

# Remote Collaboration-Study on Factors Affecting Team Mental Models

WuJing and Liu Long

College of Design and Innovation  
Tongji University  
Shanghai, China

## ABSTRACT

Design activities are becoming more scattered in place due to the development in technology and globalization of resources. As a result, the Computer Supported Collaborative Work (CSCW) for design, is not only required to adopt suitable technical products and systems to effectively support designers' work, but also the remote collaborative \_ team mental model factors affecting theory required to deeper exploration for designers team. Team mental models as cognitive variables of a team get attention in recent years. The concept that the team mental models can help team improve performance has been 20 years of history, but so far the team mental models theory has not yet formed a relatively complete system. The current measurement methods of team mental models are mostly static, individually measured for each team member's mind and then unity. This is tantamount to default team mental models are all members' mental model of simple addition, ignored the team interactive processes effects obviously. This paper will be based on the current study of team mental models, through investigate the designers' mental model of the same team, to analyze the team mental model factors of designers working in distributed environment, then establish corresponding reference models as well.

**Keywords:** Team mental models; Affecting factors; Remote collaborative design; Computer supported cooperative work

## INTRODUCTION

With the deepening of economic globalization and the knowledge-based processes, organizations face the rapidly changing of social and economic environment, with great difficulties to improve organizational performance, in this case, the team being the efficient organization became the best way to cope with environmental change. For Chinese enterprises, they are faced with unprecedented challenges, in order to survive and develop in the fierce market competition, organization managers have begun to explore effective management methods suited to today's situation. This form of organization team gradually began to prevail in the domestic enterprises, which studies how to make the team play the greatest performance is very necessary.

Currently in organizational behavior, human resource management, management, psychology and other related fields, researchers from the external behavior of individuals appearing gradually penetrated into the deep inner beliefs, values and knowledge constitute, explore the determinants behind the behavior. It is in this practical and theoretical background, inspired scholars to explore mental models, which also made some similar concepts. Industrial and organizational psychology research using concept of shared mental models; social psychology, cognitive psychology and decision-making research have also studied and presented as information sharing, team work schema, cognitive consensus and other related concepts. The concepts of representation are not consistent, but the content is similar. As the team mental models can explain why the performance of different groups there will be differences, and it promotes improved team performance, and therefore occupies a forefront position in the study team.

In the work team, members in a similar way to describe, explain and predict social events, the team members share knowledge and belief that enabling them to form a suitable explain and predict of work environment, to coordinate

their action to adapt different requirements from behavior of other members and the environment. In the team mental models, team members will tacit understanding, concerted action to accomplish team work (Cannon Bowers and Salas, 1993). Team mental models can help us understand the team performance; as well as understand and interpret the big differences of performance exist in different teams.

Currently researchers' empirical research on team mental models is far behind the theory expounded, and the sample is very lack in domestic. In this paper, focus on the IT teams of domestic Internet companies (designers based), through the methods of design team interviews, protocol analysis, from the team level to analyze the impact relationship between various dimensions of team mental models and team performance that in the remote collaboration. For team mental models, this paper draws on Cannon. Bowers and Salas' research that team mental model is divided into four types, namely, equipment or technology, team tasks, team interaction, teammate; for team performance, will be divided into participants satisfaction and team performance these two dimensions . Accordingly, the research will provide some direction for developing teams, in order to work efficient with management in remote environments.

## **RESEARCH ABOUT TEAM MENTAL MODEIS AND REMOTE COLLABORATION**

### **Type of Team Mental Models**

Team mental model with multiple structures, according to different criteria can be divided into several types. Complex tasks and team collaboration requirements of the relevant members should have multiple levels of mental models. Cannon. Bowers and Salas proposed four types and content team mental models (Cannon. Bowers and Salas, 1993): Equipment or technology, Team tasks, Team interaction, Teammate.

1) They must master the operation of tools or equipment and the corresponding technical, that's aim to understand how to hold their own operation and interaction with other team members; 2) They must understand the characteristics of the project itself, such as task flow, the required information and strategies, in addition to aware of the factors which may affect the completion of the task in the work environment; 3) They have to clear their roles in the process of task completion and how to coordinate and collaborate with other teammates; 4) They must understand teammate knowledge, skills and abilities, hobbies and other relevant personal qualities. Because of the understanding and evaluation of teammates will affect the expectations of teammates, thereby affecting teammates' behavior. Accordingly, the team members must also agree on these four levels, so the team mental models with multi-level features.

