Machine-Assisted Cooking

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ABSTRACT
We present the observations, processes, and results in designing a machine assisted cooking interface for novice chefs. We present detailed observations from our user experiments and the resulting evolution in our interface design. We describe the final interface that is the result of this process, and list important features that contributed to its success. We conclude with the current state of our work and our plans for the future.

INTRODUCTION
Cooking can be a source of enjoyment as well as a forum for creative experimentation. Compared to prepackaged and most restaurant meals, homemade meals are undoubtedly healthier, economical, and give more control over what goes into one's plate. Unfortunately, home cooking has been increasingly perceived to be too stressful and time-consuming, therefore not worthy of the trouble. Developing the proper skills to cook with confidence takes time and patience. The tools, ingredients, motor skills, effective use of heating/cooling appliances, pressures of precise timing, importance of precise timing, as well as several other factors may seem overwhelming to novices.

The vast majority of novice chefs learn to cook using printed cookbooks and websites. Recipes in printed cookbooks are often presented in a paragraph or a list format. There are many cooking blogs or websites [5, 8] that share recipes. Online recipes tends to be merely a digital version of printed cookbooks, presenting recipes in paragraphs or lists. We believe the traditional curation of a recipe increases cognitive load while cooking. With the traditional recipe design, one needs to foresee previous, current, and future ingredients and instructions in order to cook without constant interruption. Some novice chefs use cellphone applications [cite1, cite2]. For example, Cook Assistant Lite [9] makes cooking interactive by only presenting current instructions and ingredients, which is different from the traditional curation of a recipe. However, only presenting an active step requires the user to continually interact with the application, which leads to frequent interruptions while cooking.

For this work, we design a user interface for a machine assisted cooking application. The interface is improved upon series of detailed observations of novice chefs cooking. The goal of our interface is reducing unnecessary cognitive load thorough effective recipe presentation. Our design focuses on the curation of instructions and ingredients.

Prior to our work, little research has been devoted to understand the ideal curation of a recipe.

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Getting your first meal right is challenging without help, and failure may discourage people from trying again. There are few resources that currently exist which help mitigate the cognitive load experienced by first-time cooks. For instance, printed cookbooks increase cognitive load, because ingredients and instructions must be memorized in order to cook without interruption. Cooking blogs (e.g., [8, 5]) provide plenty of recipes and guides, but these sources are merely digital versions of printed cookbooks. Cook Assistant Lite is one cellphone application that has made cooking interactive [9], but the application requires the user to continually interact with the application, which leads to even more interruptions while cooking.

In this paper, we propose a digital cooking assistant design for novice cooks. Our design focuses on the following points:

- Mitigate interruptions that are due to overutilization of visual input (necessary visual observations while cooking and having to continually read something to determine what to do next) and motor functions (hands are used for cooking and clicking through applications or scrolling on a blog).

- Mitigate cognitive overload that is due to the physical and temporal demands of cooking, which are exacerbated by the memorization of ingredients and instructions.

- Make instructions in recipes more accessible, teach users new cooking techniques, and help users decide what to make with the ingredients they already have at home.

Features of our design include text-to-speech instruction; timers for managing multiple simultaneous tasks; reminders to check oven and stove temperatures; easy-to-read interfaces that display one step at a time with large pictorial, audio, and/or video aids, somewhat reminiscent of turn-by-turn navigation of a GPS; and lifelines to contact other users who have previously tried the recipe.

Our approach is user-centered. We survey both novice and expert cooks in order to identify key differences between skill levels. For instance: What do novice cooks find most difficult about cooking? What prevents them from cooking more often? What motivates experts to cook? Survey results inform our design of several paper-based interfaces. We then conduct a round of in-person questionnaires to obtain feedback on multiple paper-based designs, which help to identify prominent features and issues with each design. We show multiple designs in parallel to each participant. After incorporating feedback on paper prototypes, we implement the digital design leveraging the recipe API BigOven [1]. To assess the quality of our digital prototype(s), we conduct a within-subject experiment, comparing user performance on cooking recipes with and without our prototype(s). During the performance phase, we collect qualitative data by observation. After each cooking session, we ask the user to assess their cooking experience based on the following factors (NASA Task Load Index): mental demand, physical demand, temporal demand, performance, effort, and frustration. Finally, through further user testing and design/development iteration, our final product embodies the features that help first-time and novice cooks succeed in their cooking adventures.

