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I, Jianzhou Song, hereby submit this original work as part of the requirements for the degree of Master of Design in Design.

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Intelligible Interaction Design
-Developing a design tool to help designers find the problems in existing product interaction and reduce the mental effort exertion.

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Intelligible Interaction Design

Developing a design tool to help designers find the problems in existing product interaction and reduce the mental effort exertion.

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Abstract

People need to interact with many different products every day to make sure all their needs are satisfied. A product should explain itself instead of forcing users to seek help from the product instructions or other people. A key role of design is to reduce user effort. However, identifying problems in the product-user interaction scenario is complicated and difficult. This thesis attempts to develop a design tool to help designers find the problems more efficiently so that they can improve the design of the user experience.

This thesis is focused on user interactions, which are result-oriented, and the goal is to design a methodology to reduce the mental effort exerted by the user. In analyzing the anatomy of existing interaction and human perception models, it was determined that none focused specifically on the consideration of mental effort. This research and analysis led to the conclusion that a mental effort evaluation model would be of value to designers. MEE Model was developed and presented here, which examines where and how mental effort is exerted in an interaction process.

The two major causes of mental effort exerted are interaction complexity and interaction difficulty. Complexity refers to the number of phases in a process, and difficulty refers to the mental effort exerted in completing a single step in the process. The MEE Model is intended to help designers determine in more detail why complexity and difficulty happen, and how to avoid them by simplifying the user interaction.

The MEE Model is designed to allow designers to observe the users engaged in the interaction and then through interviewing the users, systematically
evaluate the users’ experience and use that data to improve that experience. In this way, they can locate and prioritize the problem areas, and then try to reduce the exertion of mental effort. As an example, this model is applied in the actual interaction design process to help find the problems and also give potential solutions about how to make better interaction in terms of reducing mental effort exerted. The MEE Model was tested by 24 design students, who were chosen because they might offer criticism and insight for improving the design of this model. The results of that test are shown and discussed.
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Chapter 1

Scope Definition
All the human interactions can be separated into different categories from different perspectives. Evaluation criteria are also different between different categories. The design scope should be clarified before talking about how to make better interaction. In this thesis, I focus on the result-oriented interaction and explore how to reduce the mental effort exertion during the entire interaction process.

1.1 Result-Oriented Interaction

Users interact with products for different aims. Some interactions are process-oriented. It means that users derive benefit from the act of engaging in specific activities within the process rather than only achieving the desired end result. For example the aim of working out is to make the body fit and strong by lifting weights. In this situation, users are willing to exert their physical effort during this “lifting” process. However, it will be totally different when the interactions are result-oriented. The grocery store employee needs to lift the products to the shelf. In this situation lifting weight is a result-oriented interaction. The employee hopes that the products are as light as possible so that he can save his physical effort. The comparison tells us that users will value effort exertion during the process-orientated interaction but will avoid effort exertion during the result-oriented interaction. If users have to exert a lot of effort during the result-oriented interaction, they are likely to have an unpleasant experience (Figure 1). Sometimes, an interaction can be result-oriented or process-oriented
based on different situations. Riding a bicycle is a very good example; some people use a bicycle so that they can research their destination more efficiently (result-oriented interaction) while others will choose a bicycle instead of a car because they view riding a bicycle as a very good way to keep them healthy.

In this thesis, results-oriented interaction in which users want to spend as little mental and physical effort as possible during the interaction process, is focused upon.

![Figure 1: A door with a maze lock.](image)

**Figure 1: A door with a maze lock.** People like to play with mazes because it is a process-oriented interaction. However, a door with a maze lock will definitely frustrate people since opening a door is a result-oriented interaction.

### 1.2 Mental Effort Focused Interaction

During the result-oriented interaction, effort exertion should be as little as possible. As such, I have focused on the mental effort exertion during the interaction process. I believe that there is great opportunity to pay closer attention to this problem.
Product explosion

There might be something you don’t know about the phone’s microphone control, which is a very simple product. For example, if you hold the button of the microphone for 2 seconds, the phone will play music automatically; if you double click the button, it will lead you to the next song; double clicking and holding means fast-forward; triple clicking and holding means fast-rewind and so on. This is just one simple product within a complex landscape of many products that you need to interact with over the course of a day. Actually, you will be surprised by the numbers if you try to list every interaction you need to have with different products everyday. There are too many objects that people need to know how to use in order to satisfy their everyday needs. Psychologist Irving Biederman estimated in 1987 that there are probably “30000 readily discriminable objects for the adult”[1]. Today, the number definitely will be much larger. One can easily imagine all of the interaction around these products.

