Design Cognition
– An Inter-disciplinary Platform Bridging Human Cognition, Adaptive Technology and Design –

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Abstract: Based on the deeper understanding of human cognition, now we can make designs less conflicting with human nature. However, the gap between design and cognition still impedes the progress of design cognition nowadays. In academia, the boundaries of disciplines make students hardly to learn knowledge of cognition, computing and design practice simultaneously. To build bridge across disciplines, I devise an innovative course, design cognition. The course bridges human cognition (including affect), adaptive technology and design to deduce design principles and constraints, which guide designs of products, services or systems to assist human living a happier life. Happier life requires more positive emotion and more appealing designs, which is also the goal of Affective design. Design cognition has an iterative, four-step course structure. It introduces the cognitive theories established in the past few decades and uses the real world examples to guide students how to apply the learned cognitive principles to discover the possible conflicts between human cognition and designs and to develop the possible design solutions using adaptive technologies accordingly. Moreover, the joint design project requiring inter-disciplinary knowledge, including Design Cognition, Affective Design, and User Study, allows students to consolidate the learned cognitive principles and reinforce the way of applying cognitive principles into design. Finally, the outcomes of students’ joined design project really show that the quality of affect and usability in their products and services are improved.

Keywords: Design Cognition, Human Cognition and Affect, Adaptive Technology, Inter-disciplinary Design Education

1. INTRODUCTION

Design normally requires the understanding of human capabilities, their work practices and the contexts so that it can improve the tasks for human, rather than demand human to change their nature ways of doing tasks. In the digital age, products have gradually been losing their physical shapes. Instead, their major functions and features are gradually replaced by apps, services or systems provided by the artifacts. Therefore, the focus of human-centered design should move from the understanding of human physical constraints, such as strength and size of human body, to human cognitive constraints, such as attention, cognition, memory, and affect. However, how to apply the understanding of human cognition (including affect), to the design of products or systems is still not clear. Here, this paper demonstrate a course, design cognition, which introduces an innovative approach to bridge cognitive science, adaptive technology and design to create products or services to assist human to live a better life.

Design is not only serve to give meaning to artifacts, but also to give meaning to human life. However, human requirements are not stable in their life. People in different time, tasks, contexts, and even moods often have different requirements. The products or services have to be flexible enough to adapt to human’s requirement in the moment. To be adaptive, the products or services need to be embedded intelligent technology so it can detect the different requirements and adjust the response accordingly. According to Gottfredson [1], “intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings – ‘catching on’, ‘making sense’ of things, or ‘figuring out’ what to do.” Therefore, future devices should be able to sense human behavior, interpret human’s intention, and moreover, respond to human emotional status.

The relationship between technology and human has to be carefully designed to ensure that adaptive technology only assist, but not dominate, human to live happier life in their everyday context. To implement it, the future products or systems have to understand human and provide appropriate services accordingly.
In order to understand how human think about the world, we need to know human cognition. According to Oxford Dictionaries Online [2], cognition refers the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses. *Cognitive science* integrates the approaches of psychology, linguistics, philosophy, artificial intelligence, education, anthropology to study how human perceives, processes, understands and responds to information in their living environment. But, how to apply the findings of cognitive science in design is always a question for both students in design and psychology. The Nobel laureate Herbert A. Simon suggests that the cognitive science can serve as the science of design [3-5], and accordingly, the design space can be defined [4]. Therefore, the approach toward intelligent living can be the integrating efforts including the understanding of the constraints of human cognition and then designing a boundedly-optimal system to support and extend users’ work practice in their living context.

Following Herbert Simon [3-5], the aim of Design cognition is to bridge human science, adaptive technology and design to deduce designs that follow the nature of human cognition (Figure 1). Nowadays, we seems know how to use the knowledge about human to adopt technologies in products that won’t conflict with human nature and tendencies. However, the gap between design and cognition still impedes the progress of design cognition. Particularly in academia, the boundary of disciplines makes students hardly to gain knowledge and skills from cognition, computing and design practice at the same time. For example, although human-centered design has been emphasized in courses here and there in design education, still there is not any one class systematically arranging the applied cognitive principles together and explicitly guiding people how to apply the cognitive principles into designs. On the other hand, although ecological validation has been emphasized in psychological science to increase the implications of the empirical findings, still people in psychology hardly have chance to apply their considerable knowledge of human cognition in real world. It is very difficult to image how to solve the real world problems when students devote to investigate human cognition without a real application of their findings.

Moreover, my personal experience shows that to teach psychology students how to design is more difficult than to teach design students about knowledge of psychology. However, teaching design students how to do a formal user studies and researches is also very frustrated. This is mostly because psychology students expect themselves to learn knowledge instead of applying knowledge and design students expect themselves to apply knowledge instead of doing research. As a consequence, our world is still full of a lot of designs that use inappropriate technologies that make our life even more inconvenient.