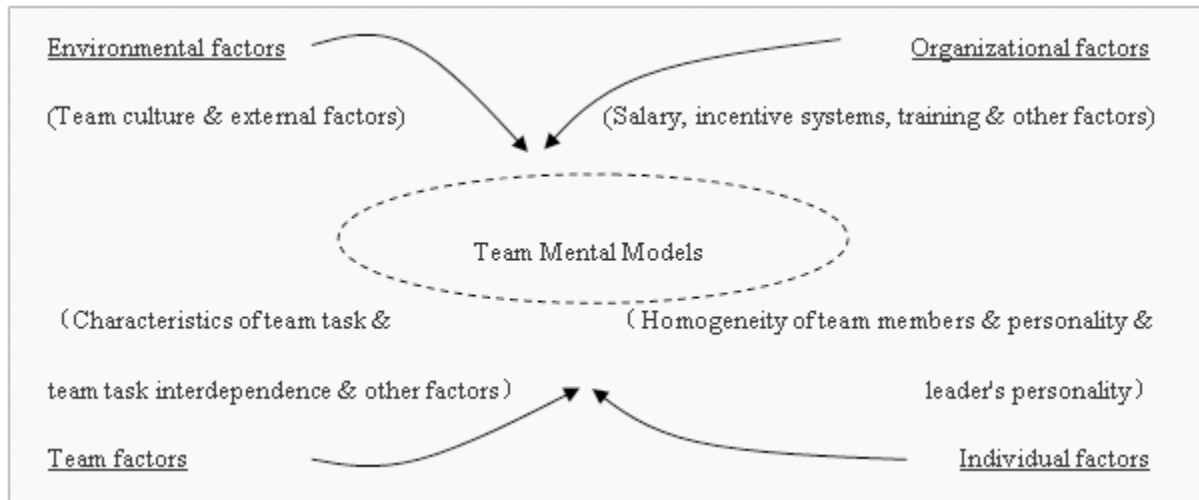
### **Measuring Team Mental Models**

Many scholars have proposed team knowledge should not only be a collection of individual team member's knowledge, but should be as a result of the interaction of the team to a comprehensive consideration (Klimoski and Mohammed, 1994). If you look from the perspective of team interaction, team knowledge should be produced by the team process, but in fact, the current team mental measurement methods are mostly static, single measure mental of each team member, and then unified, This is tantamount to default team mental models are all members' mental model of simple addition, ignored the team interactive processes effects obviously. This argument refers to the "interactive process", which is probably the most important difference between team mental models and mental models.

Currently several commonly used measurement methods are emphasized mental model of overlapping or similar, such as the concept mapping, similarity ratings, card sorting and the questionnaire (Mohammed et al, 2000). Cooke, etc. are more comprehensive consider of the overlap and distribution of these two characteristics, the heterogeneity of the team were also measured (Cooke et al, 2000). Janice Langan-Fox (2001) pointed out that the concept of team mental models is on a team level, but strictly speaking, over several measurement methods are based on the individual level, and on the basis of this integration into the team level (Janice and Anthony , 2001). Therefore, they proposed the randomization test which can further calculate the degree of similarity in the level of the team based on the data that has calculated the similarity between two team members. In general, similarity ratings method is still currently better.

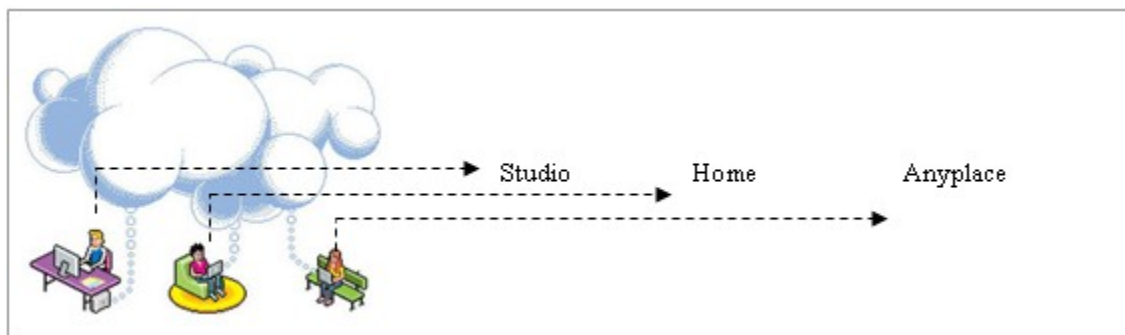
## Factors Affecting Team Mental Models

Many factors affect the team mental models, Kraiger and Wenzel proposed four types of factors in theoretically (Kraiger and Wenzel, 1997) as shown below:



## Remote collaboration

Remote collaborative design is an important development direction of digital design in the Internet environment, with traditional design and creative work in different ways, in new collaborative work environment, "transitioned away from desktop", distributed mobile office environment and a variety of application based on the reality of human-computer interaction (Reality-based Interaction, RBI) (Robert et al, 2008), will be the main mode that designers interaction with the system in future collaborative creative platform. Transitioned away from desktop, it means the possibility of diverse mobile office, regardless of collaboration software, hardware, applications, etc. will be a face-lift in the Internet environment. Due to the rapid development of mobile Internet, and more and more companies migrate their data to the cloud server from having to stick to a fixed office. Home office, remote office and mobile office model have gradually favored by more and more enterprises.



Remote collaborative based on cloud technology

## RESEARCH METHODS

First, give some concrete definitions of a few key words appear on this paper:

·Background: Remote Collaborative - According to current research, large Internet companies in the product development stage, with perfect responsibility system and adequate staff, caused by reasons such as remote long-distance to tasks, with little or no adverse consequences, but on the off-site communication does have low

Ergonomics In Design, Usability & Special Populations III

efficiency, misunderstand and higher costs; coupled with the arrival of the 4G environment, in the next decade, wearable Internet intelligent device is bound to have a big development, the purpose of this research with an explore nature of trend.

· Research areas: Domestic four Internet companies

· Research phase: Internet product development—The conceptual design phase. Conceptual design phase is an innovative stage, to a large extent influence the final results of the design, but it is also the least understood and most do not have the reasoning of the stage (David Meister, 1982).

· Research object: product designer team - non-traditional industry (industrial design product designers), but the Internet industry "product designer" - interaction designers, visual designers, user researchers, product managers and other relevant designers who are focus on the same projects. Because the Internet product design team properties particularly evident, similar lines, a lot of different areas of the designer will be involved in the same product research and development.

Collaborative design process, designers are engaged in complex cognitive thinking activity, such thinking activities are often difficult to be captured and understood, therefore, need to adopt a scientific approach to recording, analysis and processing. Methods based on oral reports (MW van Someren et al, 1994) and protocol analysis (K. A Ericsson and HA Simon, 1984) are important ways of cognitive processes research, the former by capturing external verbal report to obtained intrinsic cognitive thinking process. Methods based on oral reports can be divided into review method, questions prompted, thinking aloud method et al; while protocol analysis requires participants in the design process with thinking aloud, by recording and analysis of these words, access rules and characteristics of the designers' thinking activity.

The study used two methods for recording and analyzing four domestic Internet companies based on oral reports and protocol analysis. Group A by designers and design team's project review and supplemented by asking questions, explore their reflection on the processes and procedures in remote collaborative design work; Group B by recording its recent case of a design project with sound thinking through protocol analysis, get some details of their remote collaborative design team work.

Interviewee:

Group A ①: Internet entrepreneurial team\_3 people application-oriented design;

②: Internet entrepreneurial companies\_20 people, enterprise collaboration software design.

③: A network company UED team\_10 people, network product design;

Group B ④: Internet companies UX team \_12 people, Internet product design.

Interview steps:

1) Confirmed team of designers by telephone who are willing to accept this interviews with audio and video recordings and to inform the purpose and process of this research project, let whom understand the basic situation of the study; 2) At the appointed time to come interview the four companies for two -to-many interviews (one asked and another taking photos and recording), each about half an hour. In this process, we can also observe their working environment and realize the way they work (Group B in this step, we are the onlooker to participate in their project to discuss and record the team members thinking associated with sound, the time is also thirty minutes); 3) Collected during the interview text data, audio data and image data are analyzed to obtain the initial findings and conclusions.

Prior to the interview, I prepared about 15 questions as the main basis and content, these questions focused on two aspects: factors affecting the team mental models in concept generation stage; actual implementation details of the remote collaborative design work. In the actual interview process will make the appropriate adjustments to the problem of design experience based on the respondents.

