The Impact of Pre-Patterns on the Design of Digital Home Applications

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ABSTRACT
Recent research suggests design pre-patterns, structured collections of evidence-based research and design knowledge, provide a useful resource for design activities in emerging application domains. This paper extends previous research by exploring the impact of pre-patterns and tools to support pre-pattern exploration for the domain of ubiquitous computing in the home. We conducted an empirical study of 44 designers engaged in a two hour concentrated brainstorming and design task for the home of the future. Our results show pre-patterns are an easily adopted resource for designers that can impact even the earliest of design activities. We also provide insights for future development of pre-patterns based on designer feedback.

Author Keywords
Design, Design patterns, Digital Home, Ubicomp, Evaluation

ACM Classification Keywords
H.5.2 User Interfaces.

INTRODUCTION
When designing, one often encounters problems they have seen before and asks: "How am I going to solve it this time?" In fact, for many problems we come across, someone has attempted to solve a similar problem in the past. Design patterns are a tool for capturing and communicating this insight and experience, creating persistent design knowledge among practitioners in a community [2-5, 10, 23, 25]. A *pattern language* is a set of interconnected patterns that individually describe a problem with possible solutions and together form a vocabulary for a design domain.

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Pattern languages got their start with Christopher Alexander and colleagues in the field of architecture [2]. Alexander proposed patterns as a means of communication between the architect and the customer. Design patterns have since emerged in many fields including UI design (e.g., [4, 8, 21, 24]) and web design (e.g., [11, 23, 25]). Some companies also use patterns internally as a standards tool [15]. One area that patterns have had great impact on is software design, where the book *Design Patterns* [10] sparked the widespread usage of pattern names for communication within the software development community.

An open question for patterns research is how mature a design discipline must be before it can benefit from design patterns. Recent research suggests the idea of sharing design knowledge might also be appropriate for less mature design domains, such as ubiquitous computing (Ubicomp) [14]. Chung *et al.* coined the term "pre-patterns" to refer to this structured design knowledge in a nascent design domain [6]. We seek to extend previous research on pre-patterns by investigating how designers actually use pre-patterns in design tasks, how pre-patterns impact early-stage design, and how pre-patterns are structured and presented. We also seek to answer the related questions: How can one evaluate empirically whether a design apparatus, such as design patterns, affects early stage design? Do pre-patterns positively affect early stage design?

To investigate these questions, we developed 48 pre-patterns for the domain of the digital home; we then designed and conducted an empirical study with 44 designers in 22 two-person design teams. Each two-person team was asked to complete a two hour design task. Half of the teams had access to our pre-patterns through a web interface. At the completion of the design task, participants filled out a questionnaire and were interviewed about their experience using the patterns. Each design was then subjected to a heuristic evaluation by three external expert evaluators using a set of domain relevant heuristics we developed.

The most notable result of the heuristic evaluation was the patterns groups scored better on average (lower mean number of heuristic violations found). However, they had less detailed designs on average as rated by our external judges. We also observed that designers used pre-patterns for design ideas when it was not clear how to solve a problem and also used the patterns to find technology to implement their ideas. Many of the designers used pre-patterns' names verbally as short phrases to convey design concepts to their partner.

In this paper, we first discuss related work. We follow with a description of our research methodology. Next we describe how we created our pre-patterns. After that we specify our study design. We then present and discuss the results. Finally, we conclude and discuss future work.

RELATED WORK

There is a long tradition of trying to improve pattern languages through a variety of techniques. Much of this earlier work relies on peer evaluation of patterns through a form of group critique in pattern writing workshops [1]. In addition, researchers have had students who used their design patterns report back on usefulness and memorability[4]. There is almost no prior work that empirically evaluates the use of design patterns in a controlled manner.

Chung, *et al.* systematically constructed a set of 45 pre-patterns classified into four distinct categories and performed the first empirical test of designers using any form of patterns [6]. The results they reported, though somewhat inconclusive, suggested the following impact of pre-patterns for early design activities:

- Pre-patterns helped novice designers and designers unfamiliar with an application domain.
- Pre-patterns helped designers communicate ideas.
- Pre-patterns helped designers avoid some design problems.

Our objective in following this initial pre-patterns research is to produce more conclusive evidence of the positive impact of pre-patterns. To do that, we suggest three methodological improvements over the prior work: narrowing the domain, better quantifying measures of the quality of design output influenced by pre-patterns, and increasing the number of participants in hope of achieving statistically significant results.

RESEARCH METHEDOLOGY

This section describes our research methodology in terms of narrowing the domain and quantifying measures of quality.