Physical effort relief

Technical progress has meant that sedentary operators perform more activities, which require information processing, decision-making and problem solving as opposed to activities involving physical effort[2]. More and more manual labor has been transferring to mental labor. Instead of exerting a lot of physical effort to finish the work, people have to deal with high technology machines, which require more mental energy to operate. Because of this, reducing the mental effort for the users has become a more serious problem than reducing physical effort.
A high degree of required mental effort creates many problems

In recent years, users can easily become exhausted when trying to figure out how to interact with products. Sometimes they don't know how to use the product, even worse, wrong interaction will bring serious damage to both the users and the products. Some research also indicates that heavy mental effort leads to bigger meals \(^3\).

Design opportunity

The development of new technology creates the possibility of making some interaction, which was previously thought to be satisfactory, much better. We can reduce the mental effort exerted during the interaction process dramatically by utilizing the right technology into design. You will see some examples of how technology contributes to the interaction evolution in terms of reducing the mental effort exerted during the interaction process. We need to develop an efficient way to find the problems existing in the interaction process so that we can apply the right technology to solve the problems.

From the effort exertion perspective; interaction can be separated into mental exerted interaction and physical exerted interaction. It can also be split into process-oriented interaction and result-oriented interaction when we consider which part is more valuable to the users. This thesis focused on reducing the mental effort exertion for the process-oriented interaction process (Figure 2).
Figure 2: Scope definition.
Chapter 2

Understanding Interaction
2.1 Interaction Anatomy

Researchers have tried to understand the interaction process by setting up different interaction models. One of the classical charts is designed by Redmill and Rajan in 1977 (Figure 3). In this model, they set up different stages based on different action holders, which are human and machine. Each action holder operates three stages to make the whole interaction process flow.

![Figure 3: Human-Machine interaction chart (adapted from Redmill and Rajan, 1997).](image)

This is an effective model for understanding single-phase interaction. However, the actual interaction process is much more complex and involves a lot of phases. The Redmill and Rajan model potentially ignores problems caused by the involvement of multiple phases. Also, it is a general analysis of the interaction process, not only just focused on the modeling effort exertion. Those are the issues, which need to be considered.
The interaction process in this thesis not only considers the physical interaction users apply to the products; it includes discussion of all the information transduction stages between users and products. Therefore it is about the human perception, physical interaction and also product reaction.

How users will interact with the product mainly depends on the perception process (Figure 4). It is defined as the “process by which individuals select, organize, and interpret the input from their senses to give meaning and order to the world around them”[5]. Selection is the process by which you select or choose what you want to attend to and what you want to disregard, while organization and interpretation is the process by which you understand information and attach meaning to it[6]. The selection process can be viewed as information hunting and the organization and interpretation process is about information processing.

![Diagram](image)

Figure 4: Human perception model.

The physical interaction stage is about how users control their bodies to conduct the decision made in the brain, while the product reaction is about how products process the human physical interaction and present the reaction.
Human–machine interaction, as all other interactions of persons with their environment, involves a continuous exchange of information between the operator(s) and the machine [4]. The essential reason why users need to apply their physical and mental effort during the interaction process is because products and users are using different “languages”. Users need to “understand” products’ “language” and then “speak” that “language” so that products can understand and have the desired reaction. The more users need to “understand” and “speak” the products’ language, the more effort users need to apply to the interaction process. So, in this thesis the aim of interaction design should let the product “speak” human “language” to deliver information to the users and then “understand language” to have the desired reaction.

There is a every good example to support this idea, when the computer came out about 60 years ago, it was a very complex machine that could only be operated by the scientists, but now even the 5-year-old kids can play games with the I-pad. Why? Because the first computer requires you to talk with it in “machine language”, users needed to acquire hundreds of meaningless codes in order to understand the computer language and tell computer what they wanted it to do. While today, you can use your finger to do all kinds of gestures to control the computer, which is almost like our “own language” and the computer output is human language or familiar patterns, easily understood by the users. That is the evolutionary direction of interaction. In the future maybe you can talk with the product just like you talk to yourself, whom you understand most and understand you most.

