming to the audience member's imagination.

In our system, the generative composition of visual surrogates saturates the user with information. While McLuhan used the hot/cold distinction to compare one medium to another, we thought to apply this concept to different zones within the medium of the composition space of information samples. Thus, we call the space which the user and the agent share, *hot*. The space that is only for the user, we call *cool*. In our current implementation, the cool space is at the peripherae; the shared hot space is in the center. When information samples are partially or fully dragged from the center hot space to the cool border space, they are disengaged from the agent. Unlike hot space samples, the agent will never remove them. They are still active, in that interest expressed in them will be propagated through the model.

## Interfaces for Expressing Interest and Composing Design

The rest of this paper compares two interfaces for composing design and expressing interest in the mixed-initiative information space. It describes our iterative design process; specifically, how we developed the feature set of the new interface. A brief report on a prior study is followed by a more detailed report of the current between subjects study. Since our research introduces a new paradigm for browsing and collecting information, the short 90 minutes of a user study session may function as a barrier to understanding. Therefore we must pay special attention to the users who "get" what we are doing most readily. We refine our design in response to the most articulate feedback.

Both the Compound Mappings and Independent Mappings interfaces use some form of the popular "tool"-based paradigm of MacPaint and Photoshop. A tool represents one of a set of possible, mutually exclusive interaction modes. The active tool is selected in a toolbar. It is reflected at the point of interaction by a corresponding cursor.

There are four primary design tools. Grab enables spatial positioning of samples. Cut enables removing them. The text tool enables annotation. The navigation tool links to browsing the documents represented by a sample – its source container, and its hyperlink – in a traditional browser. Resize is another design capability.

At any moment, the user may choose to express positive or negative interest in any information sample within the space. These expressions of interest are incorporated into the model (figure 1). Expressing interest is the user's primary means for affecting the agent's generative actions.

In December 2002, we conducted a usability study to look at how our system could make recommendations to users of another metadocument authoring system, Walden's Paths (Karadkar et al 2003).

The subjects were students. Each was asked to collect material from the web to use in a presentation about a particular topic.

Several of our subjects found the task quite frustrating. One was particularly articulate in critiquing the facilities of the tool. At the same time he was enthusiastic about its potential. A dialogue between the researchers and Prior Subject 14 sprang forth from this initial session. Discussions were focused around ways in which the interface might be changed to improve the system's use as a design tool.

Figure 2: The prior Compound Mappings Interface toolbar

### The Compound Mappings Interface

The prior *Compound Mappings Interface* (Karadkar et al 2003, Kerne and Sundaram 2003) conjoined interest and design expression operations through a small set of fixed compound mappings. For example, a cut always imparted negative interest onto a sample. The design was well-intentioned. We wanted to promote the expression of interest, so that the user model would be informed.

One problem with the Compound Mappings Interface was that it did not consistently make affordances for expressing interest visible. In this version of the interface (figure 2), only grab clearly demonstrated how it affected interest: it provided the user with a visual cue, in the form of a plus or minus symbol located on the hand icon. In fact, cut expressed negative interest, web page expressed milder positive interest, and text edit expressed no interest. However, the interface did not inform the user of these mappings. They were implicit, and thus hidden. While the design space was developed with the goal of affording expression of design and interest intentions, in the Compound Mappings Interface, interest was actually treated as a second class citizen.

Prior Subject 14 discovered a deeper structural problem with the old interface. He needed to conduct design operations without expressing positive or negative interest. For example, sometimes he wanted to clear part of the space visually, without paying close attention to the semantics of samples. These visual clearing sequences were conducted without any particular intention about expressing interest, and the program's future procedural information composing operations. Yet, the grab and cut tools of the Compound Mappings Interface forced him into a positive or negative interest expression state. He felt severely hindered as a visual information space designer, because he couldn't arrange the space quickly and effectively, without expressing interest.

Prior Subject 14 sometimes needed access to a neutral interest state, while engaging in design. Further, he needed to be able to smoothly transition between making design decisions and showing interest. A new interface paradigm, which enabled interest to be expressed independently from the composition of design, was required to accomplish this.