Narrow the Domain

The work of Chung, *et al.* used pre-patterns they generated for the broad class of ubiquitous computing applications. Their experimental design exercise consisted of building a location-enhanced information system. We decided to consider an emerging, but somewhat constrained sub-domain of ubiquitous computing—applications for a home of the future, or the Digital Home. While futurists and hobbyists have explored and created demonstrations of computer-enhanced capabilities in the home, this is not a domain with a long history of widely-deployed successful systems. Indeed, it is an active area of both research and commercialization. The Digital Home is also a constrained domain, focusing mainly on the informal everyday activities of the family [12, 13].

Better Quantifying Measures of Quality

The Chung, *et al.* study primarily measured designer reaction to the use of pre-patterns and their research team's qualitative scoring of generated designs. In addition to gathering qualitative data from the designers and our observations of their design activities, we also wanted to gather objective measures of the quality of the design artifacts and more concrete evidence of pre-pattern influence on those artifacts. To do this, we had external evaluators conduct heuristic evaluations of each design. This is motivated by Mankoff, *et al*'s work that suggests heuristic evaluation is an appropriate means to evaluate designs that have not yet been implemented [16]. We also recorded more quantitative data on pattern usage through an instrumented online pattern browser.

PRE-PATTERN CREATION

In this section, we describe our method for creating pre-patterns and the format of our pre-patterns.

Pre-pattern Content

We developed our 48 pre-patterns for the digital home over the course of a few months following a similar bottom-up method as described by Chung, *et al* [6]. We began by surveying current academic, research, and commercial products related to the Digital Home and Ubicomp. We tried to identify themes or common designs among digital products or research ideas.

Using this survey and the Ubicomp pre-patterns created by Chung, *et al*, we created a list of approximately 70 candidate pre-patterns. For each of these pre-patterns we wrote a synopsis that characterized the particular problem the pre-pattern attempts to solve and found real examples from the research literature or industry in which the candidate pre-pattern had been used. We examined the resulting list to gauge their relevance to the digital home domain. This exercise brought us near the final 48 pre-patterns.

Creating the content of the pre-patterns was an iterative and collaborative process. For each pre-pattern we would make a pass at the content and references. Then other members of the research team would make comments or changes. Much of our team has been involved with research and development in the Digital Home domain for several years.

Simultaneous to creating the content of the pre-patterns, members of the research team engaged in multiple card sort

activities [22]. We used card sorting to group the pre-patterns into groups of similarly themed pre-patterns. This resulted in the creation of 6 groups: Aiding Human Abilities, Group Communication, Location-Free Access, Activity Awareness, Privacy, and Usability. Once the pre-patterns were split into groups, further card sorts were performed to establish how high or low level pre-patterns were in relation to other pre-patterns in their respective group. This resulted in an eventual ordering based on their relative level of abstraction.

The pre-patterns we created are not final products. The digital home domain is relatively new and as a result, there cannot be an expectation of evidence of many good designs. However, this is why they are called '*pre*-patterns'.

Pre-Pattern Format

We chose a format for our pre-patterns consistent with published formats for patterns used in other domains [2, 6, 10, 23]. Some of these pre-patterns can be seen in Figures 3 and 4 at the end of this paper. Each pre-pattern consists of:

- A *name* and a *letter-number* pair, where the letter indicates which group the pre-pattern belongs to. For example, "A5" means the fifth pre-pattern in the pre-pattern group A – Aiding Human Abilities. (A5 is pictured in Figure 4)
- An *image* that characterizes the pre-pattern's solution or the problem it tries to address.
- A *synopsis* describing the problem the pre-pattern addresses and hinting at the answer.
- The pre-pattern's *background*, which provides the context and scope of the pre-pattern, and describes any other pre-patterns that lead to this pre-pattern.
- The *problem* that the pre-pattern is addressing.
- The *solution* (or solutions) to the pre-pattern's problem statement, as well as pointers to other lower-level pre-patterns that help solve the problem.
- The *forces* section describes forces or tradeoffs that need to be considered when trying to fit the pre-patterns general solution to the specific problems any one designer may face.
- *Evidence* describes examples of a pre-pattern in use or examples of the problem the pre-pattern addresses.
- The *literature* section lists relevant references.

We found our pre-patterns to be more prescriptive than descriptive in many cases. While some pre-patterns were built around three or four solid example solutions, many only identified themes or issues present in Digital Home research. For example, some privacy related pre-patterns could not offer a specific solution, but instead inform the designer of potential problems that they must solve with their creativity. While not always providing any specific answers, we felt the raising of important issues would be significant to seed the mind of designers when initially considering a problem related to a pre-pattern.

EVALUATION OF PRE-PATTERNS

We wanted to study the impact of pre-patterns for the Digital Home on designer activities. Specifically, we attempted to understand how pre-patterns influence design decisions and activities, how they influence the communication of design ideas, and lastly, if they aided in the creation of better quality designs. In this section, we describe the methodology for the design task as well as our metrics of evaluation.