Based on the analysis of the human-machine interaction model and perception model, an interaction anatomy model focused on understanding the
effort exertion in the entire interaction process was established (Figure 5). In the information hunting stage, information transfers from the product to the users. In the information processing stage, information hunted from the products will transfer to the decision and then this decision will transfer from users to the products through the physical interaction stage. In the end, this received interaction will transfer to the product reaction through the product reaction stage.

**interaction anatomy model 1**

![Diagram](image)

**Figure 5: Interaction anatomy model 1**

So, in one phase, when users have the motivation of interacting with the product, they will first look for information, which supplies the clues about where and how the users should interact with the product. The relevant information coming from the products is processed by the human brain to become information users can understand so that they can decide what controlling actions are needed. After that, the users will control their bodies to enact the decision and the product will be driven to present the desired reaction.
In most cases a whole interaction process includes several phases in certain sequence until the desired product reaction is achieved. Because of this, it is very important to consider the whole interaction process instead of just one single phase if we want to evaluate the mental effort exerted during the interaction process. One important feature in this model is the consideration of interaction as the process of several phases combined (Figure 6). In this way, the influence of multiple phases in the exertion of mental effort can be clearly presented.

**interaction anatomy model 2**

![Interaction Model Diagram](image)

**Figure 6: Interaction anatomy model 2.** An interaction process starts from user’s motivation and ends at the desired product reaction

![Door Entry Diagram](image)

**Figure 7: Entering a room**

- **Insert the key**
  - 1a: Information about the keyhole
  - 1b: Decide how to insert
  - 1c: Insert
  - 1d: Key fits the keyhole

- **Rotate the key**
  - 2a: Information clue about how to rotate
  - 2b: Decide how to rotate
  - 2c: Rotate
  - 2d: Unlocked

- **Open the door**
  - 3a: Information about how to open
  - 3b: Decide how to open (push, pull, slide, where to interact)
  - 3c: Open the door
  - 3d: The door is open
2.2 The measurement of mental effort

Much research has been done to evaluate the mental effort exerted during the interaction process. Basically, those techniques can be organized into three categories. Self-assessment or subjective rating scales; Performance measures; and, Psychophysiological measures. It has already been noted that different measures are sensitive to different aspects of workload and not all workload measures are assessing the same thing \[7\].

Based on all of the research and also the interaction model we know that two characteristics of difficulty and complexity will affect the amount of mental effort exerted. Difficulty means the mental effort exerted in single phase and complexity means the number of phases in the whole interaction process.

Further more, the various research methods help in better explaining the characteristics that will cause the exertion of mental effort in each stage.

2.3 Mental effort exertion from interaction difficulty

In each single phase, much mental effort is exerted because of the difficulty of interaction. From the interaction anatomy model 1 (Figure 5) we understand that only the product reaction stage is the process without the involvement of mental effort. We need to consider all the other three stages to understand the complexity of interaction.
2.31 Information Hunting

Information hunting is the process of information transferring from product to the users (Figure 8). In order to interact with the products, users need to look for clues from the products to help them understand how to interact and where they should interact. An example can be finding the keyhole before you insert the key or looking for the handle of a tool for holding. Products are full of all kinds of stimuli and only some of them are helpful for us to accomplish certain interaction. Perception is selective. Users are not aware of everything that is going on around them [7]. They need to concentrate their mental effort to find the relevant stimuli among numerous ones. So the more easily the users can find the relevant stimuli, the less mental effort is needed for this stage. There are several factors that will influence the hunting of information and should be considered by the designers when they evaluate the information hunting stage.

Figure 8: Information hunting stage
• **Information unfamiliarity**

Information unfamiliarity can be viewed as the internal factor that will influence the information hunting. A substantial volume of psychological research reveals the importance of top-down processing [8], which means users’ expectation, experience and so on, will influence the perception process.

Information will more easily get users’ attention if users know what they are looking for to some degree. “People only see what they are prepared to see.” (Ralph Emerson) is supported by a lot of scientific research. In many cases, we might focus on stimuli that are familiar to us [9]. Such as people will be sensitive to the face of a friend in a crowd of strangers in the park. When users have no idea what they are looking for, the perception will be more like a bottom-up process, which means external factors from the products will determine the mental effort exertion in information hunting stage.

