

## Mobile HCI Optimization Based on RFID and Wireless Sensor Networks

Hongwei Jia

School of Software, Beijing University of Posts and Telecommunications, Beijing, China

Received: 28 January 2014 Accepted: 28 February 2014 Published: 31 March 2014

---

**Abstract:** Limited display space of mobile devices is inadequate for simultaneous display of all the information needed in context. Practical guidelines for how to tailor information remain a longstanding challenge for mobile human-computer interaction (MHCI) optimization. With the help of RFID, GPS and sensors, mobile devices can perceive context of themselves. In this paper, principles of MHCI optimization for field mobile devices (FMD) from the perspective of distributed cognition theory and context-awareness technology is explored. Context factors which are perceived by FMD sensor networks and analyzed, based on which, we concluded the practical guidelines which are easy for people to implement MHCI optimization. We confirm the effectiveness of the guidelines by optimizing MHCI of FMD for a storage management system and illustrate how to utilize these design principles to support FMD HCI optimization and verify the effectiveness. At last we reassure the user experience with user experience testing for five dimensions of learnability, memorability, efficiency, error prevention and satisfaction. *Copyright © 2014 IFSA Publishing, S. L.*

**Keywords:** Human-computer interaction, Cognition resources, Mobile devices, Sensor network.

---

### 1. Introduction

Popularity of mobile devices (MDs) provides more and more convenience for us. However, they have inherent limitations [1]. Firstly, because of their limited display space, mobile devices are inadequate for simultaneous display of all the information needed in actual working context. Secondly, the cognitive burden of MD users in retrieving information will be greatly increased if a large amount of untailored information is displayed at the same time. While, with help of RFID, GPS, different kinds of sensors, mobile devices (MD) can sense context of itself. For example, with support of RFID technology, MD can sense physical objects around itself.

In Reference [5], in order to perceive context, beds for patients are equipped with various RFID sensors that can identify the patient lying in the bed,

the clinician standing beside the bed, and various medical 'stuff' are embedded RFID tags. In this way the computer embedded in the beds can adapt the computer screen to the users in its vicinity. With the gravity acceleration sensor, MDs can adjust screen's direction. With a gyroscope, the MD can know the moving direction of it, and adjust the HCI information to adapt to direction variation. For field MDs (FMDs), information is often retrieved and used according to a concrete application. The information in FMDs is for supplementation and description of the working context. In coordination with the working context, the information displayed on the MD screen renders the users to fully understand their working conditions and thus directs their working behavior. [2] For instance, with the storage management system, workers can make sure whether it is suitable to store the items in an appropriate physical space according to combined

information of the physical space and the number and size of the items from the mobile device. Therefore, the context is a very important information resource for FMD users. Then how to take full advantage of information in working context to optimize FMD HCI information display.

Although many literatures have discussed mobile application design based on context-awareness, still there are no practical guidelines to be followed in designing mobile human-computer interaction (MHCI). Context of mobile devices and all aspects of mobile device adaptability to context have been discussed in Literature [3] and [4], but concrete strategies for MHCI design are not covered. There has been a lot of research work on MHCI design based on context-awareness, but they are scattered in concrete and separate application fields, such as the application of context-awareness for medical work in hospitals reported in literature [5].

However, Literature [2] analyzed the human ability in context-awareness, proposing that human has the ability to combine the information in context with that in MHCI interface, based on which human can understand the interactive resources, and based on which, the HCI information can be tailored to decrease user's cognition burden. The instance at top is that for a passenger standing on Platform 1 in Shanghai railway station, the only information needed for the MHCI interface to provide is but the time and destination of next train, saving the departure station and platform information. But the paper did not give any applicable step-by-step instructions and optimization strategies for mobile HCI, which can never be regarded as general guiding principles for mobile HCI design.

The insufficiency of guidelines for MHCI optimization is partially responsible for inadequate research to meet the rapidly developing requirements for the mobile applications. It is no wonder that, to date, the guideline remained elusive.

In this paper, to approach the practical guidelines for mobile HCI design, our research is conducted from the perspective of distributed cognition theory to analyze context for the purpose of mobile HCI optimization and utilization.

Literature [6] set forth a HCI distributed cognition resource model. The resource model indicates that the information distributed in human brain and in technical systems can formulate a structure of resources for operation, which can further enact a new allocation of resources. The whole interaction process forms a chain of "allocation of information resources-- operation action--allocation of new information resources--- a new operation action," towards the end of the interactive process.