RELATED WORK

Cognitive theory has been extensively studied in the field of instructional interface design. The majority of work is based on Baddeley's canonical model of working memory as a limited buffer for visual and auditory information [6]. When the buffer is overloaded, possibly by performing tasks that involve an ordered series of physical and mental activities, new information can fail to be processed [6, 14]. Mayer expands Baddeley's model to form a cognitive theory of multimedia learning [13]. In his model, information processing is divided into a verbal (not necessarily auditory) channel and a visual channel. Again, each channel has a fixed information-processing capacity and can be overloaded. Mayer presents a series of principles for designing instructional multimedia aimed to reduce cognitive effort required from the learner for one or more channels [12].

Over the last decade, similar principles have often been used in the design of multimedia systems for academic or conceptual instruction (e.g., Moons et al. [15] or Wong et al. [21]). However, unlike academics, most activities, cooking included, require less intellectual effort but require coordination of motion and sensation. The requirements on the channels of information processing thus differ. Paas and Sweller [17] argue that "biologically primary" skills passed through evolution require less cognitive effort than explicitly learned, often culturally driven "secondary" skills. Based on time of historical emergence, movement-based activities like sports and cooking should be more primary than many fields of academics. On the other hand, Post et al. [18] find that gesturing while watching grammar-instruction animations interferes with learning, and grammar could arguably be a primary skill. Moreover, interference from over loading could be bidirectional, for it is well established that secondary in-vehicle activities such as phoning or texting compromises driver's ability to react to road conditions, leading to injuries and fatalities [7].

Several questions arise, yet few studies have directly investigated the cognitive load effects of teaching tools in non-academic situations. In a rare study, Khacharem et al. [11] investigate the cognitive load effects of animations used for soccer instruction and find that novice players process both static images better than animations and slow animations better than fast ones, whereas expert players learn more effectively with fast animations. Their results suggest that speed and motion from instruction alone can add additional tolls on cognitive load, but these instructions were conveyed offline, as opposed to during gameplay.

The body of literature on cooking instruction is similarly patchy. Recipe recommendation and generation are well documented in the literature [10, 20, 19]; many such systems have been built but do not assist users in making the recipe. Few formal research investigates the cognitive load of cooking, and few systems seek to address the possible overload. Kraft's iFood Assistant [3] and Quasar Computing's Cook Assistant Lite [9] seem to share our goals, but their design choices and user test results, if any, are not documented.

Though not a formal academic study, the *Modernist Cuisine* series of Myrhvold et al. [16] uniquely takes a more intellectual approach to recipe presentation. To ease the cognitive load of cooks, the authors radically redesign the structure and order of presentation of print recipes: they alter the textual and graphic formatting to highlight key ingredients, times, and tools, they break down recipes into smaller, logical, often parallelizable units with clear time estimates, and explain the underlying principles behind steps. This work comes closest to our goals. In this work, we seek to formalize the design patterns used here and adapt them to a multimedia interface.

PROCEDURE

We used an iterative process to develop our design. We began with preliminary paper prototypes to gather our initial thoughts on the interface. Then we conducted experiments of novice cooks following non-interactive online recipes that they had not previously encountered (see Figure 1). With these observations in mind, we iteratively refined our paper prototypes and developed a first digital prototype system. We then observed novices using the prototype, and used our observations to refine our system.

INITIAL PAPER PROTOTYPES

The initial genesis of this project came when we noticed there was not a significant transformation of recipe presentation by means of technology. Initially, we developed several low fidelity paper prototypes in order to gain early insights into a design. Figure 2 shows an example of our paper prototypes overviewing a recipe interface, and Figure 3 illustrates a single step of the recipe interface. Initially, we envision to add features such as text-to-speech instruction, timer for managing multiple simultaneous tasks, reminders to check oven and stove temperatures, and many other features that can be assisted by advanced technologies. However, as we progressed

Figure 1. Observing Subject #1

our experiment, we realized there were more fundamental issues in traditional recipe presentation. The next section describes our experience observing novice chefs cooking, and presents fundamental challenges in traditional recipe presentation.

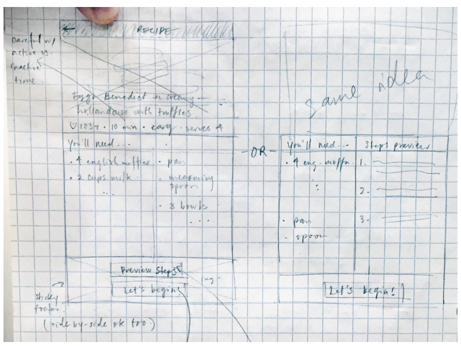

Figure 2. Recipe Overview Interface

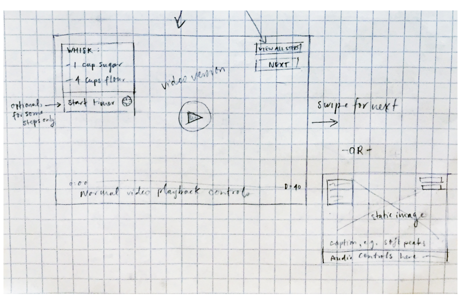

Figure 3. Recipe Step Interface

USER STUDY #1

For the first experiment, we observed three subjects. The experiment was conducted as follows: each subject was asked to cook a dish that he/she had never made before. We asked subjects to narratively describe the process that they are taking. The subjects' responses, behaviors, and surroundings were documented and occasionally recorded on pictures and videos.

