Reducing Cognitive Load and Supporting Memory in Visual Design for HCI

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Abstract
In the field of Human Computer Interaction (HCI) we have a broad range of ways to understand how our memory and cognitive load is affected by interactions in the world. The research described here aims to distil the complexity of activity theory, embodied interaction, distributed cognition and human factors engineering into a HCI framework for understanding and developing visual designs in HCI (a design methodology). To assist this process, interviews were conducted with visual designers from human-computer interaction, marketing, art and design. The designers were asked about their design process and how they handle memory and cognitive load. The results revealed a consistent effort towards understanding a target audience, the effect of the situation of a design artefact and the effect of cultural experience and expectations on design. These results inform a simpler, generalist approach which targets the heart of making effective and inspiring design artefacts for HCI.

Author Keywords
cognitive load; memory; visual design; interviews; HCI framework; design methodology

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces – Theory and methods, User-centered design

Introduction

In HCI we have a rich understanding of the cognitive impacts of visual design decisions. The complexity of this knowledge in its entirety, makes it difficult to adopt and build upon in design research and practice where it would be relevant for solving design problems. Despite this, the persistent aim of visual design is relatively straightforward and involves determining how to most effectively convey a particular message or set of messages that jumpstarts interaction. The broad set of visual designers interviewed provided us with a broad set of ways to achieve this aim. To achieve this communication goal specifically in a HCI situation, we aim to lower cognitive load on an interactor and support their memory. The research described here sought to identify the way experienced researchers and design practitioners reduce cognitive load and support interactor's memory in visual design. In addition to exploring the interviewees' established practices, they were exposed to a HCI framework which describes how visual user-interface elements support interactor's memory by supporting a sense of *place*, *space* and *activity*. The HCI framework formed a simplified theoretical base for discussing the support of interactors memory and lowering cognitive load. The study consists of two main research questions: How do the interviewees conduct work to lower cognition and support memory? And based on the responses provided, what should a design methodology that distills HCI theory focus on?

Background

What we mean by visual design

Visual design is aptly defined by the seminal artist and designer Bruno Munari as a field "concerned with images whose function is to communicate and inform visually: signs, symbols, the meaning of forms and colours and the relations between these" [9]. This is the closest design practice correlate to visual HCI practice which involves visualisation design and addressing the visual aspects of user interface design. The connection is important as it merits drawing upon the knowledge of our neighbours in design on the basis of a common goal to communicate and inform visually. We are able to answer the research questions on this common ground. While appreciating any discipline specific assertions or philosophies regardless of a humanities or science based perspective.

Theoretical basis

The theoretical stream presented covers what is known in HCI for understanding cognition and supporting interactor's memory to address visual design problems. In visualisation, it's accepted that human understanding and memorability are intertwined and that it's possible to make certain aspects of a visual 'stick' in mind [2]. This 'sticking' is synonymous with visual hierarchy in visual design, by modulating the prominence of various elements to guide focus and prioritise certain interactions. Using the example of an application or dialogue box, we can consider the relative position and size of an exit button versus the main content presented. If we have an idea of what should be achievable while interacting with the content, we can use the model of *Fitt's Law* [7] to justify the optimal size and position of the visual targets. Stepping outside of the screen, *Activity Theory* shines light on how computers are not objects of activity, instead they mediate our interaction with the world [6]. Similarly, the philosophical perspective of *Embodied Interaction* claims computer systems interact with us by occupying our world of physical and social reality [4]. In looking to how we explain cognition through a computer or device and into the world, the theory of *Distributed Cognition* states that cognitive processes across time are distributed across members of social groups and material and environmental structures [5][12]. *Distributed Cognition* is explored through *embedded data representations* where

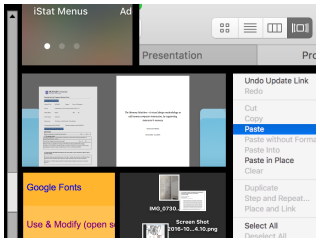

Figure 1: Reminders of *place*.

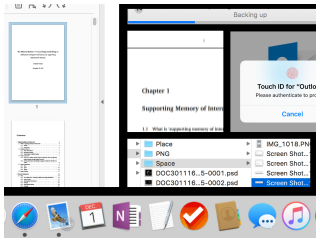

Figure 2: Reminders of *space*.

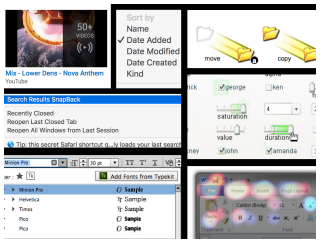

Figure 3: Reminders of *activity*.

data is viewed outside of a desktop screen and placed in-situ [14]. Finally, in practice, guidelines from the field of *Human Factors* suggest supporting cognition by minimising memory load through feedback, chunking information and memory aids [13]. We are also aware we can improve experiences through design approaches that model humans' natural behaviour and allow expression through multiple modes to accomodate for working memory limitations and cognitive load [10]. In summary, interactions with screens are based in the world, and the cognitive processes that facilitate interaction are influenced by what interactors can associate from their memory onto the screen.