Method

Participants. Twenty-two pairs of professional designers were recruited from design firms and other companies employing designers in the Seattle area. They were paid $50/hour for their time. While design experience varied between groups, all 44 designers had at least two years experience as a professional designer and experience with user interface or industrial design practices. They were randomly split into two groups of 11 teams each.

Procedure. We used a between-subjects design in which the control group was asked to perform a design creation task without any external aid and the experimental group was asked to perform the same task but given access to the digital home design pre-patterns via a pre-pattern browser. Throughout the paper we refer to the experimental group as the *patterns group*.

The pre-pattern browser consisted of a web site viewed in a full-screen browser window (as seen in Figure 4). The layout of our pre-pattern browser was inspired by the pattern browser on the web site companion for the *Design of Sites* [23]. The browser consists of three frames. On the left side the names of the pre-patterns along with their letter and number were listed by pre-pattern group. Beside each pre-pattern is a checkbox users can use to keep track of the pre-patterns they found useful or relevant. Pre-pattern descriptions can reference other pre-patterns and the top right frame of the browser visualizes which pre-patterns have links to the selected pre-pattern (and which pre-patterns the selected pre-pattern links to). The bottom right frame contained the actual pre-pattern description. All the names of pre-patterns in any of the frames are hyperlinks. When a pre-pattern name is clicked, its description is loaded into the main frame and the top frame adjusts accordingly.

We instrumented the pre-pattern browser so we could better understand how it would be used in any design task we studied. By logging each click of a pre-pattern name we were able to identify which pre-pattern was on the screen at any given time and for how long[1]. This logging provided us

[1] The tool was built within a Web browser, but we disabled the back and forward buttons of the web browser to make this knowledge possible.

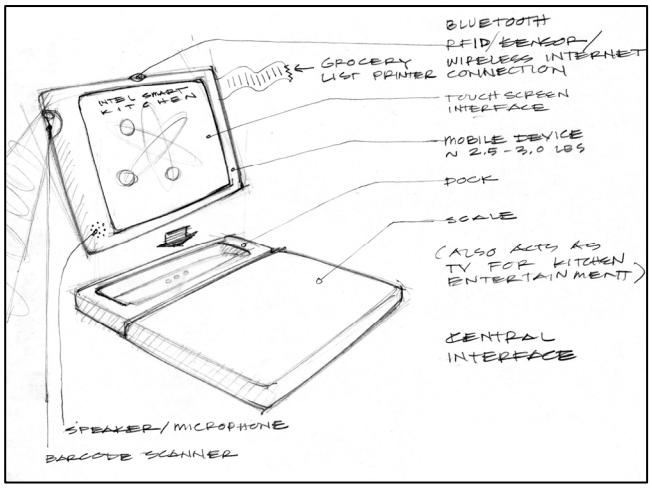

Figure 1. Sketch by one design team.

information regarding the number clicks any one pre-pattern received during a browsing session. In combination with time stamped, video-recorded sessions, this pre-pattern-browsing information helped us examine how designers used the tool and pre-patterns content in design activities.

Task. Neither the experimental or control group were given any materials prior to the study. Each team was given 120 minutes to create a design for a digital home application; specifically, they had to create a solution for a home food inventory system, including knowing what food a user currently has and when items are running low, receiving feedback on their household's food consumption, and recipe suggestions based on users' food at hand. This task was chosen, not because it was a compelling application for the digital home, but rather, because it was representative of previous efforts in the domain and contained many different elements that were challenging for creating a usable design. These challenges include diverse users, strong existing practices, privacy and infrastructural concerns, and appropriate levels of interaction.

In addition, during the design task the designers in the patterns group were given access to the digital home design pre-patterns. Each designer had access via their own computer terminal. They were familiarized with the pre-pattern's content and browser application prior to the task through viewing a 5 minute instructional video, a 10 minute exploration period, and a simple quiz which ensured a requisite baseline comprehension of how to operate the browser.

To prevent uncontrolled variance in the presentations of the designs, the teams were asked to transfer their final designs to a standardized presentation form that would be presented to the evaluators. The presentation form asked them to describe their solution, its use, as well as any technology it employed. In addition, they were instructed to sketch any interfaces or systems they used or created (see Figure 1 for an example sketch).

Designer Feedback

After they completed their design, each designer was asked to fill out a background questionnaire assessing both their experience as a designer, any prior experience they had designing for the digital home or Ubicomp domains, or using design patterns in the past.

In addition to the background questionnaire, the patterns group was given a questionnaire assessing how the designers felt about the pre-patterns they used and what they believed the affordances of these pre-patterns would be for other designers. This instrument rated their agreement or disagreement to eight prompts about the design pre-patterns using a 5-point Likert scale.

Evaluation

To obtain an objective and external evaluation of the quality of the designs that both experimental groups created, we had three expert outside evaluators perform a heuristic evaluation of the designs and score them using three subjective metrics. We paid each evaluator $500 for their time.