According to the actual context of FMD operation, the cognition resource distribution environment is extended to the working field. So for the FMD users, the cognition resources distribute in the user brains, the MHCI and the field of FMD.

Literature [7] gave a cognition resource model with six basic information resources, i.e. plan, goal,

affordances, history, the action-effect relationship and state, and provided a cognition resource structure with these six resources plus some interactive strategies with one computer HCI. Literature [8] proposed resource model of collaborative HCI design, which contains not only local design resources, but also resources in support of collaborative work. The present research tries to innovate a new cognition resource structure for FMD HCI.

However, in the related work above, there is no in-depth analysis of correlations and differences between mobile device context-awareness and human context-awareness. Our research proposes, from the perspective of distributed cognitive resources, that context-awareness can be used as a tool for tailoring and optimizing FMD HCI. Design principles are put forward for tailoring and optimizing cognition resources of FMD HCI in an innovative way, which is based on making a comprehensive analysis of the different context-awareness ability between mobile devices and humans. The general optimization design principles can guide the FMD HCI design, reduce the user's cognitive burden and improve the support level for FMD users' jobs.

The main job of FMD is to provide the most appropriate information for the device users. Thus, how to take full advantage of the context to optically tailor the information for the users of FMD is the target of this paper.

This paper mainly:

- 1) Analyzes cognitive resource distribution of FMDs with the theory of distributed cognition (DC);
- 2) Provides the context factors of FMDs, and proposes that context-awareness technology is a feasible tool to optimize the distribution of cognition resources and tailor the HCI information of FMDs;
- 3) Discusses the context factors in four separate situations, depending on whether the context factors can be perceived by the user and by the FMDs or not, and for different situations, puts forward respective HCI optimization design principles for FMDs;
- 4) Applies the optimization design principles of FMDs founded in this research to practical cases to illustrate how to utilize these design principles to support FMD HCI optimization and verify the effectiveness of the principles.

## **2. Two Application Scenarios**

The following are two application scenes of FMD in separate working fields.

Scene 1: In a storage management system (Fig. 1), workers need some storage item information from mobile devices. For example, in the stage of warehouse entry inspection, they need the storage items' inventory information, including vendor information, volume, weight, quantity and so on; in the stage of warehouse storage, they need information to assign the appropriate storage location

for the item storage according to physical information and warehousing storage requirements.



Fig. 1. Storage Management.

Scene 2: The FMD is used to support solar power monitoring. In a solar power station as in Fig. 2, workers need status quo of any equipment, such as power generation conditions, equipment maintenance information, and so on.



Fig. 2. Solar power station.

### 3. Distributed Cognition Resources of FMD's User

Distributed cognition resources are for humans to determine their behaviors. Distributed cognition theory suggests that information for cognition systems are distributed throughout the whole cognition environment, comprising not only the information in internal human brain, but also external information. The human cognition system does not have any boundary between external and internal information. In a cognition process, external information does not need to be transferred into internal information; it can directly activate a cognition process, together with internal information, direct human behavior. The externalization of internal information renders computer to take on more information, which not only reduces human's memory and cognition burden, but also meet the

need of human cognition, and thus make computer more efficiently assist human work [6] [7].

Through the analysis in the first section, it is discovered that large information externalization in the mobile device has inherent limitations. How to tailor information in FMD HCI according to the context in order to reduce user's information retrieval and improve the user's usability experience has turned out to be the focus of this paper.

#### 3.1. Distributed Cognition Resource Model for a User in Field

Based on literature [6], [7] and [8], this paper put forward a cognition resource model with seven basic resources, namely working plan, working goal, working activity, working knowledge, working tool, working state, coordinators' state.

Working plan resources and working goal resources are considered to be internal resources in human brains. A FMD system can extract, store and provide them for users.

Working activity resources are a series of work in progress by the user according to a working plan in order to achieve a working goal, such as machinery repair and cargo storage, which may exist either in a working environment or in users' brain. They can be displayed in HCI interface after users' interaction with the FMD in advance.

Working knowledge resources are inherent in human brains. Therefore, mere externalization of the knowledge can effectively reduce cognition burden.

Working state resources, i.e. different states of the working environment, may either intrinsically exist in the working environment, or be needed to be expressed in HCI interface. For example, the physical conditions of a warehouse exist in the working environment are explicit information, but the volume and weight of the items are implicit information needed to be expressed on HCI.