Subject 1

Subject 1 had very little experience in cooking. His primary source of meal was delivery or prepackaged food. For the experiment, the subject was asked to cook Ravioli with Creamy Sun-dried Tomato and Basil Sauce [8], which the subject had no prior experience in cooking.

One of the first things we noticed upon observation of the subject was the organization of ingredients. Prior to cooking, the subject put out all ingredients that were listed in the recipe and measured their accurate portions. Even though all ingredients were measured accurately *in the beginning*, he roughly guessed portion of ingredients using mugs and bowls *while cooking*. After preparing all ingredients, he started boiling ravioli with sliced tomatoes. There were minor confusions on how much water to put in to cook ravioli and what shape tomatoes need to be cut but these issues were easily resolved based on the subject's prior experience and analyzing the final image of the dish.

Every time the subject completed a task (e.g., slicing tomatoes), he looked at the recipe, found the position of the task he has just completed in the paragraph, and read the next step. Over the course of cooking, he looked at the recipe more than 20 times where each reading took a good amount of time trying to find the position of the step he has completed in the paragraph. The subject remarked, "I have to constantly read over the paragraphs to see what step I am currently on." One interesting observation is when the subject did not look ahead. The subject mistakenly used all ingredients when some were needed again in later steps. The subject commented: "My assumption is, unless it is specifically stated to save some for later, put all ingredients in. It would have been helpful if recipe is structured in a form that is easier to see what ingredients are coming ahead." While closely reading individual steps were well-comprehended, coordinating such task while multitasking did not work well at all. Evidence of this was given when the subject was missing steps.

After cooking, we found that all ingredients (including the ones that were no longer needed) were kept in open air as shown in Figure 4. The ingredients were kept open and outside for an additional hour even after the completion of cooking.

Figure 4. Ingredients were kept open and outside

Subject 2

Subject 2 was a relatively experienced cook. The subject was asked to make Spaghetti Squash Gratin [4]. She had experience roasting spaghetti squash, but had no prior experience preparing this recipe.

She spent about one minute reading instructions and realized that Roasted Spaghetti Squash ingredient required significant preparation. After preheating oven and heating water, she read instructions again to scan for instructions that could be done while the oven preheats and the water boils. After preparing for all ingredients, she read the entire recipe again, from beginning, to re-evaluate her process. The subject continuously multitasked while cooking (e.g., prepped flour while waiting for liquid solution to reboil). Timer was used only for ingredients that may burn (e.g., warming milk). While cooking, she continuously read the recipe to to reassess her own mental process for cooking the recipe.

Similar to Subject 1, Subject 2 repeatedly read/scanned entire recipe, often standing idle, contemplating how to go about executing recipe. Time spend reading the recipe ranged from 30 to 90 seconds. Unlike Subject 1, Subject 2 took more control over reading the recipe instruction, and did not completely rely on the presented ordering of the recipe. Furthermore, Subject 2 reviewed past instructions to determine if she has made any mistakes. While observing the subject, we realized there was a significant gap between the number of steps carried out by the subject and the number of steps.

While whiskering flour into liquid solution, she encountered unexpected situation where flour started clumping. Later, she realized that the amount of sage she used was incorrect. Similar to Subject 1, Subject 2 read individual steps of recipe multiple times, however coordinating instructions while multitasking led to mistakes in keeping track of active ingredients.

Subject 2 was relatively comfortable improvising instructions for current needs. For example, when pot called by recipe was too small, she improvised by mixing spaghetti squash and liquid/flour mixture in a larger container.

Subject 3

Subject 3 also had some experience in cooking. The subject was asked to make Mushroom Ravioli with Goat Cheese from scratch [2]. The subject did not have prior experience making the dish and unexperienced working with dough.

Subject began by skimming both recipes. He commented that he likes to "parallelize" when cooking to minimize time spent, and to do that, he needs to read all steps a few times to process them and decide what to do first. Noting that the filling needed to cool before being wrapped, and that the dough preparation really only had 20 minutes of downtime, he decided to first prepare the filling and then move on to the dough.