• **Lack of intensity**

The intensity of information is one of the external factors that influence the information hunting. Relevant information should be obvious enough for the users to find. The more obvious the information is, the less mental effort is required in the information hunting stage. Information intensity can be achieved by colors, size, contrast, repetition, motion and other physical characteristics (Figure 9). The problem of this is that the intensity of one might be helpful for certain interaction, but it will probably become the interference of others. The application of information intensity should be done very carefully.
Figure 9: Staples easy button. Staples easy button use bright color to get users’ attention.

• Information interference

Another external factor is information interference. The information interference includes two situations. One is that relevant information is disturbed by some more intense information. This situation is caused by the inappropriate application of information intensity mentioned above. Another situation is that the relevant information is disturbed by similar information, meant to be helpful for another interaction. Both of these two situations require a lot of mental effort input to eliminate other irrelevant information. There are a lot of examples of this situation. An interface with a lot of similar buttons is really hard for users to find the right information (Figure 10). Another example is the brake and gas pedal of a car. That is why drivers will step on the gas pedal when they want to stop and can cause a horrible accident. We will discuss this situation in details later.

Information interference also will influence the information intensity at times. In order to avoid interference, we should make all the information different with each other. However, this will weaken the effect of information intensity since when everything is special, nothing is special.
So there should be a balance between interaction intensity and interaction interference.

**Figure 10: Information interference.** A product interface has a lot of similar buttons with different functions.

2.32 Information Processing

**Figure 11: Information processing stage**
When the relevant information enters the human brain, with the input of mental effort, it will be processed and will help users make the interaction decision (Figure 11). This is the most important part during the whole interaction process when we consider the mental effort exerted. The relationship between information and decision can be categorized into six different groups when we consider the amount of mental effort exerted from low to high (Figure 12).

![Information processing hierarchy](image)

**Figure 12: Information processing hierarchy.**

**Natural Processing**

Natural processing is the individual’s innate qualities. Information will be processed automatically. It is fast, not conscious, and rigid, requiring almost no resources or attention and can be performed in parallel [10]. It doesn’t need the information hunting stage. It is the reaction of human body to the outside environment stimuli, if a product interaction can be embedded into the natural process, it will reduce the mental exertion to zero in most cases. Such natural processing can be a reflex motion caused by cold or fear or excitement, reflex changes in the eyes that enable an object to be focused on the retina, and so on. An excellent application of natural processing is the operation of Segway. Users
can just lean their body backward to stop the Segway. This behavior is also human’s self-protection natural behavior, which means that almost no time and mental effort is required for people to make the reaction. The application of natural processing in the interaction of Segway helps users to avoid some accidents every efficiently.

**Second Nature Processing**

The term second nature is used to describe that the behavior operation is almost like natural processing. It is also an automatic process; the difference is that it is not innate and follows frequent, consistent practice \[^{10}\]. When a movement is repeated over time, eventually it can be performed without conscious effort. This process decreases the need for attention and creates maximum efficiency within the motor and memory systems. An example is how driving has become second nature to drivers, typing on the keyboard of a computer requires almost no mental effort for experienced computer users. Riding a bicycle is also second nature once you have learned how to ride. Another term that has been used to describe this phenomenon is muscle memory. The repetition can make many interaction behaviors, even the most difficult ones become second nature, but at the same time, it also means that whether a behavior is second nature depends on different users. It is hard to judge one interaction behavior while ignoring the particular user.

**Familiar Processing**

When familiar material encountered is perceived to be easily understood, regardless of whether it actually is easily comprehended, individuals tend to invest less mental effort in processing the information \[^{11}\].
In this situation, users will exert their mental effort to get help from their memory, applying their prior experience to help them make the decision. Most of the affordance in design is about humans’ familiar processing. It refers to the perceived and actual properties of the thing that could possibly be used. Affordances provide strong clues to the operations of things. When affordances are taken advantage of, the user knows what to do just by looking: no picture label, or instruction is required\[13\].