Coordinators' state resources include online coordinators' personal physical and mental state and coordinative working state, which need to be reflected on HCI interface.

Working tool resources include not only a set of selection tools in HCI interface for the user to trigger the next operation, but also include operations in field, such as operation to store items in a warehouse, or operation to move the FMD.

As shown in Table 1, distributive cognitive resources distributed in the working environment ( $W$ ), and HCI of FMD ( $H$ ), are external information; those which are distributed in the human brain ( $B$ ) are internal information. In TABLE I, 0 indicates that the cognition resources on the column can never exist in the distribution environment on the row. 1 indicates that the resources on the column must distribute in the distribution environment on the row.  $\{1, 0\}$  means that the resource distribution has two possibilities. The last row of the table is the

maximum values, indicating maximum times of repetition distribution of a resource  $R$  in all environments.

$$R_{\max} = W_{\max} + B_{\max} + H_{\max} \quad 1)$$

For example, the maximum of working plan =  $\max\{0\} + \max\{1, 0\} + \max\{1, 0\} = 2$ .

In a cognition process, external information does not need to be transferred into internal information, as it can directly activate a cognition process, and

combined with internal information, direct or determine human behavior. [6] Therefore, if no consideration is given to redundancy in the cognitive environment, a cognitive resource only need one time distribution, but from Table 1, it may be distributed up to 2 times, which provides margin for information tailoring in HCI.

Designing Principle 1: When cognitive resources have been distributed in human brain or in field, they have no need to be distributed in HCI in the case of redundancy negligence.

**Table 1.** Distribution of cognition resource.

Distribution environment	Cognition resources						
	Working plan	Working goal	Working activity	Working knowledge	Working state	Coordinators' state	Working tool
Working environment ( $W$ )	0	0	1, 0	0	1, 0	0	1, 0
Human brain ( $B$ )	1, 0	1, 0	1, 0	1, 0	0	0	0
HCI of FMD ( $H$ )	1, 0	1, 0	1, 0	1, 0	1, 0	1	1, 0
Maximum repetition distribution ( $R_{\max}$ )	2	2	3	2	2	1	2

## 4. Context of FMD

To explore how to take advantage of the context to tailor the information for the user of FMD, we will have to discuss the context of FMD. Before that, we will see the previous research work on context of a mobile system.

### 4.1. Context of a Mobile System

Context of a mobile system is for a mobile system to sense and perceive (context awareness), based on which, the system can make appropriate adaptations and adjustments according to HCI users actual needs. Context definition of the mobile systems has numerous versions, i.e. Literature [3], [4] and [5], which pointed out that the context contains two major categories: human factors and physical factors. Human factors include three categories: user information (user profile, emotional state, etc.), users' social environment (other relationship, group dynamics, etc.) and the users' task (current activities, goals, etc.). The physical factors include three categories: position (absolute and relative positions, etc.), infrastructure (computing resources, etc.) and physical conditions (noise, light, etc.).

### 4.2. Context of FMD

In this paper, the context of FMD, referring to [5] and based on the analysis of actual scenarios, has two factors: human factors and physical factors. Human factors include:

1. Users' personal information such as identity of a user, warehouse manager and user's knowledge.

2. User's social settings, which especially refers to the collaborative relationship with other online staff members. For instance, in a collaborative design team, the social settings are majorly constructed with co-designers.

3. Users' working plan and working goal refer to those of FMD users, such as, storing cargo in shelves with suitable condition.

4. Users' current activities.

Physical factors include:

1. Actual locations, such as the locations of mobile devices, or the location of a physical object, etc.

2. Current time.

3. Physical factors of a working environment, such as a geographical environment, the physical condition of a warehouse, humidity, temperature, etc.

4. Operation tools, such as temperature or humidity regulators.

## 5. MHCI Optimization with Context-Awareness

There are essentially two ways in utilizing context: automatically adapt the behaviors according to discovered context (using active context), or present the context to the user on the fly and/or store the context for the user to retrieve later (using passive context). Active context awareness means that an application automatically adapts to discovered context, by changing the application's behavior. Passive context awareness means that an application

presents the new or updated context to an interested user or makes the context persistent for the user to retrieve later [3].