The subject referred back to the recipe at least twice in each step, often once every couple of ingredients (and some steps had many ingredients), to double check the quantity and amount of time necessary to process each. Each time he checked the recipe, he only glanced at it a second or two, skimming for key numbers.

Making and rolling dough was a challenge, because the subject had never before worked with pasta dough. Here, he still followed the recipe step by step, but referred to it more to understand how to work the dough rather than what to put in it. As a result, each recipe check was longer and more involved; he read the sentences of the recipe and scrolled back and forth to check the pictures.

Next came filling and wrapping the ravioli. He first unsuccessfully skimmed both recipes looking for specifics on the optimal ratio of filling to dough, as well as how large to cut the ravioli. He then Google searched quickly, before deciding that it was useless since nothing was to scale and decided to just use "gut" and his prior experience with Chinese dumplings. He did not need to consult wrapping instructions after that point.

The last step written on the recipe was to boil the ravioli. This he did without consulting the recipe. He did wonder aloud when the ravioli would be done but decided that he'd just wait until a bit after they floated, like dumplings. As per his "parallelization" tactic, he set the water on a boil when he still had a few more ravioli to wrap so that he could get moving immediately when the ravioli were ready. He commented that it would be faster to have started boiling the ravioli in batches, while more of the ravioli were still unwrapped, but that it was unimportant because boiling time was so short.

Evaluation

As a result of these observations we found that existing curation of a recipe was very difficult for the novice users to comprehend while cooking. Subjects repeatedly read and scanned the entire recipe. Novice subjects had a lot of difficulty remembering the current step within the paragraph and spent significant amount of time keeping track of current and upcoming steps. Additionally, there were poor connections between recipes that were parts of one dish. These observations were further corroborated in our interface evaluation.

Based on these observations, we decided to focus on the curation of recipe instructions and ingredients.

SYSTEM DESIGN

After gaining this background knowledge, we developed a new interactive prototype that focused on curation of recipe instructions. From the user study, we found the difficulties of identifying current step in traditional recipe design. In our proposed interface, we included a feature that highlights the current step. We expect highlighting the current step will reduce the cognitive load of users, because they no longer need to scan the entire recipe to identify the step they have just completed. The position of the highlighted box remains consistent throughout the instructions. We further discuss the details of this feature in the later section. While highlighting the current step, our interface also presents the summary of previous and next steps. We have found that reviewing previous and future instructions are important for successful cooking but the traditional recipe design makes it difficult to quickly