Generating Digital Home Heuristics

Heuristic evaluation has been shown to be a useful evaluation methodology in usability [19]. However, we believe the digital home as a domain presents many new problems not adequately addressed by any one existing set of heuristics. For example, while Nielsen's canonical set of ten heuristics are appropriate for traditional graphical user interfaces, they do not address the additional considerations brought upon by a diverse set of users and their behaviors that occur in the home.

We compiled a set of heuristics that include Nielsen's ten, Mankoff's modified set of twelve for ambient displays [16], and Scholtz and Consolvo's Ubiquitious computing Evaluation Areas's (UEA) for ubiquitous computing [20]. After compiling a complete list including all of the above, we removed those that were agreed to be non-applicable to the digital home based on three independent reviews by members of our research team. We then modified the structure of the heuristics (including the titles) to create a uniform format without modifying the content.

Further revisions to the heuristic set were informed by two pilot studies where researchers familiar with heuristic evaluation used our set of heuristics to evaluate a hypothetical digital home prototype design. The revisions included eliminating heuristics that were rated as non-applicable to digital home applications as well as consolidating some heuristics that addressed the same issues. The 28 heuristics that remained were categorized into eight groups, which were each given a summary that enabled evaluators to quickly understand what the heuristic addressed. A final evaluation of the heuristics by a researcher experienced with heuristic evaluation and the digital home domain validated the categorization and format of the heuristic set (an example heuristic group is shown in Figure 2). The eight heuristic groups are

Trust (C)	The technology should ensure personal information stays personal and should allow users to gain access to and manipulate that information, if desired.
	• The technology should request only information from the user required to obtain value from the application; it should mediate other users' and third-parties' access to this information. • The technology should coordinate personal information transfer with many simultaneous users, ensuring personal information remains personal. • The technology should provide information about what types of data is being recorded about the user, how it is being used, and what inferences can the system draw from this data. • The technology should enable users to manage how and by whom their data is used and allow for adjustments to be made in the event that their data is misused.

Figure 2. One of the eight heuristic groups used to evaluate the designs.

Attention, Adoption, Trust, Conceptual Models, Interaction, Interface, Appeal, and Application Robustness.

Heuristic Evaluation

For the heuristic evaluation of the designs created by both our control and patterns experimental groups, we followed Nielsen's methodology with some minor modifications [19]. We employed the use of three evaluators experienced in heuristic evaluation rather than a larger group of novice evaluators. In addition, because of the time involved with performing the evaluations and the limitations of the evaluators' memory (it took on average 14 days to complete the evaluations), we chose to combine the heuristic violations ourselves.

Each evaluator was emailed instructions to access a password protected web site that contained instructions and links to the 22 designs that were to be evaluated. Each design page consisted of the digitized, standard presentation form; we scanned in all the sketches and transcribed all the text that was written by hand. During this transfer, we did not modify any of the content, but took out any explicit references to the pre-patterns (e.g., "A5" or "all privacy pre-patterns apply here") to keep the evaluations blind to the study conditions. Each of the three evaluators were asked to perform a heuristic evaluation using the digital home heuristics we created and evaluate each design using the randomized order that we created for each evaluator. After each heuristic evaluation was performed on each design, the evaluators were asked to rate the severity of the violations using a standardized 5-point severity scale.

Subjective Evaluation: Detail, Completeness, Quality

We had each evaluator perform a subjective evaluation of each design after performing the heuristic evaluation. They were asked to rate the detail, completeness, and quality of each design on a 7-point Likert scale, (e.g., it ranged from "Very Undetailed – 1" to "Very Detailed – 7" for Detail). Each evaluator was given a standard definition of each criterion (see Table 1). The quality metric was used to gain a global understanding of the quality of a design and the detail and completeness metrics were used to validate that the number of heuristic evaluation issues corresponded to the number of violations in a design and not the level of detail or completeness.

How **detailed** was the design?	How low-level, readily implementable, and non-vague are the elements of the design? What is its depth?
How **complete** was the design?	Does the design contain all the necessary parts that it will need to work? What is its breadth?
What is your **overall perceived quality** of the design?	Overall, how good of a solution is the design?

Table 1. The subjective metrics used to evaluate the detail, completeness, and quality of each design.

RESULTS

In this section, we present our own observations, the designers' feedback, and the external results from the heuristic and subjective evaluations of the designs.

Observations

This subsection presents our observations from video and pattern usage logs.

Pre-Pattern Reading

Analysis of the pre-pattern access log indicated that on average, each pattern group viewed an average of 26 distinct pre-patterns. The pre-patterns most heavily viewed were: "Inventory", "Home Automation", "Activity Monitoring Systems", "Electronic (family) Message Board", "Proactive Health Services", "Augmenting the Senses", and "Memory Aids/Personal Reminder Systems".