In this paper, we mainly discuss the active context awareness. For users of FMD, they sometimes need the system to adapt to the discovered context, for example, when the system discovers a physical place with help of GPS technology, it can provide physical conditions of the place with the help of wireless sensor networks, such as temperature and humidity, based on which users can determine whether the place is suitable for some item to store or not., based on which users can determine whether the place is suitable for some item to store or not. Context factors sometimes can be perceived by users, but sometimes not. Likewise, context factors sometimes can be perceived by the FMD, but sometimes not. The in-depth discussions can roughly be categorized into four situations.

### **5.1. Context Factors Perceived by Users, but not by FMDs**

The example of such situation could be the users' current activity, which sometimes cannot be perceived by the FMD, but which is to the intelligible knowledge of users. Under such circumstances, HCI should provide interactive selection/option tools for users, determining which stage the current activity is on, and then providing the corresponding information. For example, in storage management, if the system can not perceive whether workers' activities are in the phase of inspection or warehousing storage, users would be offered an interaction with the system to make sure which stage it is on.

Design Principle 2: If context information can be perceived by users, but not by FMDs, HCI should provide interactive selection/option tools for users, determining which context factor is, and then providing the corresponding information accordingly.

### **5.2. Context Factors Perceived by both FMDs and Users**

The example of such situation could be users' location information, which is explicitly perceived by users and by FMD with support of RFID, GPS or sensors, and thus HCI needs to provide only adaptive information corresponding to current location.

Design Principle 3: If context information can be perceived by both users and FMDs, then only adaptive information to current context needs to be provided in the case of redundancy negligence.

### **5.3. Context Factors Perceived by FMDs, but not by Users**

The current context information perceived by the FMDs, but not by users should be provided by HCI,

together with adaptive information of current context, such as online coordinators' state should be provided on HCI for users needs as they can not perceive it.

Design principle 4: If users actually need a context factor which can be perceived by FMDs, but not by users, context information and its adaptive information should be provided by HCI.

### **5.4. Context Factors Perceived by Neither FMDs nor Users**

For example, if the current physical conditions such as humidity can be perceived neither by users nor the system, we can not make the FMD HCI adapt to the physical conditions.

Design Principle 5: If the context information can be perceived by neither FMD nor users, then we can not use the context factor to tailor the HCI.

## **6. Optimization of FMD HCI Depends on Context Factors**

Table 2 shows a context factor is either perceived by users or by the system. The relevant discussions are as follow.

### **6.1. Perception of Users' Individual Information**

According to analysis of literature [2], as well as the practical application testing, the dynamic personal information, such as personal activities, often requires users to interact with the system, which can synchronically perceive it based on reasoning with the support of calendar, etc. However, according to the testing of practical applications, users are usually reluctant to interact with the system, which may account for FMDs' malfunction in perceiving changing information or current activities. Therefore, users often have to either distrust or neglect human factors provided by the system. According to Design Principle 2, mobile devices should firstly present all ongoing activities for users to confirm, before providing the adaptive information of users' selection; If there are no selection from the users' side, the system would have to list out the information of all the ongoing activities for the users.

### **6.2. Perception of Working Plans and Goals**

Users can intrinsically perceive working plans and goals, which is a challenging job for FMDs. Therefore, as it is stated in Design Principle 2, FMDs have to provide all the possible working plans and goals for users to select, before providing the adaptive information according to the selection result.

**Table 2.** Context factors perceived by users or by systems.

Perceived	Human Factors			Physical Factors				
	Personal Information	Plans and Goals	Social Environment	Locations	Current Time	Objects	Physical Conditions	Tools
Perceived by user	yes	yes, no	no	yes	yes	yes	no, yes	yes
Perceived by system	yes, no	no	yes	yes (with GPS's help)	yes	Yes (with RFID's help)	yes, no (with sensors' help)	yes, no

### 6.3. Perception of Online Social Environment Information

Under the support of network, especially wireless network, users of mobile devices can work more collaboratively and efficiently. However, the online social environment is more effectively and immediately perceived by the system than by users.

According to Design Principle 4, collaborators' personal information and working state needs to be tailored before effectively displayed on the interactive interface.

### 6.4. Perception of Location Information

Literature [3], [4] and [9] have analyzed the location perceptibility of mobile system. According to the analysis of [2], users can intrinsically perceive location information. As a result, location information can be perceived by both users and systems. For example, users can perceive location of a machine, which the system can also detect by means of location service and the position information in the system's database.