For example, making a cup of coffee can easily confuse people if the hi-tech espresso machine does not follow the tendency of human cognition. Do people know they should stop a machine by double pressing the same button as the start button? Do people know they should stop the stream by turning the knob before they start the machine? They may figure it out after making several mistakes or even few minor burns. The end of the coffee machine could be either that people gradually understand the machine or it becomes a decoration only. All of these small inconveniences in daily life not only decrease the experience of using but also the experience of feeling or emotion. This exemplifies the important correlation between the extent to which designs fit human cognition and their using and affective experience. The more the designs fit human cognition, the more positive emotion and using experience can be aroused. However, when we design products or services to induce positive emotion and experience, we often forget human cognition is constrained. As a consequence, a lot of time, hi-tech products or services are only built for showing off technology rather than for human nature.

Here, I demonstrate an innovative course, design cognition, which integrated cognitive science, engineering psychology, and human factors into a comprehensive design education and practice program. It also considered the rationale of using technology. The course, design cognition – the approach of integrating human cognition (including affect), design and adaptive technology to create products or services.
cognition, devised an iterative, 4-step course structure (Figure 2) to approach the integration. In the first step, the course introduced the cognitive principles found in the past few decades. In the second step, the course used the examples to show students how other pioneers adopted cognitive principles to analyze the work practices in the everyday context, and how they discovered the conflicts between human cognition and the design. In the third step, students really practiced how to apply cognitive principles, learned from each lecture unit, such as perception, attention, memory and so on, to discover the problems of their everyday living space and to develop the design solutions. This course design can allow students to consolidate the learned cognitive theories via really applying them to design practice. In the final 6 weeks, students of design cognition would be separated into several design projects which require inter-disciplinary collaboration from Design Cognition course, Kansei course and User Study course.

The course is designed to teach students how to integrate cognition, technology and design into a comprehensive design process and practice via an iterative, 4-step structure. In the future, the iterative, 4-step structure can server as an example for other courses which intend to integrate inter-disciplinary knowledge into a complete course. I expect that this method can be dispersed among all relevant disciplines in human science, design and adaptive computing.

2. COURSE CONTENTS AND OUTCOMES

According to Wickens (1992) “the aim of engineering psychology is not simply to compare two possible designs for a piece of equipment ... but to specify the capacities and limitations of the human ... from which the choice of a better design should be directly deductible” (pp.3-4, Wickens, [6] cites Poulton [7]). Following Wickens, our course includes an iterative, 4-step course structure (see Figure 2) to guide students how to deduce a better design from the understanding of human capacities and limitations of information processing. The following paragraphs introduce this structure step by step.

2.1 Introduction of Cognitive Principles from Empirical Findings

Fundamental psychological and cognitive principles introducing the human capacities and tendencies on information processing were included in the first part of this course. It also included human factors emphasizing on how to optimize performance in real world tasks. And, the engineering psychology introducing theory-guided researches motivated by applied needs was also included. The goal of the first step is to understand the major cognitive theories from the empirical findings of human information processing and performance and their possible design solutions. The lecture’s range was from sensory processing, perception, memory, action selection and execution, and feedback to attention engaged in every stage of human information processing (see Figure 3a). Each week, a unit of human cognition, such as sensory information process (see Figure 3b), was taught based on the framework of human information processing (see Figure 3a). Figure 3c shows a few sample slides of cognitive principles, human factors and engineering psychology taught in design cognition.

2.2 Introduction of Designs Guided by Cognitive Principles

Students from design school often find that it is difficult to learn theories without examples. In this course, the cognitive principles were introduced by lots of real life examples. Most examples were re-designed from the book, “Engineering Psychology and Human Performance” by Wickens and Hollands [8], and the book, “Universal principles of design: 125 ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design” by Lidwell, Holden and Butler [9] and the slides and the materials of new empirical findings used in my previous lecture, “engineering psychology and human performance” in the department of psychology at the University of Illinois at Urbana-Champaign. There were lots of real life design examples showing the implications of cognition theory for design – from small scale, such as maps and the
routes in space, to large scale, such as the complex systems of nuclear power station. The goal is to guide students to learn how to apply cognitive principles to improve the designs of products or service systems. Figure 4 illustrates sample slides of real world designs guided by cognitive principles.

2.3 Practical Evaluation of Designs by Cognitive Principles

After each lecture, students were asked to practice how to apply the taught cognitive principles from each week lecture to evaluate human behavior and artifacts in their everyday context. Students had to choose the context which they are interested in to explore in the first two weeks of the course. Each student group used the learned cognitive principles in the lecture to evaluate whether the designs in the selected context are good or not. Generally, they chose their daily work practices in the context close to their living environment. For example, they chose to observe and discover the hidden confictions of cognition in teashops, music stores, kitchens, and convenience stores. Especially, a group chose to visit and explore a zoo in their hometown.