Theoretical framework

The theoretical basis described, inspired the aforementioned HCI framework of *place*, *space* and *activity*. The framework acknowledges a fair amount of trickery takes place to leverage phenomena we experience in the world into constructed on screen cues for seamless interaction. The framework can be neatly described as follows:

Place Figure 1: reminds the interactor where they are, through pagination indicators, cursors (for pointing and text), scrollbars, button states (active, inactive, disabled), labels and arrangements of content such as icons or documents and windows stacked on top of one another.

Space Figure 2: reminds the interactor of an application's capabilities or intent through docks, panels and lists containing text, thumbnails or icons, found in a document viewer, option menu or application menu. Transitions when moving or progress bars. Modal or dialogue boxes presented in the foreground of its application and other preset hierarchical structures.

Activity Figure 3: helps interactors reflect on what they've done or might want to do, through historical actions which can be undone, redone, replayed or reopened. Split menus which present frequently used options on top. Sorting by date added, modified or created. Suggestion systems, such as music and video recommendations. Animations which reinforce actions (e.g. Phosphor [1]) and computational wear (e.g. Patina [8]) which visually tracks how an interface has been used over time, with local and community information.

Based on the theory described, the framework is built on the premise that computer software is an intermediary or tool constructed for activities in the world. It is presented as a set of reminders for smooth interaction—an interactor must know where they are when interacting (place), know what they can do (space) and know what they have done or should do (activity). Additionally the framework acknowledges that our cognition is already spread across and associated with objects and environments (through place and space), social groups and time (through activity). Take for instance a presentation of an endless stream of scrollable content—referents such as common themes (like an event) or qualities (like colour or quantity) across subject, time or location will help the interactor form associations between what's on screen and the meaningful world they are perceiving and acting in. The harder it is for an individual to make meaningful associations, the more obscure the visual will appear. For this reason, the alliance between models of cognition based on embodiment within the world and internal representations (human memory) [11] are compelling for the pursuit of less obscure visual design in HCI.

Interview Process

The interviews followed a semi-structured process [15] where answers could be elaborated upon with additional questions if needed. Interviews commenced with a brief introduction to the research. Interviewees were asked about what work they were involved in to provide context for the

Table 1: Interviewees' identifiers and specialisations.

ID	Specialisation
P1	communications design, communications functionality, interface design, cognitive science
P2	Expression of Interest and Capability Statement strategy, presentation, ex-teacher
P3	printmaking, etching, screenprinting, lithography, relief, publisher, teacher
P4	visualisation of geographic information system (GIS) and application programming interface (API) data
P5	web design for complex information, organisational strategy, photography, participatory photography
P6	branding, identity, strategy, positioning, print/digital design
P7	geographic information systems (GIS), cartography, statistics, presentation, data analysis, creativity techniques
P8	cultural identity, user experience, perception of space, perception of identity, perception of engagement with world

discussion. They were immediately asked what they thought about memorability or the memory capacity of an audience. Then, the interviewer showed their own design work to prime the interviewee for a question about the unique angle of their work. They were then asked what principles or methods they use generally to communicate information clearly. The HCI framework was shown, alongside applicable design problems and in use for a design project. After showing the framework the interviewee was asked whether, and how they handle cognitive load in their work. Finally they were asked what they thought of a design methodology based on reducing cognitive load and supporting memory. Table 1 provides the interviewees' identifiers (P1–8), followed by their specialisations as described during the interviews.

Interview Results

Interview transcripts were coded into categories of design considerations, which are outlined below. Consistent category responses are described in table 2 and highlighted as follows, for context, empathy, memory & method/process. **Bold** sections pertain to **memory** and **cognitive load**. The categories were influenced by the questions asked, as well as 'theoretical questions' [3] based on emergent patterns in responses given.

P1 Does not compete against the user's workflow. **Supports memory**: **Pen based** input—**permanent ink trace** and **location** act as a **memory aid** to trigger a **reminder**. **Very interested in cognitive load**: considers different **contexts/situations** and supporting **self-management** of cognitive load by providing a **range of modalities** to choose from.

P2 Guides communication based on client defined criteria and client's successes and failures in the past. **Supports memory**: Making a **vital impression** by emphasising the main point. **Human approach** in place of cognitive load: how information is **taken on-board** and **pedagogical theory**. **Accessibility** through **common language**, **common sense** and **empathy**.

P3 Avoids didacticism, by ensuring work is not overtly obvious in its message or sentiment, allowing the opportunity for deeper engagement. An 'aesthetic hook' is implemented to captivate the audience for this kind of engagement. **Not consciously supporting memory**: working in a **tradition/context** which is **relatable** to the audience. **History**. **Subjective experience**. **Documentation** of process and outcome as memory. **Physical interaction**. **Layers** and **obscuring** in printmaking through qualities of ink. **Invariably, but not consciously considering cognitive load**: **Narrative** to avoid overwhelming audience and qualities of printmaking ink to set a **visual hierarchy**.