## **RESULTS ANALYSIS**

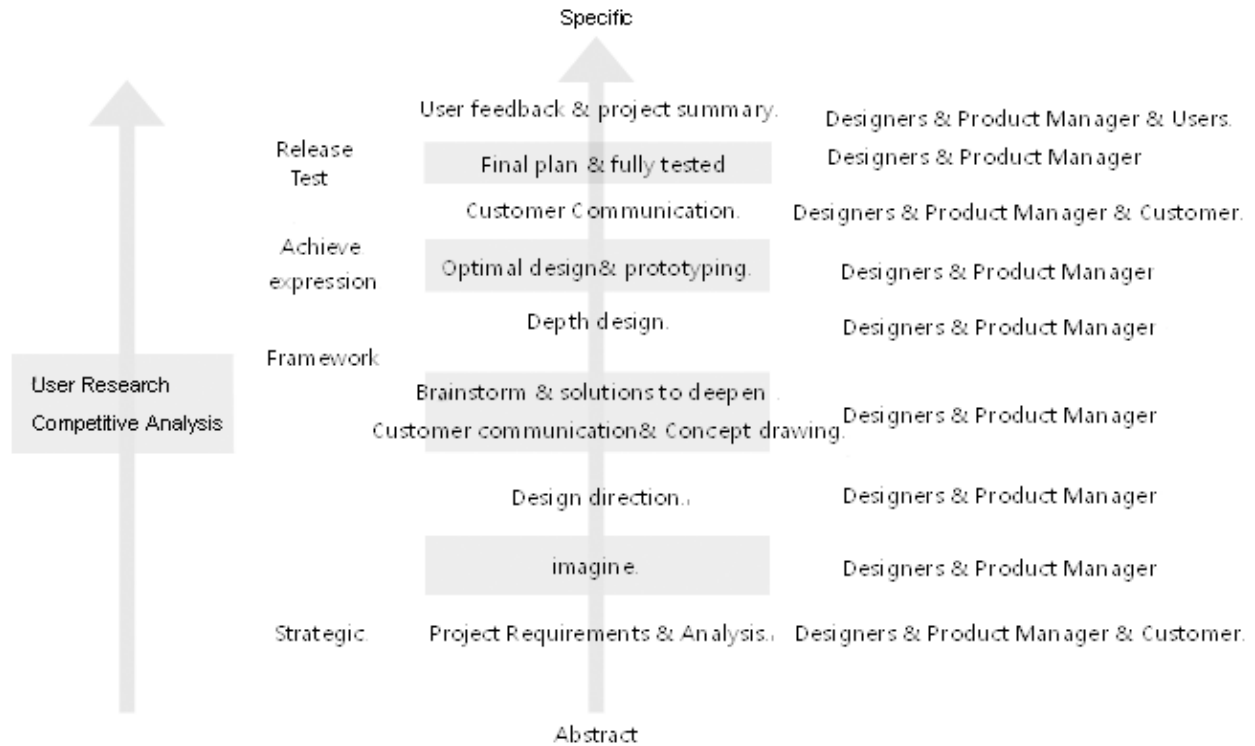
The results use the interview records, protocol analysis and related raw image as the primary source of data, the results analysis consists of two parts: 1) Analysis factors affecting the team mental models in remote collaborative environment through the design process; 2) Analysis of the potential demand for designer collaborative work.

When analysis these data needs to consider several dimensions associated team mental models: Team task, team interaction, equipment or technology, teammates, especially in the context of remote collaborative work over several dimensions relevant for designers of cognition and understanding. In particular need to investigate problems include:

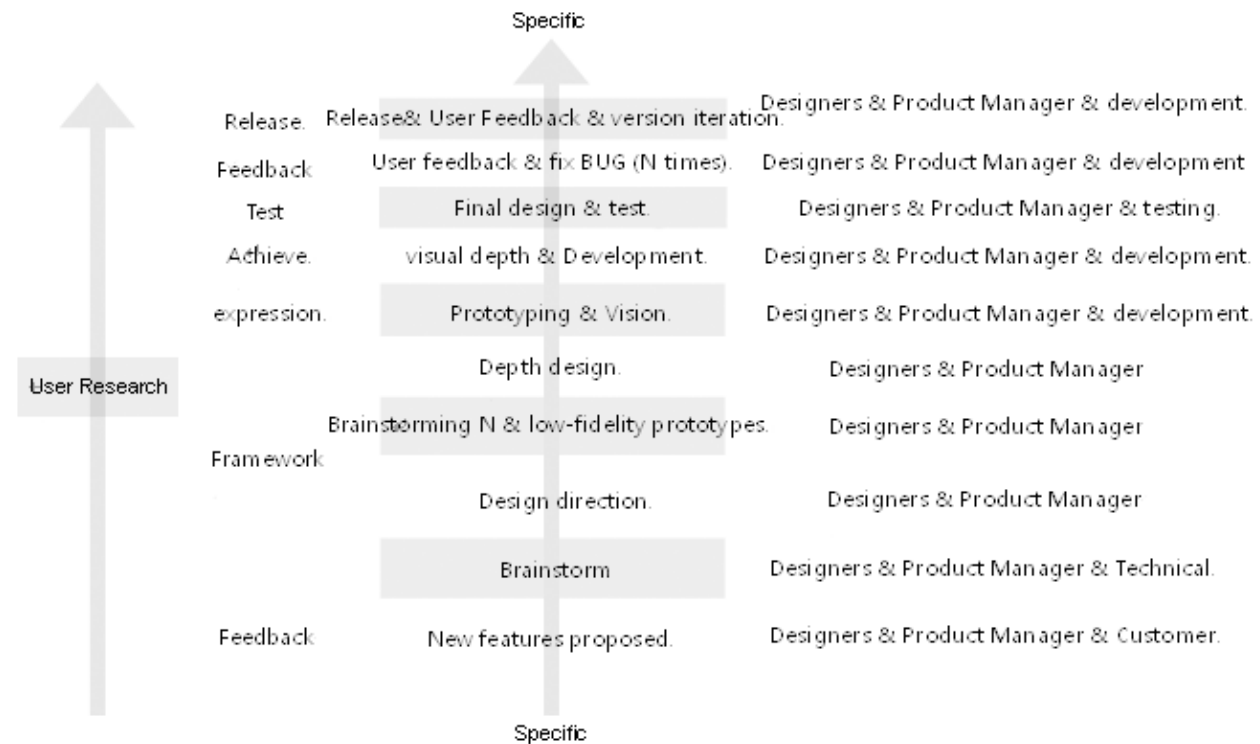
- 1) Designer to understand the design task itself: there is a clear design issues or is relatively vague without a clear definition of design problems in concept generation phase;
- 2) Designers in the task implementation process for problem solving oriented grasp: Is there a clear way to make the problem more clear and specific questions or make further divergence and complex;
- 3) Methods to promote solve the problems in the design process used by designers; help designers find problems-solving- tools and ideas-generated-tools, to understand the designer's mental model;
- 4) Designer's breakthrough approach in problem solving bottleneck periods, especially the team 's push to break through the bottleneck, the problem makes sense to explore the creative generation mechanism for collaborative design;
- 5) Common methods, research needs and data processing, designers need what types of data in problem solving process and what roles of data for the concepts generation, data sources and designers' understanding of the data, share and so on;
- 6) Remote real-time (project descriptions, research and analysis, sketches, renderings, solutions discussed at various stages), which communication tools will be used, and how the results;
- 7) Whether brainstorming will be used within team in the case of remote collaborative;
- 8) In the similar brainstorming meeting, whether recorded the ideas of others by the own way (special symbols), and how, if there is an electronic version of record, will this have an impact;
- 9) If remote communication, prefer pen and paper or electronic to exchange ideas;
- 10) The views on the design process with the virtual reality and other emerging human-computer interaction technology.

The analysis is on the process of looking for clues based on the proposed dimensions, as well as through data analysis, extract mental factors and abstract the processing of express the model, will provide an analysis conclude based on several dimensions \_ remote collaborative factors affecting team mental models in concept generation stage.