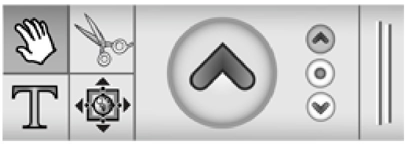

Figure 3: Independent Mappings Interface toolbar.
Expression = grab and increase interest.

## Orthogonal Expression of Interest and Design

We undertook a redesign to address the issues of forced interest expression, and invisible interest expression state. We began the redesign by removing direct association of positive or negative interest from the design tools, and at the same time, added a third, neutral interest expression state. Our concept was to make expressing interest and composing design independent, while still enabling them to be combined. This enables the visual articulation required by the task of arranging a design space to be augmented by the freedom to express interest and provide relevance feedback sometimes, and not at others.

The result (figure 3) is an interface which makes the expression of interest independent of the active design tool. Interest state acts as a modifier of design. The active design tool (on the left) and interest expression state (on right) are selected independently on the toolbar, or with the keyboard. As this enables a matrix of combinations of design tools and interest states, these operators become orthogonal. The capability of flexibly blending the orthogonal interest and design operators constitutes an interaction paradigm.

## Creating a Visual Language

Figure 4: A visual language for interest expression.

Using an iterative design process, we developed a set of symbols to represent this new conceptual model. Since we didn't see how to congruently represent neutral in our old visual paradigm for representing interest, we discarded the + and – symbols that had been representing positive and negative. While developing a new visual language for interest (figure 4), we sought to connect clear and simple visual representations of the new model with intuitive and ergonomic keyboard mappings. We chose up arrow and down arrow because of their visual clarity, their proximity on the keyboard, and their physical arrangement. Up arrow, meaning more interesting, is above down arrow. In this way, we also leveraged people's inherent knowledge of popular computer game interfaces. Up arrow means advancing, and down arrow means withdrawing.

Mutually reinforcing representations work together to make interest visible. Smaller interest modifier controls were placed on the main toolbar, next to a very large display of the current state of interest expression (figure 3). A third representation of the active interest symbol was introduced, in conjunction with the design tool, into each cursor icon (figure 5). Making interest expression visible in the cursor focuses the act of interest expression at the point of interaction with an information sample.

Figure 5: Examples of design-interest pairings in cursors.

Having made interest expression state visible, and easy to change with the keyboard, we re-examined the keyboard mappings for the design tools. Using mnemonics had seemed nice, but the distance between G for grab, C for container, and T for text is awkward. To physicalize the orthogonality of the design and interest operators, we decided to use the left and right arrow keys for cycling through the design tools. They orthogonally surround the up and down keys. The experimental subjects experienced the orthogonal keyboard mappings as intuitive and easy to use.

## Evaluating the Facilitation of Creative Process

Each problem in a convergent thinking task has one answer (Finke Ward Smith 1992). Methods for assessing the effectiveness of interactive systems for performing convergent thinking tasks are well understood (Nielsen 1993). Performance can be evaluated via measures of efficiency, by combining accuracy and speed. A typical approach is to compare efficiency on the same task using different interfaces or systems.

Methods for evaluating systems that facilitate engagement in more open activities, such as idea generation and entertainment, are less established. Users' goals and processes are often not completely specified, and subject to iterative changes (Kerne et al 2004). When one seeks to find the cure for cancer, to formulate a thesis topic, or even to discover new approaches to an everyday problem at hand, the key is not efficiency. If a better solution emerges, it may be alright for it to take longer. What matters is the experience of creativity. How do we know if a system facilitates creative experience? We need to discover methods for assessing the effectiveness of interactive systems in facilitating creative process.