For example, when users try to use the PC for the first time, it will take them sometime figure out how to think and act with “computer language”. Once they can use the computer skillfully, it is not a problem for them to switch from PC to MAC, because a lot of required operation knowledge they already know. The familiar processing helps users to find the similar characteristics between new products and experienced products so that users can make the right decision. As with other acquired processing abilities, the familiar processing also comes from study and repetition. So it also varies from user to user.

**Logical Processing**

Logical thinking is the process in which one uses reasoning consistently to come to a conclusion. Problems or situations that involve logical thinking call for structure, for relationships between facts, and for chains of reasoning that “make sense”\[14\].

Compared to familiar processing, instead of users knowing how to interact with the product by applying the existing information from their experience, users need to apply their mental effort to deduce the decision by using the existing information in their mind. The basis of all logical thinking is sequential thought. This process involves taking the important ideas, facts, and conclusions
involved in a problem and arranging them in a chain-like progression that takes on a meaning in and of itself [15]. The information process is when the users consider all the potential interactions, eliminate the interactions that will lead to undesired reactions and then make the decision can be viewed as the logical thinking processing example (figure 13).

![Figure 13: Arrow traffic sign.](image)

The meanings of the arrows are quite clear to the drivers. However, a person who has never seen this sign before still knows what those mean. Through logical thinking, he can eliminate the potential meaning of “driving to the sky” and take the right decision, which is moving forward.

The process of logical thinking is learned through osmosis or experience [16]. That is quite similar to the familiar processing. The experience that familiar processing based on is closely related to the information being processed. That means users need less mental effort to make the decision, but at the same time, the experience has less application for other information processing stages. The logical processing is quite different. The experience can be applied to more information processing stages but users need to apply more mental effort to deduce the decision (Figure 14).
Unclear Processing

When material perceived as new, unfamiliar, or complex is encountered, higher mental effort is likely \[^{11}\]. Novel and surprising material require a greater effort of processing than do more familiar stimuli \[^{12}\]. Unclear processing is the main reason that drives the increase of the mental effort exertion of users’ everyday interaction (Figure 15). In order to have the desired product interaction, users will exert a lot of mental effort to consider the potential interactions before they try to interact with the product. There is a high possibility they will fail and start over again. This is similar with adding one or more phases to the entire process, increasing the complexity of the whole interaction process. This will be talked about in the complexity issue of interaction later. The unclear processing is a very serious issue that result-oriented interaction design should try to avoid.

Figure 15: Electric door lock in the car
Misleading Processing

The required product interaction is different with users’ existing cognition. For example, you pull to open a door but it turns out that pushing is the right interaction (Figure 16). You twist a video’s volume knob to turn down the voice, but the voice is even louder. In this situation, the expected reaction does not show up, even worse, the opposite reaction happens sometimes. Misleading processing will bring very serious problems. First, like the unclear processing, it will add one or more phases to the whole interaction process. Another problem is that the confused interaction will weaken users’ existing cognition and influence their decision-making when they interact with another product next time.

![Figure 16: Misleading processing.](image)

Information Processing Evolution

The evolution enables human being an important ability that is reducing the effort exertion for the same behavior through repetition. A person will strive to minimize the probable average rate of his work-expenditure (over time). And in so doing he will be minimizing his effort [17]. Certain information processing can
transfer to a higher level through repetition. The relationships can be seen in the chart (Figure 17).

![Diagram showing processing evolution from misleading to natural]

**Figure 17: Processing transformation**

For the information processing, interaction design should achieve the familiar level or better, avoiding the unclear and the misleading processing. Designers should also be aware that only natural processing is the human innate quality. All the others vary from person to person based on different experience. In order to understand certain processing behavior, user testing is very necessary. Also, when a certain interaction design is supposed to achieve a better processing level, we should make sure that the target users share the same experience.
2.33 Physical Interaction

In this stage, users should make sure that their decision is transferred to the product correctly by applying the “language” that product can understand (Figure 18). In order to complete the physical interaction precisely, the use needs a lot of concentration, which consists of focusing the mind upon a given subject, or object, firmly and fixedly and not allowing itself to be diverted or distracted from its object \(^{[18]}\). Concentration means complete attention and intense mental effort \(^{[19]}\). An example can be threading a needle (Figure 19), which requires a high level of concentration and mental effort even after users have figured out how to interact in their mind.