According to Design Principle 3, only the adaptive information to location needs to be provided. For example, HCI displays the storage capacity of certain items at current location which the users can integrate with their current personal location in due information process.

### 6.5. Perception of Time Information

Mobile devices are easily available in time perception. According to actual usability testing, users intuitively accept that contents on HCI is to support information of the current time. According to Design Principle 3, FMDs can directly display adaptive information to current time. For example, a warehouse's inventory displayed on HCI is intuitively accepted as current inventory.

### 6.6. Perception of Physical Objects

According to Literature [2] and actual application testing, objects are easily perceived by both systems and users. The location information of surrounding

physical objects can be perceived by devices with assistance of location database. Alternatively, by means of RFID technology, physical objects can be accurately located. Therefore, according to Design Principle 3, adaptive information to a physical object can be displayed directly.

### 6.7. Perception of Physical Conditions

Users can intrinsically and accurately perceive some physical factors, such as temperature, humidity, etc. under the support of indicators in a physical environment. However, with the aid of wireless sensing technology, FMD can display the physical factors on HCI. Here we have two possibilities in physical condition perception for discussion.

1. If a system cannot perceive a physical factor, according to Design Principle 2, HCI information adaptive to the physical factor cannot be trimmed. Alternatively, HCI should provide interactive selection/option tools for users, identify which physical factor it is, before providing the corresponding information accordingly.

2. On the contrary, if a mobile device can perceive certain physical factors, such as current temperature and humidity, by means of wireless sensing technology, then, in accordance with Design Principle 3, only adaptive information to current physical factors need to be shown.

## 7. How to Apply the Design Principles to Practical Work

The FMD HCI design methodology generalized from the design principles set forth in this paper. Cognitive resources needed for field work have to be in place in context before users enact their working actions. The step-by-step procedures below which can be followed in designing HCI information provision for FMD.

1. Analysis should be made in terms of what kinds of cognitive resources are in need for users to enact their work;

2. Analysis needs to be made in terms of whether the cognitive resources discovered in Step 1 are present in context; if not, it is necessary to supplement them in the FMD HCI according to Design Principle 1;

3. Analysis should be made in terms of whether the cognitive resources in Step 1 can be perceived by either users or the system;

4. Based on the analysis in Step 3, and in accordance with Design Principles 2, 3, 4, and 5, identification and discrimination need to be made in terms of whether the supplement resources mentioned in Step 2 can be tailored to fit context factors.

5. Presentation of the supplementary information needs to be made in accordance with the results of analysis in Step 4.

## 8. Applications of the Design Methodology in an Actual Case

### 8.1. Tailoring Interface

The above design methodology with optimization design principles is verified with a practical case of FMD HCI design of storage management system. Generally, a storage management system needs to support the phases of warehouse entry inspection, product storage, product delivery, etc. Because of space constraints, we pick only the phases of warehouse entry inspection and product storage for detailed discussion.

#### 8.1.1. Warehouse Entry Inspection

On arrival of products from suppliers, warehouse inspectors need inspection information, such as serial number, product name, price, manufacturer, quantity, size, etc. Fig. 3 shows the untailored interface in the phase of warehouse entry inspection, which includes all the information needed and unneeded.

The redundancy is evident and the tailoring will be greatly facilitated in batch process if we follow the step-by-step procedures in VII:

1. Cognitive resources needed by users include physical storage items and their relevant information for inspection, such as name, quantity, price, supplier information, inspection experience and inspection activities.

2. In context, physical storage items are present in physical environment; but inspection experience and inspection activities are inherently in users' brain;

3. According to Design Principle 1, the FMD HCI needs to provide inspection information for the storage items;

4. The information user can thus perceive: physical storage items, acceptance experience, acceptance activities;

As for FMD's malfunction of activity perception, according to Design Principle 2, mobile devices should firstly present all ongoing activities for users to confirm, before providing the adaptive information of users' selection, while storage items can be perceived by FMD with the assistance of RFID technology;

5. After users' confirmation and according to Design Principle 3, only the information for the storage items to be inspected need to be shown. The refined and optimized interface design is shown in Fig. 4.