**Flow**

The beneficial constituents that result from creative processes include direct products, such as innovations, and experiential by-products. Among these by-products are psychological benefits, such as gratification, inspiration, catharsis, and self-esteem. One such by-product, which has been comprehensively defined and measured in prior research (e.g., Csikszentmihalyi and Csikszentmihalyi 1988) is *flow.* Flow is an intrinsically rewarding motivational and behavioural state in which one's experiences are optimal. Flow activities "facilitate concentration and involvement." They enable people to achieve peak performance, by generating feedback that sustains engagement. It is during flow states that artists are said to do their best painting, athletes and entertainers perform best, and inventors do their best work. Flow states are highest when one is successfully engaging in challenging activities. Flow occurs in activities with clear goals and unambiguous feedback. The experience of flow has been correlated with the production of creative products (ibid). As with other experiences, the experience of an interactive system that facilitates creative process should have the by-product of better flow states.

The experience of flow hinges on the balance between a person's senses of challenges and skills in an activity (Csikszentmihalyi 1988). When challenges are greater than skills, the experience state is anxiety. When challenges are less than skills, the state is boredom. When challenges and skills are balanced, but lower than average, the experience state is one of apathy. When they are balanced and both are at a high level, this is the flow state. The prior research develops and validates a methodology for measuring these attributes.

Studies using the Csikszentmihalyis' experience sampling methodology have assessed subjects' experience of flow across diverse activities and/or environments, over many days. They ask Likert scale structured questions about challenges and skills, as well as open questions, at random times. In order to address the effectiveness of an interactive system, we adjust the methodology, by focusing the context. We ask a subset of the same questions, but only once, in a shorter time frame. Some questions from the Csikszentmihalyis' flow questionnaire (1988) that we asked are:

The challenges of the activity?

low … medium … high

Your skills in the activity?

low … medium … high

**Method**

We designed a between subjects study to observe the effectiveness of the interfaces in facilitating creative process. In our exploratory study, the subjects were 10 undergraduate and graduate students. Five used the Compound Mappings Interface; the rest used the Independent Mappings Interface. The program was instrumented to produce log files of interactive operations.

Subjects were given an explanation about what an information space is, and about how to use the system to collect and compose information samples. The experimenter conducted a warm-up activity in which subjects browsed a curated information space, such as news or art museums. Subjects continued this until they felt comfortable using the system's tools for interest expression and design composition. During the warm-up, subjects could ask the experimenter questions at any time. Experimenters discussed the program with subjects to confirm that they understood how to use the system.

Each participant was asked to spend an hour creating an information space intended to express what entertainers and artists that they like. The recipients of the information space would be imaginary prospective roommates. The activity requires subjects to collect and compose information elements around their interests. The topic and framing of the creative activity were selected to be highly familiar to the experimental participants, and personally expressive for them. This activity is quite similar to collecting a set of popular media artifacts (such as DVDs or CDs) for purchase from Amazon. The difference is that in the task we used, self-expression is less constrained. Also, it would seem that in situations with many shared apartments and prospective roommates, that posting information spaces like this on the web could facilitate the roommate matching process. The activity was followed by a flow-oriented questionnaire.

**Case Study: Subject 25 Experience Narrative**

Here is a case study narrative to illustrate the combinFormation user experience. Subject 25 used the Independent Mappings Interface. He started off from the "re:searches" seeding page, where he started searches on "smashing pumpkins", "radiohead", "stuff magazine," and "world cuisine." After launching the information space system, the first thing he did was to use the text-image slider to indicate that he wanted more images than text (figure 6, top right). After some text and images relevant to his search queries started popping up on screen, he shifted to the negative interest state (from the initial neutral state), and began using the grab and cut tools alternately to remove information elements that he didn't like from the screen, as well as to simply express negative interest in some elements. He often shifted to the neutral state to cut elements that he didn't want in the space, even though they represented ideas of interest. This is visual design without expression of


Figure 6: Subject 25's information space. The draggable toolbars float to the right. The top toolbar controls the mix of image and text samples; the middle toolbar contains Independent Mappings Interface components, including the large interest expression indicator; the bottom toolbar of tape recorder metaphor generative controls includes a rate slider. The active cursor combines the grab design tool with positive interest expression state. The light grey background in the upper peripherae is the visible portion of the cool design space. Recombinant information effects, such as alpha compositing of images and age wear of text, are evident.

interest. Subject 25 then shifted to the positive interest state and began grabbing and laying out elements that he liked on screen and indicating positive interest in them at the same time. He also used the web-page tool to navigate to the source container or hyperlinked page of some information samples. Typically subjects tend to drag and drop other pieces of information that they're interested in from these pages onto the collage workspace, but this particular subject seemed satisfied with the pictures and text that the system brought in.