To better understand how much each pre-pattern was used during the task, we calculated how long each designer spent viewing each pre-pattern. To do this, we created an application which would aid us in tracking how long and when a designer viewed the pre-pattern browser. Essentially, we went through all the video and recorded when a participant was reading the screen. We then correlated this with the pre-pattern log (showing which pre-pattern was on the screen at that time). From this, we were able to generate an accurate listing of how long each pre-pattern was viewed and the duration each group spent reading the pre-patterns.

On average, each experimental design team spent a combined 26 minutes reading the pre-patterns; this represents eleven percent of their total design time. There was some variation in the amount of time each group spent reading the pre-patterns (standard deviation of 9 minutes), and we had one outlier group which only spent 3 minutes reading the pre-patterns. Additionally, the patterns that were accessed the most tended to be the ones where the most time was spent reading.

Pre-Pattern Use

In observing the recorded video sessions for designers in the patterns group, we developed a coding scheme for each instance of the pre-patterns being consulted. We identified four distinct activities:

- **Discovery** is looking through the set of pre-patterns to determine what content might be relevant to the design task. This is mainly quick browsing done mostly near the beginning of the design task. For example, one user commented to his partner, "one thing we should do is just walk the list of the patterns and flag ones which would be useful for us".
- **Idea Generation** is more goal-oriented, evidenced by a designer looking through the pre-patterns to discover ideas which may assist in solving high-level design problems.
- **Issue Clarification** is the activity of reading through a pre-pattern to discover a specific solution to a specific, articulated problem.
- **Re-reference** is merely looking back at the pre-patterns to reference something that the designer had encountered earlier.

For the few instances where the designer searched through the pre-patterns without verbalizing their intent, we attempted to guess their activity based on context. Piloting this technique with three members of our research group resulted in a sufficiently high level of inter-rater reliability for confidence.

Across the eleven pre-patterns design groups there were 103 identifiable pre-pattern references. Of these, *Re-reference* and *Discovery* each accounted for 17% of total activity. *Idea Generation* accounted for 31% of pre-pattern references and *Issue Clarification* accounted for 35%.

Idea Generation

In the previous section, one of the pattern reading activities we identified was idea generation. To further investigate the extent to which pre-patterns influenced the generation of ideas we reviewed video transcripts of the pre-patterns groups and coded the number of instances of this behavior. We only counted an idea generation instance when it was explicit and verbalized; for example, a designer mentioned to his partner "in the inventory one, they discuss the guy who registered the garbage". We also counted how many of these ideas actually made their way into the final design document.

We found 98 total idea generation instances in the pre-pattern groups' sessions with an average of 8 per design group (standard deviation of 3.5). Of these verbalized idea generation instances, 69 were realized in the final design document (70% of the total idea generation instances).

	SA	A	NAD	D	SD
1. Idea Generation	7	10	4	1	0
2. Shared Vocabulary	7	13	2	0	0
3. Communicating Knowledge	6	11	5	0	0
4. More Detailed Designs	6	11	3	2	0
5. More Complete Designs	9	11	2	0	0
6. Higher Quality Designs	3	11	6	2	0
7. Unfamiliar Domain	12	8	2	0	0
8. Enjoyable to Use	3	12	3	3	1

Table 2. Results from designer feedback survey. Designers in the pre-patterns group rated statements about the affordances of using the digital home pre-patterns using a Likert scale. Numbers in table indicate how strongly a designer felt about a statement (SA = Strongly Agree, A = Agree, NAD = Neither Agree or Disagree, D = Disagree, SD = Strongly Disagree).

Pre-Pattern Language Use

To understand if the pre-patterns helped to create a shared design vocabulary for the digital home, we also coded instances of a designer using a pre-pattern name (either the entire title – "Inventory" – or the code – "A5"). Here, we took careful note to only count the instances in which the term was used to refer to the idea of the pre-pattern, and not just the pre-pattern itself. For example, a designer telling her partner, "Look at the pattern Inventory" would not count as language adoption; whereas "we need *inventory* here" would be counted. In addition, while most deictic motions were used in this fashion, we did encounter an instance in which the pointing gesture was used to refer to the solution in a pre-pattern and not just the pre-pattern itself.

As we were coding it became clear that the number of instances of pre-pattern language use was not as informative as the number of groups that adopted certain terms; this was because after a group member used a particular term, this term was frequently adopted and used with regularity in all subsequent referrals to the specified idea.

We found that 11 different design terms were adopted by the pre-patterns groups during the study. These terms were not, however, uniformly adopted by all design teams. In fact, of the 11, only two terms were adopted by more than two different groups. These two exceptions include "Inventory" and "Activity Monitoring Systems", which were adopted by nine groups and three groups, respectively.