There are a lot of designs that have been focused on this stage and try to solve this problem. A good example can be the multi-touch control of Apple products and the game interaction of Wii. All of them allow users to interact with the product more naturally and less precisely. Users don’t have to apply high concentration to make sure that their interactions are understood by the products correctly.
2.4 Mental effort exertion from interaction complexity

The complexity of interaction is another main factor that will increase the mental effort exertion. Complexity increases with an increase in the number of stages of processing that are required to perform a task \cite{11}. One more phase added to the entire interaction process means that users have to exert more mental effort to finish the information hunting, information processing and physical interaction stages, which have been talked about above.

There are two causes of this issue. One is the failure of a certain phase, which means that users have to start this phase over again, resulting in the addition of one or more phases to the interaction process. Mistakes that happen in any of the three stages in the single phase can cause the failure of this stage. Studies in fields such as aviation have shown that high mental workload is associated with poor performance \cite{20}. High mental effort in a single phase leads...
to mistakes, which will add one or more phases to the entire process and drive the mental exertion even higher.

Another cause is that unnecessary phases are included. Users can still achieve the final goal without certain phases. The design of the Apple smart cover is a good example of trying to reduce the number of phases. Instead of pressing the button to make the I-pad go to sleep, and then protecting the I-pad by a cover, the Smart cover can put the I-pad into sleep mode simply by closing the cover. It does not need any button pressed. One phase is removed from the product hibernation interaction. The same situation happens when you want to have the I-pad wake up (Figure 20).

![Figure 20: I-pad smart cover](image)

In order to solve the first cause, interaction design should try to reduce the mental effort in each single phase. The solution for the second one is to remove unnecessary phases from the whole process.
Chapter 3

MEE Model
3.1 MEE Model Introduction

All the statements and research conducted in the previous chapters made it clear that in order to evaluate the mental effort exertion during the interaction process, 6 characteristics need to be taken into consideration. They are:

- **Information Unfamiliarity**
- **Lack of Intensity**
- **Information Interference**
  
  These three characteristics are applied to evaluate the mental effort exertion during the Information hunting stage to make sure that the users can find all the relevant information from the product about how to interact and where to interact easily.
- **Processing Hierarchy**
  
  This characteristic is applied to evaluate the mental effort exertion during the information processing stage to make sure that users can process the information easily to make the right decision.
- **Interaction Restriction**
  
  This characteristic is applied to evaluate the mental effort exertion during the physical interaction stage to make sure that users can transfer their decision to the products without the requirement of a high degree of concentration.
- **Number of Phases**
  
  This characteristic is applied to evaluate the complexity of interaction to make sure that no unnecessary phases exist in the interaction process.
One more characteristic is evaluated in the model in order to help designers understand the priority of all the problems. That is the importance of the phase. In the multi-phases interaction process, some phases are more important than others and will cause serious problems if the user failed to make it happen. So, the width of each phase represents the importance of the phase. If one phase is more important than others, the phase represented in the model will be wider.

When these 6+1 characteristics are put together, MEE Model (Mental Effort Evaluation Model) is formed (Figure 21):

![MEE Model](image)

**Figure 21: MEE Model**

In the MEE Model, these 6+1 characteristics are evaluated on different axes. The horizontal axis evaluates the complexity of interaction. It represents how many phases are included in the whole interaction process from user motivation to
product reaction. The width of each phase is decided by the importance of it (low, medium or high). The vertical axis evaluates the difficulty of interaction. The upper vertical axis represents all the considerations in the two information transduction stages (information hunting and physical interaction). If a certain consideration is missing in the design, a red block will be added in the grids to represent the mental effort exertion because of the absence of this characteristic. In the bottom part of the vertical axis, processing hierarchy is considered. The height of the red block corresponds with the level of processing hierarchy. After evaluating the entire process, the more space is occupied by the red blocks, the more serious the mental effort exertion problem is. It is very intuitive for designers to realize the mental effort exertion situation of a certain interaction process. There are three interactions, all of which are trying to achieve the same goal (open the door), that are evaluated by the model (Figure 22). It is very clear to the designers that the third one is the best interaction in terms of mental effort exertion. The first has the complexity problem and the second has the difficulty problem. Both of them require more mental effort exertion than the third one.
Figure 22: Evaluation example.
3.2 MEE Model Application

The manipulation of the MEE Model in interaction design process is discussed. Designers need to discover the problems of existing product interaction. All the problems need to be evaluated based on the consideration of the problem’s negative influences to the users and the design resource limitation. The evaluation result helps the designers to decide which problems will be targeted and then solutions will be further developed into the final concept.