Subject 25's process of using the program consisted primarily of cycles of positive expression, followed by neutral or negative cuts, and layout. Layout involved using the grab tool (usually with neutral or positive interest) to place information samples in the peripherae, where they would not be removed or covered up by the system. In fact, once Subject 25 was happy with the information on "radiohead" that he had in the collage workspace, he used the design tools to lay them out in the border space, and then proceeded to create text elements in positive expression state for "super troopers" and "big lebowski", in the center generative area of the information space. As there wasn't enough information on these elements already within the system's internal collections, combinFormation synthesized Google search queries for these terms. Subject 25 then began engaging in design and interest expression, as before, with the newer elements that appeared in the space as a result of these searches.

The experimenter observed that the subject approached the activity in a consistently focused manner. Using the design and interest expression tools to manipulate information samples, Subject 25 was able to work fast. He interleaved using the arrow keyboard accelerators for fast shifting between design tools and interest expression states, and using the mouse for interacting with particular information elements around the workspace. He commented on this process: "I enjoyed my role as a filter. In a normal search I would have to do the searching and the filtering. combinFormation did all the work for me, I simply told it what I did and didn't like.” At the end of his session, Subject 25 hit pause, and then went through a sequence of grab operations to utilize the whole space for his collected elements.

## Data and Analysis

The post-experiment questionnaire included structured Likert scale questions, with a scale of 0-4. Higher ratings indicated more positive evaluations. Open-ended questions were also included. Some results are uniform across the Independent Mappings and Compound Mappings, while others differentiate them.

### *UNIFORM RESULTS*

The experimenters report that all of the subjects seemed to get personally involved in the task. Examination of the resulting information spaces indicates that the topics the subjects chose were quite diverse. Examples include:

- Radiohead, Super Troopers, and The Big Lebowski;
- aircraft, aviation, and war planes;
- country music, and bull riding;
- alternative music, movies with Robert Duvall, baseball, and football;
- Harry Potter, Kevin Spacey, Stephen Jay Gould, and Ender’s Game;
- Frieda Kahlo, Johnnie Depp, Marilyn Monroe, and Robert Redford.

All 10 of the experimental subjects said they would like to use the program again. 80% said they would recommend the program to other people. This result is consistent with that of prior studies (Karadkar 2003, Kerne 2001). People seem to be interested in using mixed-initiative composition as a means for browsing and collecting information.

We asked users how they perceived using combinFormation in comparison to other ways of collecting bookmarks.

- "You can have a visual picture of what you like instead of just a link, so it is easier to remember what the website was and why you wanted it."
- "More things come to you, instead of you having to go to them."
- "Somewhat complicated to use, but once mastered would perhaps be more efficient" (Compound Mappings Interface).
- "This is better because it brings the media to you…"
- "This is a great idea and could very well become the next generation of thought-provoking web crawling."

A category of 7 items from the questionnaire was directed generally at the feelings and psychological states associated with the experiment activity. These included questions about aspects of ideation, concentration, and enjoyment. There was no significant difference between those who used the new (mean = 1.9) versus the old interface (mean = 1.6).

*DIFFERENTIATING RESULTS*

As per the experience sampling method (Csikszentmihalyi 1988), questions on challenges and skills of the activity were utilized to measure optimal experience, or flow. Flow is the region where challenges and skills are balanced, and both are at a high level. The mean of these measures of flow (0 - 4 scale) was significantly greater for Independent Mappings (rating = 2.7) than for the Compound Mappings (rating = 1.8), $\underline{t}(9) = 7.851$, $\underline{p} < .01$. For the Independent Mappings Interface the challenges mean was 2.4, and the skills mean was 3. This indicates a mild flow state. For the Compound Mappings, the challenges mean was 1.2, and the skills mean was 2.4. This indicates a state of boredom.