Designer Feedback

The post-study questionnaire given to the pre-patterns groups assessed how the designers felt about using the pre-patterns in creating a design (results shown in Table 2). We found that 90% of the 22 designers given the questionnaire either agreed or strongly agreed that the digital home pre-patterns would be useful for designing for unfamiliar

	Heuristic Issues	High-Severity Issues	Severity Ratings
Control Group	Mean: 20 Std: 5.7	Mean: 9.3 Std: 3.379	Mean: 3.6 Std: 0.24
Patterns Group	Mean: 17 Std: 4.5	Mean: 8.5 Std: 4.2	Mean: 3.6 Std: 0.28

Table 3. Results of the heuristic evaluation for each team

	Detail	Completeness	Quality
Control Group	Mean: 3.9 Std: 1.0	Mean: 3.7 Std: 0.83	Mean: 3.6 Std: 0.97
Patterns Group	Mean: 3.4 Std: 0.70	Mean: 3.6 Std: 0.90	Mean: 3.5 Std: 0.75

Table 4. Results of the subjective evaluation for each team.

domains, creating more complete designs, and aiding in the creation of a shared design vocabulary for the digital home domain. In addition, of all the prompts, evaluators were most negative about the design pre-patterns being enjoyable to use. Based on their comments, it seems that this was mainly caused by the difficulty in understanding the pre-pattern relationship visualization, and the omission of 'back' and 'search' functionality in the browser.

External Observations

In this subsection we present the results from our external evaluators.

Heuristic Evaluation

Prior to our consolidation of heuristic violations, the external evaluators found 255 issues in the control groups' designs and 222 issues in the patterns groups' designs. Three members of our research team then combined the violations that were identified by more than one evaluator. After our consolidation, there were 220 unique issues in the control group and 183 unique issues in the patterns group ($t > 90\%$, $p=.0696$)[2]. However, if we consider issues for which the average severity rating (on a scale of 1 to 5 with 5 being most severe) was a 4 or 5, the difference between the groups decreases (see Table 3 for results).

In addition to consolidating the issues, three members of our research group categorized the issues into the specific heuristics they violated; a specific issue could violate more than one heuristic. Here we found that the patterns group had fewer "Attention" ($t > 90\%$, $p=.0466$) and "Conceptual Model" ($t > 90\%$, $p=.0992$) heuristic violations than the control group.

Subjective Judging

The scores for the control group and the patterns group on *Completeness* and *Overall Perceived Quality* were not statistically different. However, surprisingly, the control group's *Detail* scores were higher ($t > 90\%$, $p=.0874$)[2] than the pre-patterns groups (see Table 4).

DISCUSSION

In this section we discuss the results as they relate to our research questions.

[2] We used a two-sample, assuming unequal variance t-test using the mean heuristic violations found for each design pair.

Effect of Pre-Patterns on Early Stage Design

Our empirical study suggests pre-patterns have a positive effect on early stage design. The heuristic evaluation of designs yielded a higher mean score for teams in the pre-patterns condition (they had on average fewer heuristic violations identified by the evaluators). This is however tempered by the result that the two conditions showed no statistical difference in terms of high-severity issues. Interestingly, the two conditions received a similar mean qualitative *Quality* scores from our evaluators. The fact that there were less Conceptual Model heuristic violations in the pre-patterns condition also leads us to believe these designs are more fundamentally sound.

We argue these results support the conclusion that pre-patterns do not take away from early stage design processes; but instead, pre-patterns allow designers to eliminate more issues early in the design process.

Designers' Use of Pre-Patterns

Re-reference and *Discovery* each accounted for 17% of total activity. *Idea Generation* accounted for 31% of pre-pattern references and *Issue Clarification* accounted for 35%. From this we can see the pre-patterns are not only effective in aiding in the generation of ideas, but designers are also able to go back to the pre-patterns to get specific questions answered.

The analysis of reading time revealed the pre-patterns that were accessed most heavily were also read for the most time. In our view, these were the most relevant pre-patterns to their design task. This suggests the patterns browsing tool, the hyperlinks between pre-patterns, and the pre-pattern format were effective in allowing designers to quickly find patterns relevant to their task while not being distracted by less relevant patterns.

Structure and Presentation of Pre-Patterns

Among the questions in our post-study questionnaire, designers most strongly agreed that pre-patterns would be helpful in unfamiliar domains. This suggests future pre-pattern languages should continue to include information about available and relevant technology when discussing the possible solutions to problems.

We observed designers adopting some of the language of the pattern names as they performed their design task. This was particularly noticeable in verbal communication

between the designers. This emphasizes the importance of properly naming pre-patterns so they form a language as with traditional design patterns.

Evaluation Technique

Our empirical evaluation technique of having pairs of designers make rough designs in two hours and having those designs heuristically evaluated proved useful. However, there are still some lessons learned from our approach.

Two hours appeared to be a good time frame for our design task. A few groups were a little hurried and a few groups were done early. However, most groups were able to finish in the allotted time.