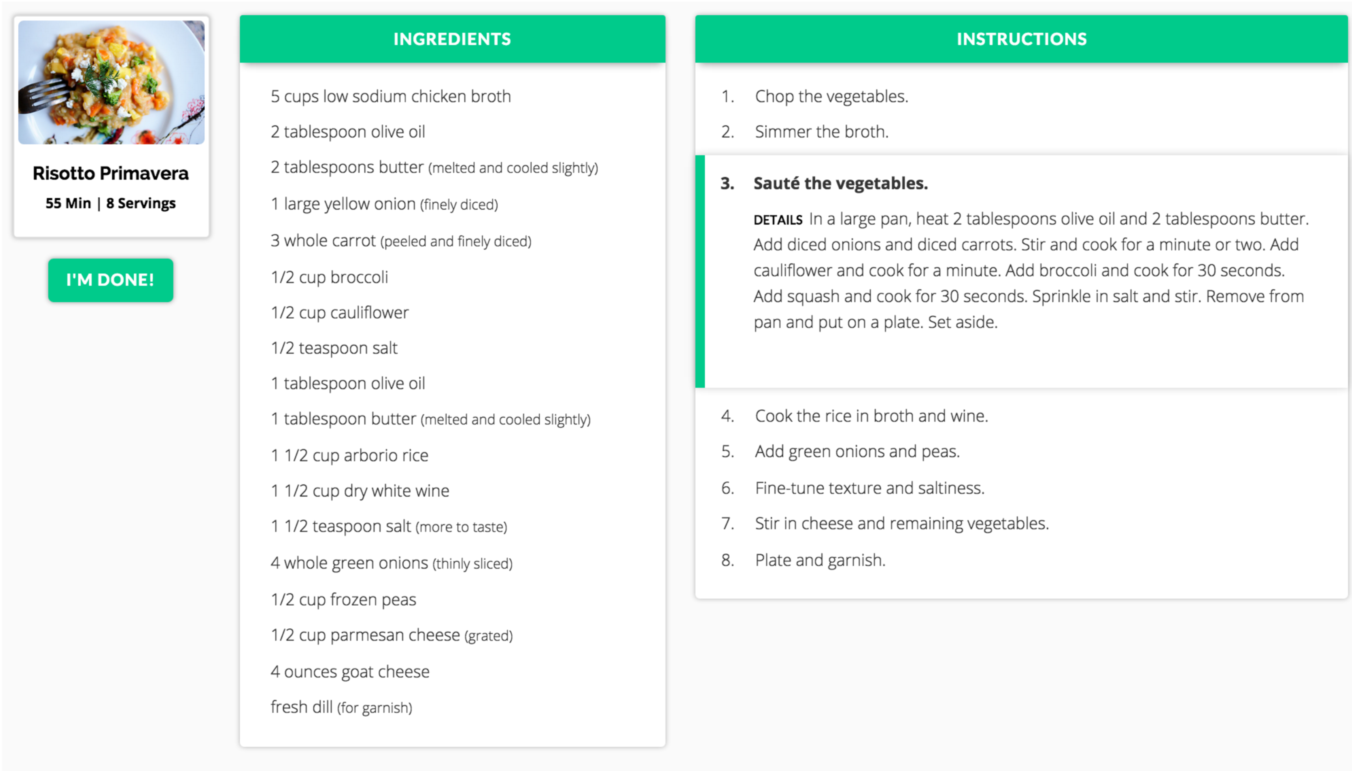

Figure 5. Example view of our proposed interface

review the steps. For that, we design our interface to only include the summary. An example view of our proposed interface is shown in Figure 5.

In order to compare effectiveness of different recipe interfaces, we developed three interactive web-based interfaces: traditional recipe interface, step-by-step interface, and our proposed interface. Figure 6 shows the traditional recipe interface curated as a list. Step-by-step interface is commonly used for cellphone-based recipe interface. As shown in Figure 7, it presents a single step at a time and allows user to click next or previous to navigate the instruction.

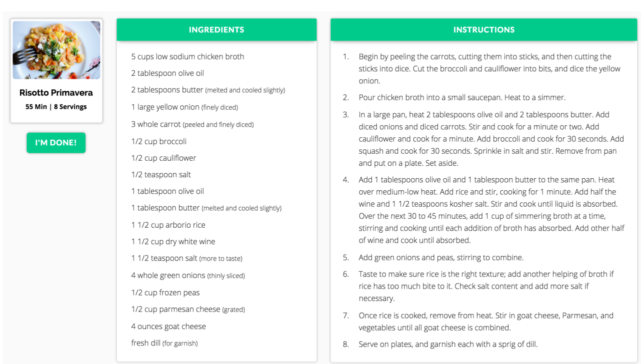

Figure 6. Traditional interface of a recipe

USER STUDY #2

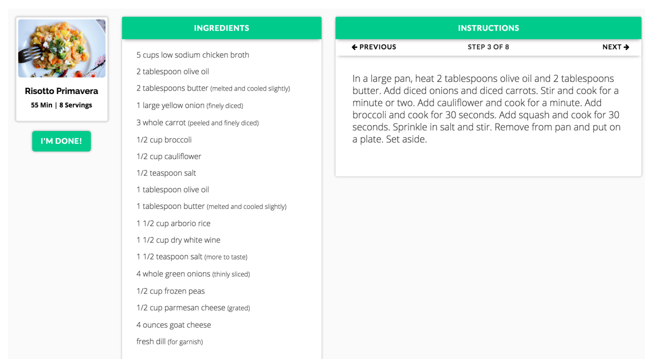

Figure 7. Step-by-step interface that is commonly adopted for cellphone application

Three subjects are observed and interviewed for this study. Each subject was asked to test three interfaces (traditional, step-by-step, and our proposed interface). We curated three recipes (risotto primavera, mushroom lasagna, and baked eggs with spinach and mushrooms) that the subjects did not have prior experience making. Subject 1 tested traditional interface with risotto primavera, step-by-step interface with baked eggs, and our interface with mushroom lasagna. Subject 2 tested traditional interface with mushroom lasagna, step-by-step interface with risotto primavera, and our interface with baked eggs. Subject 3 tested traditional interface with baked eggs, step-by-step interface with mushroom lasagna, and our interface with risotto primavera. Similar to user study #1, subjects narratively described the process that they were taking and the subjects' responses, behaviors, and surroundings were documented.

Subject #1

Subject #2

Subject #3

EVALUATION

...Compared to step-by-step interface that only showed a single step at a time, we found that presenting the entire view of the recipe provided users a sense of control. ...

DESIGN OBSERVATIONS

In this section, we describe added features of our final design, and some factors that led to its relative success.

Ingredient Highlighting

CONCLUSIONS AND FUTURE WORK

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