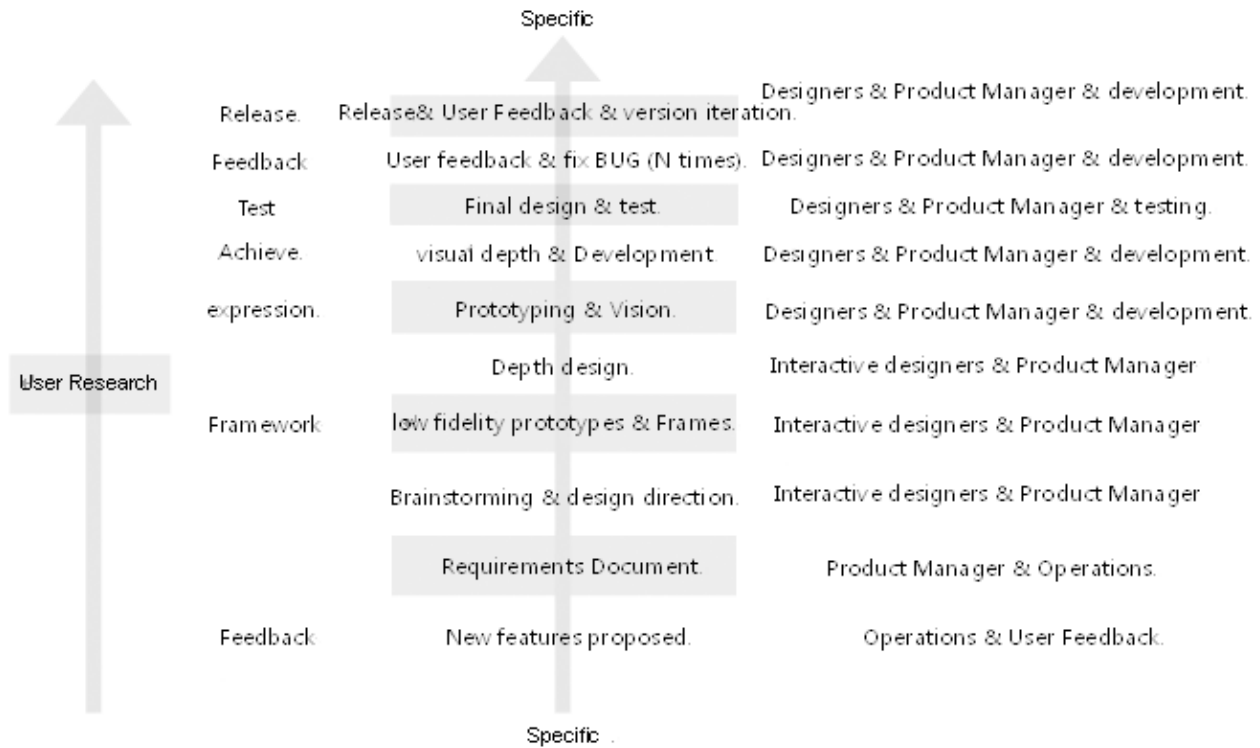
Preliminary results analysis of each group is include their main work procedures, methods requirements and the remote collaborative design tools. As shown are the four designer teams' interviews summary.



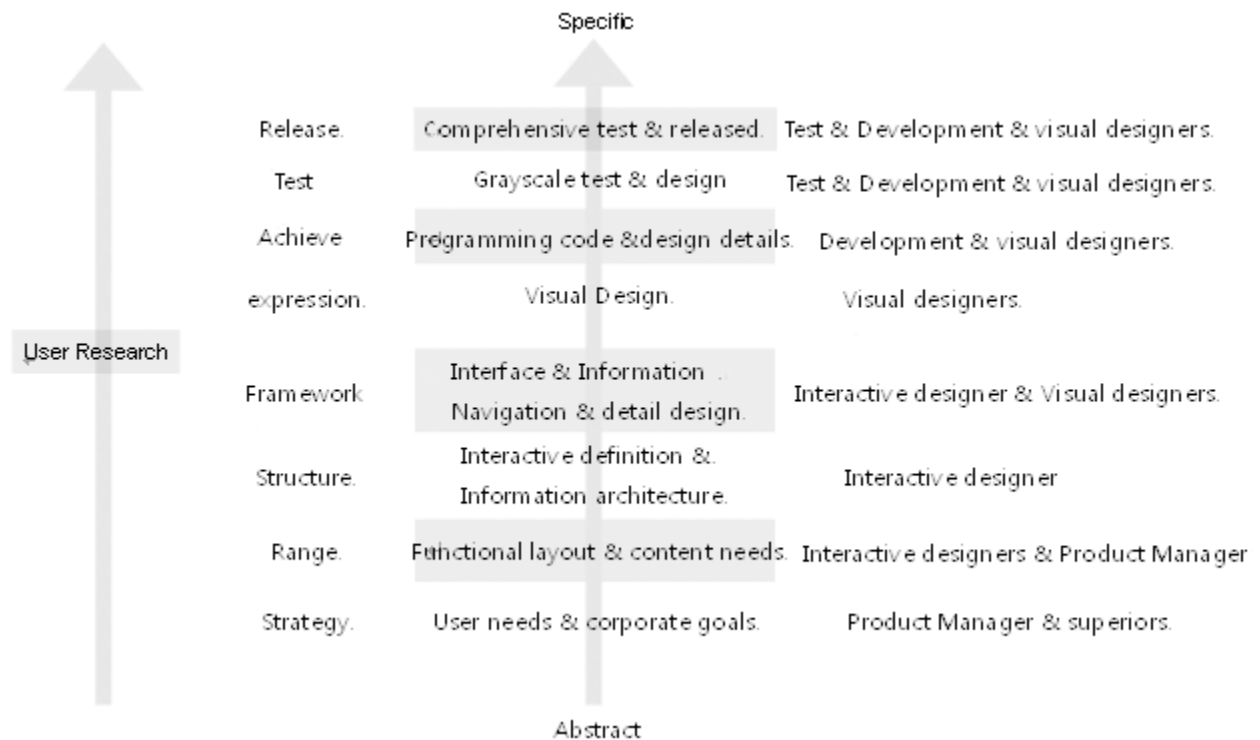
Enterprise ① \_ Internet entrepreneurial team\_3 people \_ Task flow model:



Enterprise ② \_ Internet entrepreneurial companies\_20 people \_ Task flow model:



Enterprise ③ \_ A network company UED team\_10 people \_ Task flow model:



Enterprise ④ \_ Internet companies UX team \_12 people \_ Task flow model:

## Preliminary Results Discussions

As can be seen from the above four tasks process models, product design in the Internet field, the design process is substantially the same. But comparing the four companies, due to different factors such as enterprise scale, establish a length of time, resulting in a lot of differences in the details of the task flow. Designers' work content is very diverse which can be found in the concept generation phase, and the designers describe this phase of the work is also more clear, simultaneously reflected the most profound memories in this phase. This confirms the weight of subjective creative activity participation in concept design stage.

At different levels of concept generation phase, design problem definition of clarity have obvious difference, especially in the initial strategic and scope layers are relatively obscure. However, in the process of seeking to solve the problem, the problem itself in the program design will be more or less fixed. And, in the face of unexpected and professional problems, designers understanding of the issues and solutions often require some time, the length of time and the quality of results always affected by the designers themselves experienced. In this process, the exchange with clients and other team members are essential for a consensus understanding of design issues.

Generation phase of the concept, four companies have encountered remote collaboration situations.

1) The remote collaborative (R&C) often appear in the deepening stage of enterprises ①, made it clear that R&C does not appear in the concept generation phase: such as brainstorming not commonly used in remote real-time design scenarios, which means that entrepreneurial teams hope to mutual break-in at concept generation stage, to guide each other; while enterprises ② ③ ④ have encountered R&C in each level of the task; 2) Four companies' designers have a clear distinctive attitude between exchanges in different places and face to face: they generally believe that the concept generation stage need more face to face discussion and communication, in order to avoid bias and understanding of design problems resulting deviation from the design direction and cost waste; 3) In the implementation process of the entire task, the four companies, without exception, throughout the conference, there will be different responsible person to initiate a conference for each different level. Enterprises ① mainly use face-to-face meetings, QQ, telephone; Enterprises ② uses face-to-face meetings, internal IM tools, QQ; Enterprises ③ also uses face-to-face meetings, remote video conferencing, telephone, internal IM tools; Enterprises ④ uses remote video conferencing, internal IM tools, telephone and face-to-face meetings; 4) Enterprises ① and ② have no segment, the situation of R&C also belong to colleagues on business, so the demand for cloud storage and high-quality mobile devices are more urgent; Enterprises ③ and ④ have business segments and in different places, therefore, the situation of R&C has more types, also used more communication tools; 5) Four companies currently widely used communication tools as QQ, business QQ, MSN, etc. Enterprises ① usually use QQ and telephone; while enterprises ② ③ ④ were developed in-house IM tools, and IM tools from enterprise ② and ④ are market-oriented. Provide related functions such as text chat, video conference, screenshots, file transfer, project sharing; 6) The ① enterprises' designers reflect QQ, telephone and MSN can not be fully effective support their creative work, especially when communicating in different places, less efficient for designers perception and other aspects like the design details of the grasp of little help; ② enterprises' designers said in the office using remote collaboration tools and management tasks, in real time to see the progress of colleagues and sharing, that's good for promote the projects and team building; ③ and ④ enterprises' designers said the company has been using an internal self-developed IM tools which is useful for enterprise architecture, personnel communication, task view, it's a highly efficient platform.