P4 Tailored to needs of technical audience. Outcomes situate data spatially on maps, with heatmaps where applicable. **Does not consciously support memory**: **Habituation**. **Consistency** in designs, with simple explainable functions. **Legibility** informing memory. **Supports cognitive load, without attention to memory**: Avoid **too many data dimensions**.

P5 Engages with target audience to determine offerings, interaction preferences and how the design is situated and responds to various audience contexts. **Does not consciously support memory**: Content **positioning**. **Consistency**. Remembering **where you are** while interacting. **Relatable** images and graphics. **Orientating by memory of surroundings**, **maps** and value of **spatial and individual context**.

Table 2: Interviewees' consistent responses. Colour-coded to assist identification in interview results.

context empathy memory method/process

ID	Consistencies
P2, P4, P6, P7	Domain, target market
P1, P3, P5, P8	User/audience behaviour
P1, P2, P4, P5, P6, P8	Wants, user's modalities, needs, expectations
P3, P4, P6, P7, P8	Avoid overwhelming, storytelling, narrative, providing agencies
P1, P5	Support purposeful behaviour
P3, P4, P5	Familiar Visuals
P1, P2, P5	'Human centred' approach
P1, P4, P5, P6, P8	Iterative process
P1, P4, P7, P8	Prototyping
P3, P4, P5, P6, P7	Workshops

Does not support cognitive load: **Layout choice** based on user behaviour. **Contextual relevance** to audience.

P6 Emphasis on design research (scrapbooking, gap finding, iterative idea refinement and using applicable data). The design brief plays a critical part—a guiding document based on research, market data and client collaboration to ensure the final outcome meets client and audience expectation. **Not consciously supporting memory**: Intelligent and **considered** solution. **Not consciously supporting cognitive load**: **Typesetting** skills. **Hierarchy**. **Audience** and **public relations** requirements, or **required outcome** based on brief. **Good design**.

P7 Investigates the relevant domain of a design outcome. Workshops help to decipher source material and get audience feedback. **Does not support memory**: **Perception/recognition** based on **audience context** e.g. **maps**. **Memorable** map legend, with clear scale. Greater **contextual information** to make mental links. **Exploratory data analysis/crime analysis** require identifying **links**, **notes** and **patterns**. **Context** as memory—adding the **user's experience/knowledge** into tools. Displaying **histories**. **Supports cognitive load**: **Feeding information gradually** to audience—**necessary data**, **minimise** data. **Focus+context** visualisation.

P8 Goes against human cultural constraints in digital media. Seeks to re-write existing visual grammar by seeking what is 'digitally native' or has the least amount human influence on it. Forms narrative by providing senses of agency—to be able to act on something and observe a meaningful response or consequence based on an action. **Does not support memory**: **Novel idea**. No clues or tutorials, **allow exploration**. **Quantity of tasks** impacts memory. **Considers cognitive load, but not as a driving factor**: Utilises **user feedback**. Rationalises humans can **adapt** despite the capacity to overload. **Frustrated with new modalities and metaphors**. Impertinent **cultural artefacts** impact load.

Interview Analysis

Table 2 provides us the clearest view of what the interviewees regarded as important. Context demonstrated the importance of domain specific and user behaviour led approaches. Empathy was concerned with user's past experiences, expectations, ways of working and enablers for narrative and gradual progression. Memory was concerned with what was relatable and familiar. Method/process was concerned with human first approaches, making use of workshops and iterative processes to gain interactor's insights and/or refine designs. Where responses waned from supporting memory, interviewees described unconscious processes or alternate ideas such as providing contextual information or allowing exploration—however even these alternate ideas fit into the HCI framework's notion of interactive applications needing to fit into activities in the world. Similarly, the one 'no' response to cognitive load was followed by an aim to construct designs based on consistent user behaviours—which caters to interactors' lowest cognitive load option. While the key terms were not always articulated, the processes exist in practice to support memory and cognitive load.

Conclusion

The results and analysis demonstrate a variety of approaches for supporting memory and cognitive load. Regardless of whether the interviewees consciously supported memory or aimed to lower cognitive load, didn't get in the way of these

good design practices. This speaks volumes about differences in language and focus across disciplines, but provides us plenty of ideas to contemplate towards enhancing experiences. Allowing self-management of cognitive load, considering the influence of past experiences and avoiding didacticism, are just a handful of these ideas discussed. Enhancing the HCI framework described is dependant on its purpose. As a utility for the HCI community we can build upon ideas surrounding the impact of cultural experience on how we understand, and what we expect from a visual design by continuing the study of meaningful associations we form between the world we experience and computer interactions.

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