No.	Name	Manufacturer	Device Belonged	2G/3G	Price	Total Price
1	Power module	Zhongxing	BTS	2G	3763.26	11289.78
2	SEU	Zhongxing	BTS	2G	4581.36	22906.80
3	RIS40-DIC	Zhongxing	NoiseB	3G	14018.80	70094.00
4	OMP	Zhongxing	GSMT Controller	2G	5403.60	5403.60
5	PSN	Zhongxing	RNC	3G	5282.30	5282.30
6	ANCG	Aiong	BTS	2G	6068	6068
7	CP4	Aiong	RNC	3G	10305	10305
8	900MGR RU	Jingxin		2G	4000	8000

Fig. 3. Untailored interface for the phase of warehouse entry inspection.

Warehouse Entry Inspection

product name : PSN

Manufacturee : Zhongxing

Device belonged : RNC

2G/3G: 3G

Price :5282.30

Qunatity: 1

Fig. 4. Interface tailored for warehouse entry inspection.

#### 8.1.2. Warehouse Storage

In the phase of storage, appropriate stock location needs to be allocated for certain stock items. The two vital parameters concerned are physical storage conditions at a set location and warehousing requirements of the stock items. If we follow the

step-by-step procedures in VIII in storage processing, we get:

1. Cognitive resources needed by warehousemen includes warehousing experience, current storage activities, the stock items, location which can meet stock items' requirements, item warehousing requirements such as temperature, humidity and size;

2. In authentic context, physical stock items themselves as well as every location's temperature and humidity are present in physical environment; but inspection experience and approaches and steps as to how to conduct the inspection activities are inherently in storekeepers' brains.

3. In authentic context, shelves and stock items are in physical environment. Warehousing experience and approaches and steps as to how to conduct storage activities are in user's brain.

4. According to Design Principle 1, the mobile device HCI needs to provide item storage conditions including requirements for temperature, humidity and size.

5. The information user can perceive: physical stock items, warehousing experience, and storage activities. According to in Section VI, mobile devices can perceive stock items;

6. According to Design Principle 3, the storage condition information for the stock items can be trimmed out from all the items. Only the item name, conditions requirements such as temperature, humidity and size need to be shown.

## 8.2. User Experience Testing

Now that we have developed prototypes of untailed and tailored HCI for warehouse entry inspection and warehouse storage, we come to user experience testing. Because context plays a central role in the interpretation of information in FMD, all the prototypes are formulated in authentic field rather than in laboratory settings. The evaluation testing included 10 participants using the four prototypes. All participants are testing users familiar with both mobile devices and storage management. They went through the untailed HCI testing first, before they did with the tailored testing. The warehouse entry inspection and warehousing storage testing operations are conducted by the testing users in a spare part warehouse. They were asked to think aloud during the whole course of testing, and all the records are kept on file. The user experience testing is conducted from five usability dimensions, including learnability (L), memorability (M), efficiency (E), error prevention (EP), and satisfaction (S). The testing result of warehouse entry inspection is shown in Fig. 5, below.

Analysis of the testing results manifest, as it is in Fig. 5, that for learnability (L) and memorability (M), untailed HCIs are more easily conducted than the tailored HCIs. After learning, the efficiency of the tailored HCIs is observably upgraded. In addition, the

error prevention of tailored HCIs is measurably improved. Consequently, users' satisfaction with tailored interface is elevated to enjoyable altitude.

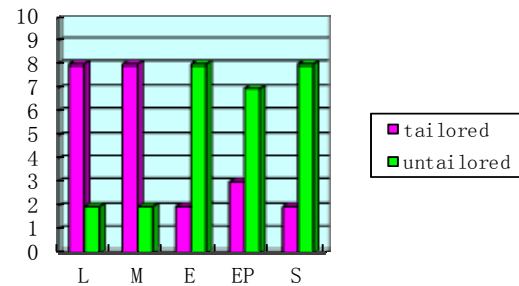


Fig. 5. User Testing for Warehouse Entry Inspection.

The reasons behind the user testing findings are that, for learnability and memorability, because participants were accustomed to untailed HCIs, eighty percent participants presume the untailed is better than the tailored HCIs; as for efficiency, 60 percent participants discovered that the tailored is better used than the untailed HCIs, except for four of them (40 percent), who confided that when it comes to comparing different parts of information, the tailored HCIs were no better as the users have no visual aide in sorting out the categories and thus a straightforward, intuitive and direct contrast is unavailable, i.e. the untailed HCIs have better information comparability than the tailored ones. In terms of error prevention, when operating on untailed HCIs, participants complained of the vague and similar captions and entries of information which appear misleading and confusing in information identification and selection.