The most problematic feature for both the designers and the evaluators was design detail. Designers had to scope how much and what kind of detail were appropriate for their designs. These heavily impacted what kind of heuristics are appropriate for evaluation. In our case, the evaluators had a mix of traditional user interface heuristics as well as more social ones like privacy that affect overall system design. So we needed our designers to give both interface detail as well as a complete picture of the overall system. While our designers provided enough detail for evaluation, it is clear that a goal of any future study of this nature would be to increase the amount of detail the designers can provide.

CONCLUSION & FUTURE WORK

In this paper we presented our findings from an empirical study of the effect of pre-patterns on early stage design. The patterns groups' had a lower mean number of heuristic violations than the control group suggesting pre-patterns aided in creating higher quality designs.

We also discovered designers quickly began to use pre-patterns names to communicate design concepts to one another. Designers were also successful in using the pre-patterns to help them generate ideas as well as get specific information they needed for their design.

In future work, we want to build upon these findings by exploring the effect of pre-patterns on later stages of the design process beyond early design sessions.

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REFERENCES

1. Third European Conference on Pattern Languages of Programming and Computing. http://www.coldewey.com/europlop98/cfp.htm
2. Alexander, C., *A Pattern Language: Towns, Buildings, Construction*: Oxford University Press, 1977.
3. Bayle, E.*, et al.*, Putting it all together: towards a pattern language for interaction design, *SIGCHI Bulletin*, vol. 30(1): pp. 17-23, 1998.
4. Borchers, J., *A Pattern Approach to Interaction Design*: John Wiley and Sons, 2001. http://hcipatterns.org
5. Casaday, G. Notes on a Pattern Language for Interactive Usability. In Proc. of *Human Factors in Computing Systems: CHI 1997*. pp. 289-290.
6. Chung, Eric, Jason I. Hong, James Lin, Madhu K. Prabaker, James A. Landay, and Alan Liu. *Development and Evaluation of Emerging Design Patterns for Ubiquitous Computing*. In Proceedings of Designing Interactive Systems (DIS2004). pp. 233-242.
7. Dearden, A., J. Finlay, L. Allgar, and B. McManus. Evaluating Pattern Languages in Participatory Design. In Proc. of *Human Factors in Computing Systems: CHI 2002 (Extended Abstracts)*. pp. 664-665.
8. Erickson, T., The Interaction Design Patterns Page. http://www.pliant.org/personal/Tom_Erickson/InteractionPatterns.html
9. Erickson, T. Lingua Francas for Design: Sacred Places and Pattern Languages. In Proc. of *Symposium on Designing Interactive Systems 2000 (DIS2000)*. pp. 357-368.
10. Gamma, E., R. Helm, R. Johnson, and J. Vlissides, *Design Patterns*: ***Elements of Reusable Object-Oriented Software.*** Addison-Wesley, 1995.
11. Graham, I., *A Pattern Language for Web Usability*. Reading, MA: Addison-Wesley, 2003.
12. Hindus, Debby: The Importance of Homes in Technology Research. In Proceedings of CoBuild 1999: 199-207
13. Hughes, J.A., O'Brien, J., Rodden, T., Rouncefield, M., Viller, S., Patterns of home life: informing design for domestic environments, Personal Technologies 4 (1), pp. 25--38. Kluwer.
14. Landay, J.A. and G. Borriello, Design Patterns for Ubiquitous Computing, *Computer*, **36**(8): pp. 93-95, 2003.
15. Malone, Erin, Matt Leacock, and Chanel Wheeler. Implementing a Pattern Library in the Real World: A Yahoo! Case Study. 2005. http://www.boxesandarrows.com/view/implementing_a_pattern_library_in_the_real_world_a_yahoo_case_study
16. Mankoff, Jennifer, Anind K. Dey, Gary Hsieh, Julie Kientz, Morgan Ames, and Scott Lederer "Heuristic evaluation of ambient displays," In *Proceedings of CHI 2003*, pp. 169-176.
17. Meszaros, G., A Pattern Language for Pattern Writing. 2000. http://hillside.net/patterns/writing/patternwritingpaper.htm
18. Nielsen, J., When Bad Design Elements Become the Standard. 1999. http://www.useit.com/alertbox/991114.html

19. Nielsen, J., and Molich, R. (1990). Heuristic evaluation of user interfaces, *Proc. ACM CHI'90 Conf.* pp. 249-256.

20. Scholtz, J., & Consolvo, S. Toward a Framework for Evaluating Ubiquitous Computing Applications. Pervasive Computing, April-June 2004 (Vol. 3, No. 2), pp 82-88.