Empirical user interaction log file data also contributes to our analysis of the results. Grab operations arrange elements within the information space. Cut is a means for eliminating unwanted elements. These are the operations most invoked by users. The ratio of grab operations to cut operations indicates how much the user arranges, rather than eliminates. It is one measure of how effective the program is at choosing information samples that match the user's interests. For the Independent Mappings Interface, the grab-cut ratio was significantly higher (mean .87) than for the Compound Mappings Interface (mean .47), $\underline{t}(9) = 1.925$, with $\underline{p} < .05$.

We also examined the ratio of design tool change to interest state change operations for the Independent Mappings Interface. We were concerned about the cognitive load that concurrently selecting both operations puts on the user. We wondered if users would understand and use the interest expression affordances, and be able to interleave them with design decisions. The average design tool to interest state change ratio was 1.67. This indicates that while users express design intentions more than interest with Independent Mappings, they express them each at fairly comparable levels. (There is no comparison for this across interfaces, since Compound Mappings does not afford selecting interest state independently from design tool.)

Ten subjects were used in this exploratory study. This is a relatively small sample size, with a correspondingly low sensitivity to differences between experimental treatment conditions. The t-test is a particularly sensitive measure, appropriate for discovering the presence or absence of correlations during exploratory research (Hays 1993). Thus, the difference thus measured between the Compound and Independent

Mappings Interfaces is so robust that we can observe it in spite of the small sample size.

## Discussion

When correlated, the findings demonstrate the effectiveness of the Independent Mappings Interface. On the one hand, the lower grab-cut ratio indicates that users obtained what they wanted from the program more often. At the same time, the need to select orthogonal design and interest operators, instead of a single compound operator, clearly increases the interaction demands and cognitive load of using the program. This problem may have been reduced by the ease of use of the keyboard accelerators, In any case, in spite of the demands, participants made substantial use of the orthogonal design and interest operators, apparently as a function of their flow states. With challenges and skills balanced, the experience seems to be self-motivating, or *autotelic*.

We observe that when flow is greater, cognitive load is mitigated. While expressing interest and composing design through the orthogonal operators, users of the Independent Mappings Interface were more precise in their expressions. The system was able to more accurately model their interests. Therefore, these users experienced the satisfaction of the system presenting more interesting samples. This, in turn, motivated them to continue to engage in the expressive task. They accepted the greater challenge, because they experienced having better skills. Since these effects are so large and robust, we are encouraged in concluding that independent mappings for expression of interest and design facilitate users' experience of flow in the task of creating an information space through mixed-initiative composition.

## Conclusions

We were able to discover a user interface that facilitates creative process through an iterative design and flow measurement methodology. Users are more able to express their interests with the more complex Independent Mappings Interface. Our system, in turn, is more able to model them. The result is that users have more control over the system. They experience a greater sense of skill. A clear visual language and keyboard accelerators contribute to the interface's effectiveness.

Subjects were able to let the agent know their interests through expressive interactions with information samples as surrogates. The samples, often in the form of images, were able to convey the sense of the underlying information. The surrogates tell a story, and afford expression of interest. The ability to manipulate the surrogates visually, in the space, enabled the subjects to create an expressive personal collection of information resources that reflects their interests.

The Independent Mappings Interface is in some sense a step back from our initial attempts (in The Compound Mappings Interface) to infer the user's interests from other interactions. We remain interested in adding interest inference mechanisms to the system. What we understand now is the importance of detailed, clear interaction semantics, which give users fine-grained control of the mixed initiative system. The orthogonal design and interest operators of the Independent Mappings Interface are an important step in this direction.

Additionally, we note that a flow-based methodology is an effective means for measuring an interactive system's facilitation of creative process. In light of the prior research, measuring flow is more scientific than adhoc subjective measures. Flow measures may be correlated with empirical measures of system usage, in order to produce a more powerful integrated framework for evaluation. While a number of methods for evaluating the efficiency of interactive systems for convergent thinking tasks were previously established, this approach to using flow measures can support a range of needed research into new digital tools for supporting creative activities.

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