Fig. 6 shows the testing results of warehousing storage testing.

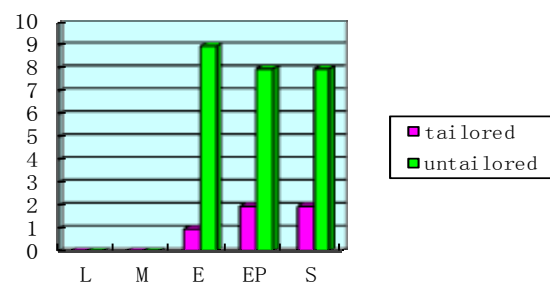


Fig. 6. User Testing for Storage Stage.

From Fig. 6, participants consider the tailored and untailed are equally learnable and memorable which is partially account from ordering effects as the participants had familiarized themselves with both tailored and untailed HCIs in the testing for inspection phase beforehand. As to the rest of usability dimensions, more than seventy percent of the participants assert that the tailored HCIs are more usable than the untailed.

The similar user testing experiments are also conducted on power station monitoring systems and we arrive at similar results. For space constraints, the details have to be omitted.

## 9. Conclusions

The pragmatic and practicable FMD HCI optimization methodology concluded from the present research has brought forth changes to the status quo that the present HCI designs have no rules to follow and thus completely dependent on the designers personal experience, filling the gap in the relevant fields. This methodology is reached through inspirations from and integration of distributed cognition theory and context-awareness theory with follow-up analyses and deduction in reference to the actual authentic application contexts and backgrounds. The generalized principles and methodologies set forth in this paper are reached through unprecedented concretization of FMD HCI optimization methodologies in authentic contexts, and, therefore, are universally instructive, enlightening and significant to the technologists and researchers in relevant fields and their practical contexts, who could improve and polish this set of theories and methodologies through further verifications and amendments. It is noted that the supplementation of information redundancy on the users' side calls for some more guidelines and methodologies for other researchers to work on.

For those interface optimization engineers, this research has provided readymade rules and principles to follow in their FMD or mobile device optimization designs, but they are especially advised to note the fact that this is but a set of general guiding HCI optimization methodologies which deserve modifications and adaptations on their actual application background, and through their user experience tests. The bottom line: users' needs and satisfaction are the criteria for any design and this is a golden rule, unchangeable and imperishable.

## Acknowledgements

This paper is supported by National Natural Science Foundation (60873244, 60973110), Beijing Natural Science Foundation (4102059) and Jiangsu Science and Technology Support Program (BE2010017).

## References

- [1]. C. Xia, L. Ren, D. Teng, Ubiquitous Human computer interaction in clouding manufacturing, *Computer Integrated Manufacturing System*, Vol. 17, Issue 3, 2011, 17, pp. 504-510.
- [2]. K. Jesper, P. Jeni, Indexicality: Understanding Mobile Human-Computer Interaction in Context, *ACM Transactions on Computer-human Interaction*, Vol. 17, Issue 4, 2010, pp. 1-14.
- [3]. L. Chen G, D. Kotz, A Survey of Context-aware Mobile Computing Research, *Dartmouth Computer Science Technical Report TR2000-381*, 2000.
- [4]. W. Liu, X. Li, D. Huang, A survey on context awareness, *Computer Science and Service System (CSSS), International Conference on Digital Object Identifier*, 2011, pp. 144 - 147
- [5]. J. E. Bardram, Applications of Context Aware Computing in Hospital Work-Examples and Design Principles, in *Proceedings of the ACM Symposium on Applied Computing*, 2004, pp. 1574-1579.
- [6]. J. Holla, E. Hutchins, D. Krrish, Distributed cognition toward a new foundation for human-computer interaction research, *ACM Transactions on Computer-Human Interaction*, Vol. 7, Issue 2, 2000, pp. 174-196.
- [7]. P. Wright, B. Fields, M. Harrison, Analyzing human - computer interaction as distributed cognition the resources model, *Human Computer Interaction*, Vol. 15, Issue 1, 2000, pp. 1-41.
- [8]. H. Jia, W. Tang, Human computer interaction resource model in collaborative design, *Computer Integrated Manufacturing System*, Vol. 13, Issue 12, 2007, pp. 2351-2357.
- [9]. Y. Chen, Design and development of warehousing management system of electronics manufacturing based on context awareness, *Doctor Degree Dissertation in Fudan University*, 2010.