21. Tidwell, J., Common Ground: A Pattern Language for Human-Computer Interface Design. 1999. http://www.mit.edu/~jtidwell/common_ground.html

22. UsabilityNet, Card Sorting. http://www.hostserver150.com/usabilit/tools/cardsorting.htm

23. van Duyne, D.K., J.A. Landay, and J.I. Hong, *The Design of Sites: Patterns, Principles, and Processes for Crafting a Customer-Centered Web Experience*. Reading, MA: Addison-Wesley, 2002. http://designofsites.com

24. van Welie, M., GUI Design Patterns. 2003. http://www.welie.com/patterns/gui/

25. van Welie, M., Web Design Patterns. 2001. http://www.welie.com/patterns

26. van Welie, M., K. Mullet, and P. McInerney. Patterns in Practice: A Workshop for UI Designers. In Proc. of *Human Factors in Computing Systems: CHI 2002*. pp. 908-909. http://www.welie.com/patterns/chi2002-workshop/

27. Weiser, M., The Computer for the 21st Century. *Scientific American*, 1991. **265**(3): pp. 94-104.

Figure 3. More examples of Digital Home Pre-patterns from different categories

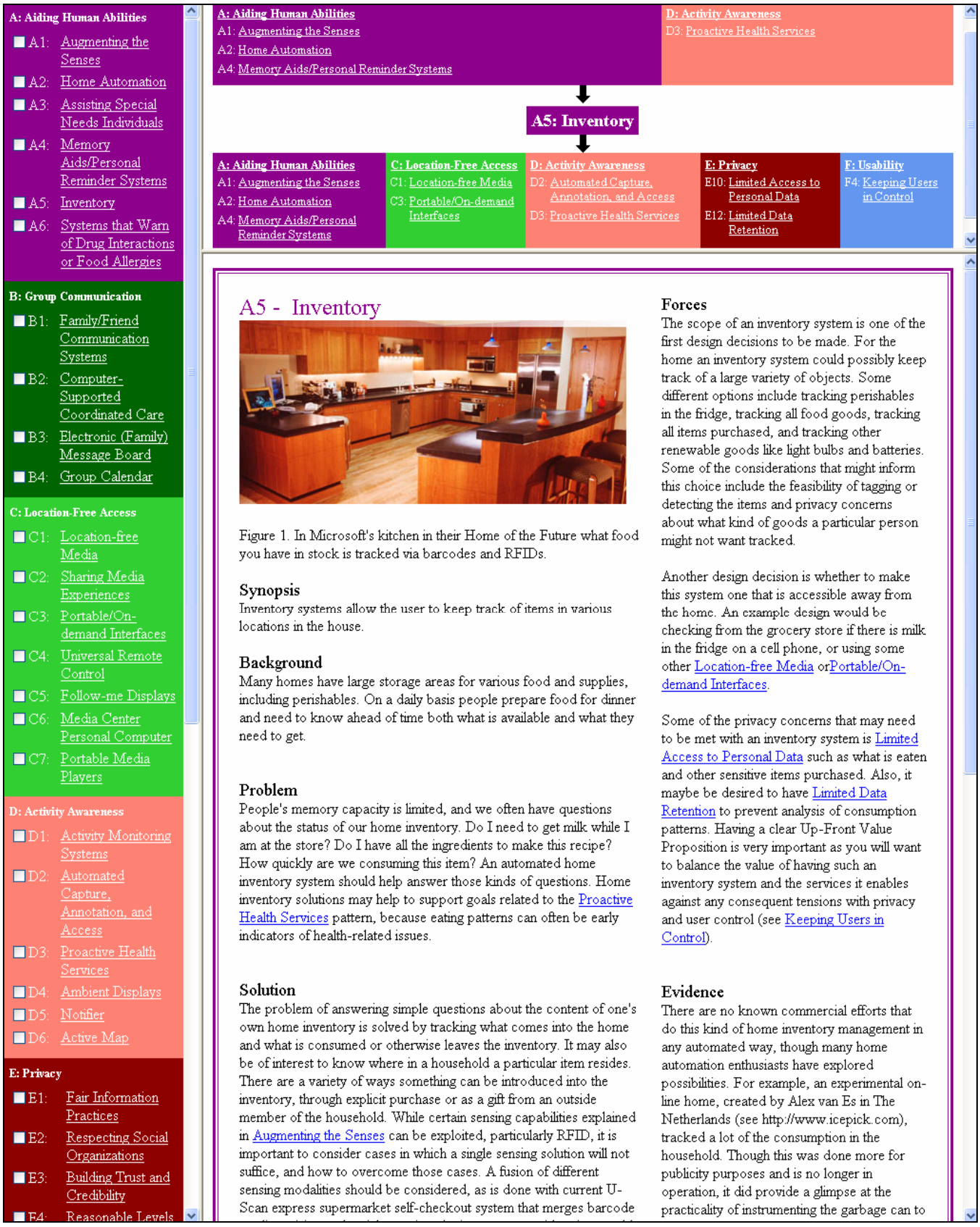

Figure 4. An example of a Digital Home Pre-Pattern in the Patterns Browser