3.21 Model based user testing & problem discovery

In the first phase, the MEE Model will help the designers to get feedback about mental effort exertion by asking the users more targeted questions. Users were requested to accomplish a certain action associated with a function of a product. Through user observation and interview, designers need to explore the questions listed below:

1. How did the user achieve the final desired action?
   
   *Asking this question should inform the designer as to how many phases the entire interaction process has.*

2. In each phase, what will happen if the user was not able to achieve the desired level of interaction?
   
   *Asking this question should inform the designer as to how important a certain phase is (low, medium or high).*
3. What is the user’s experience about the information hunting and physical interaction in each phase?

*Asking this question should inform the designer as to which characteristics of the four (information familiarity, lack of intensity, information interference and interaction restriction) have been considered and which are not.*

4. How did the user figure out the right way to interact with the product?

*Asking this question should inform the designer as to which level is the information processing in each phase.*

After answering all the questions, designers can fill out the MEE Model easily. The model will not only display the general mental exertion situation, but also represent all the problems that lead to mental effort exertion.

### 3.22 Problem evaluating

Here is an example about how to solve the problems based on the MEE Model (Figure 23).
From this model, we can understand that this is a four-phase interaction process. We can also know where the mental effort is exerted during the entire process.

There are several directions designers can try to approach:

1. Are there any phases that can be deleted from the process without influencing the final desired reaction?

2. We know that if users were not able to achieve the desired level of interaction, phase 2 will cause a more serious negative influence. Phase 2 should be the main phase that design focus on if we cannot solve all the problems. Then, explore if there is any familiar level or even better interaction behavior can be applied to phase 2 to reduce the mental effort exertion during the information processing stage. How can design increase the interaction tolerance to reduce the concentration required for physical interaction stage?
3. Phase 4 is also important since the information processing stage is the misleading level. The designers should try to modify the interaction to fit users’ existing experience.

4. If possible, designers should also explore solutions for the rest of the problems.

The application of the MEE Model can be described in the following three levels of design problem identification (Figure 24):

![MEE Application in Problem Identification](image)

**Figure 24: MEE Model application in problem identification**
Chapter 4

MEE Model Evaluation
The Evaluation of the MEE model focused on two areas. First is the evaluation of the 6+1 characteristics, which are believed in this thesis to be the guidelines that will influence the mental effort exertion during the entire interaction process. It was necessary to prove that those 6+1 characteristics are very important to evaluate in terms of reducing the mental effort exerted. It was also necessary to confirm that there were no other important characteristics missing from this model that might affect the interaction.

In order to assure that the guidelines based on the MEE model are truly effective, it was necessary to confirm the validity of the MEE model itself. This is the second area that should be tested. The MEE model should be very efficient for the designers. It should be effective to collect valuable information and the output should be very intuitive for designers to base decisions upon.

For this purpose, 26 design students gave their feedback about this model. First, as designers, they have a very good understanding about interaction design; they know much about what will influence the mental effort exertion in the interaction process. Second, as the users of this model, their feedback is also valuable to make this model more intuitive and effective.

Surveymonkey was used as the media to collect the quantitative research result about the value of those 6+1 characteristics that were evaluated in the model. An interview process was also applied as the qualitative research method to collect the feedback about the easy use of this model.
4.1 Characteristics Consideration Test

The quantitative research was conducted online. There was a brief introduction of all the characteristics before the questions were asked.

The questions asked were about the subjects’ opinion toward the value of these 7 characteristics considered in the model. The results are listed below (Figure 25):
Figure 25: Characteristics value test result
Another question about these characteristics was whether or not they think there are other characteristics having an important influence on the interaction mental effort exertion? The test result is listed below:

![Figure 26: Other important characteristics test result.](image)

The seven subjects who believe that there are other important characteristics also gave their feedback. All their feedback was considered carefully to make sure that valuable factors were included in the model.

In general, the feedback about the characteristics received from the SurveyMonkey test supplied very positive support to the model. These characteristics have included the mental effort exertion influence in a very high degree and the consideration of these characteristics will strongly support the evaluation of mental effort exertion during the interaction process.
4.2 Model Application Test

The subjects also gave their feedback toward the application of the model in the design process.