Apart from the reports of the observations, students proposed the possible design solutions that follow the learned cognitive principles. For example, they found that the signs in the zoo are confusing to visitors so that people got lost easily. Another team found that products

Figure 3: a. Framework of human information processing. b. The unit cognitive theories. c. The sample slides of cognitive principles from empirical findings taught in the course, design cognition.
in the convenient store should be rearranged so that customers could find what they want faster and easily. Figure 5 shows some samples of students’ works in the practical evaluation of designs. Students could learn how to evaluate designs and develop potential solutions based on the cognitive theories and design principles in this step.

2.4 Interdisciplinary Collaboration in Practical Design Project

In the last six weeks of the total 18-week course, each student in design cognition joined a design project with other students from the other two courses, Introduction of Kansei and User Study. The Introduction of Kansei is a course about how information can be sensed, processed, and felt and how to bring positive affect in the artifacts and the User Study is a course about how to understand users. In total, there were eleven inter-disciplinary design teams. Each team had students from three different backgrounds.

Students were encouraged to bring their own perspectives learned from their original course to the joined design projects. They also learned how to discuss with people who have different perspectives and ideas and learned how to integrate these ideas into a design.

Figure 6 shows some samples of students’ works in the inter-disciplinary design projects. For example, a group used the principle of operant conditioning – “a technique used to modify behavior by reinforcing desired behaviors, and ignoring or punishing undesired behaviors [9]” to encourage people to park their bicycles in the correct line. A group suggested the usage of color should consider the color blindness people. A group used cultural awareness method to arouse the living status of fishermen and related people working in the fish market. A group used the bandwagon effect to redesign a recycle trashcan. The new design allows people to easily perceive the cue which indicates what kind of trashes should be in the can and as a consequence, people can easily do the recycle in their nature way. It is worth mentioning that one group used the
salient red color to attract people when they served free Chinese tea for local people who are doing their activities, such as running a dog, walking or doing Tai-Chi, in a campus park. Interestingly, the red color served as happiness in Taiwan culture. Local people said that this service design arouses lots of their positive emotions and the service was full of high value of affect.

3. DISCUSSION

In the design cognition, students were taught how to apply cognitive principles to design products or services. They learned how to use the cognitive principles to constrain the usage of the adaptive technologies. For example, in the inter-disciplinary cooperative project, student design teams evaluated the work practices to discover the possible conflicts between human cognition and the artifacts in the living context by observation, contextual inquiry, and team brainstorming. Then, based on the insights from the discovery, students developed the possible solutions with potential adaptive technology. Students were not only asked to discuss how to apply cognitive principles to designs in each lecture, but also they were required to present a complete design that can reduce cognitive load and improve human life in the chosen living space. They also make a small video to show the scenarios about how their designs can be used in the context and, in particular, how technology can be designed to adapt to the immediate requirements of human to increase the happiness in human life.

Moreover, design cognition also introduced the scientific methodology and adaptive technology in the course. The first half of the lecture in each weekly course focused on the introduction of the cognitive principles and the experimental methods related to the findings of the principles. This setting allowed design students to learn how to use formal scientific methodology from psychology and cognitive science to approach the hidden design questions related to human cognition. Engineers often arbitrarily estimate the requirements by their own experience and use try-and-error to find the solutions. This way often misses the real but hidden requirements of users,
particularly users’ affective needs. Design cognition is a course to teach students to use technology to mediate human work practices in living space, rather than increase the loading of their work. In the course, students learned that each design is a single hypothesis of the design problem so that experiments and contextual inquiries are required to prove that the design is the bounded-optimal solution toward the problem. They also learned how to use the adaptive technologies to deliver the solutions to the design problems.

4. CONCLUSION

According to Moran and Carroll [10], “design rationale is the notion that design goes beyond merely accurate descriptions of artifacts, such as specifications, and articulates and represents the reasons and the reasoning processes behind the design and specification of artifacts”. Not only the comprehensive understanding the reasons behind the design, Design cognition, an innovative course that I propose here also tries to provide a way to bridge cognition and affect, design and adaptive technology to deduce better design solutions in human life. Design cognition is a general concept that can be applied to the designs of artifacts for any people and any work practices in any contexts. It can give designers the foundational perspectives and enhance the design rationale into a design. In design cognition, students from both psychology and design background can learn how to apply cognitive principles to design. They can learn from each other to go beyond their original boundaries in their discipline.

In the future, the proposed iterative, 4-step course structure can be served as an example about how to integrate inter-disciplinary knowledge into a course, in particular, for the inter-disciplinary course emphasizing on both theory and practice. Our course outcomes were very rich. Most groups applied one, two or more cognitive principles in their final joined design projects. The application of cognition to design really improved the quality of their designs, particularly in the aspect of affect and usability. The eternal goal of design cognition is to disperse itself among all the relevant disciplines in the

Figure 6: Samples of students’ works and activities in the interdisciplinary collaboration in the practical design project.
future so as to create a better and happier smart living environment. Therefore, my next step is to make the course into several small modules so that they can be more easily integrated into other courses.

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REFERENCES


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