Some subjects believed that this model would help designers during the interaction design process. It can be applied to all kinds of interaction design that aims to reduce the mental effort exertion. An evaluation model will include more concentrated information and will be more efficient than other guidelines. However, the MEE Model needs to be modified so that designers can apply it to the design process more easily. Suggestions included developing this model into a digital product, for example, an ipad app. During the interview process, it will be very efficient for designers to input the relevant information to fill out the chart. It is also easy to share the evaluation results with other designers for discussion.
Chapter 5

Conclusion
It is very important to reduce the mental effort exertion in the result-oriented interaction process. This thesis seeks to understand the mental effort exertion problem from the difficulty and complexity perspectives and analyzes all the characteristics that lead to the difficulty and complexity situation systematically.

The aim of the MEE Model design in this thesis is to help designers evaluate the mental effort exertion of the interaction more efficiently based on the consideration of the characteristics. The evaluation result will help designers clearly understand the interaction mental effort exertion. Based on the model, designers can find all the problems that cause the mental effort exertion and prioritize them, so that designers can focus on the most serious problems to solve them. The application of this MEE Model can set up a valuable guideline for designers to evaluate interaction mental effort exertion and at the same time will give designers suggestions about how to reduce the mental effort exertion.
Reference


5. George, Jennifer.

   [wps.prenhall.com/wps/media/objects/1598/1636589/GJ4_PPT04S.ppt "Chapter 4: Perception, Attribution, and the Management of Diversity"].


    *Traffic Research Centre, University of Groningen.*

    media: A conceptual review.

    Prentice Hall.


    Solving Skills.* Prentice Hall Trade.

    Supervision & Curriculum Deve.

    introduction to human ecology.* Addison-Wesley Press.


20. Byrne, A. (1998). Errors on anaesthetic record charts as a measure of 
    anaesthetic performance during simulated critical incidents. *British Journal 
    of Anaesthesia.* 98, 58-62.
1. Introduction

The goal of this survey is to evaluate a interaction model, which is intended to help designers find the mental effort exertion problems in the interaction process and also give potential solutions about how to make better interaction in terms of reducing mental effort exerted.

First, there will be a brief introduction about the application of this model in the actual design process. And then questions you are going to be asked is about your opinion as a designer of whether model is valuable for designers in the design process. It will take you around 10 minutes. Thank you for your time and thoughtful consideration.

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2. Introduction of MEE Model

Please take a look of this link http://issuu.com/theis_test/docs/test.presentation.
It is about a brief introduction of the model and how this model can be applied to the actual design process. You might need to look back during the question section.

3. Characteristics Value

All the questions asked are based on the consideration of reducing mental effort exertion. (Introduction page 2)

3.1 Do you think the consideration of information unfamiliarity is valuable?
   - Yes
   - No
   - Not sure

3.2 Do you think the consideration of information interference is valuable?
   - Yes
   - No
   - Not sure

3.3 Do you think the consideration of interaction restriction is valuable?
   - Yes
   - No
   - Not sure

3.4 Do you think the consideration of processing hierarchy is valuable?
   - Yes
   - No
   - Not Sure
3.5 Do you think this hierarchy is reasonable?

- Yes
- No
- Not Sure

3.6 Do you think the consideration of how many phases included in the entire process is valuable?

- Yes
- No
- Not Sure

3.7 Besides the considerations above, are there any other characteristics that should be considered in the model? If yes, what are they?

- Yes
- No
- Not Sure

Other Considerations?

3.8 In general, in order to find problems about mental effort exertion during the interaction process, do you think the MEE Model is valuable?

- Yes
- No
- Not Sure

3.9 In general, do you think the evaluation model is valuable in terms of giving designers suggestions about how to reduce mental effort exertion?

- Yes
- No
3.10 Do you think the consideration of negative influence from wrong interaction is valuable?
   • Yes
   • No
   • Not Sure

3.11 Do you think it is valuable to apply this model to the actual design process?
   • Yes
   • No
   • Not Sure

3.12 Do you have any suggestions about the model or its application?

4. Thank you

Thank you for your time! Your feedback is invaluable and will help make this model stronger!