Analysis Summary:

Group A: Enterprises ① \_ Internet entrepreneurial team has founded two years, lack of the teammates, without mature experience, for build the remote collaborative \_ team mental models have limitations, therefore enterprise ① do not appears in next depth analysis;

Enterprises ② \_ Internet entrepreneurial enterprise has founded three and a half years, 20 people, has genetic innovation, focus on research and development collaborative projects management platform, which is based mainly on cloud services; the number of users over one hundred thousand. Therefore, this company belongs to one of the objectives of the study;

Ergonomics In Design, Usability & Special Populations III



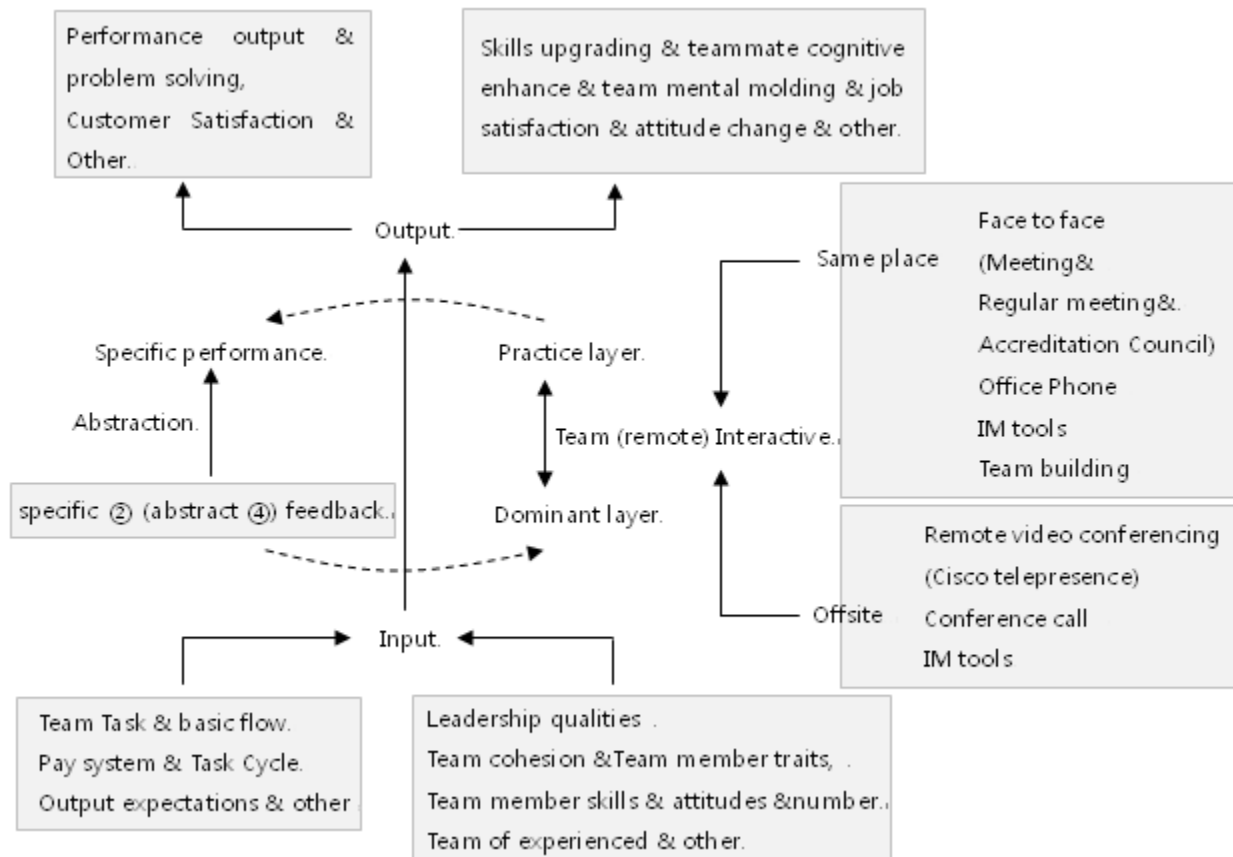
Enterprises ③ \_ A network company \_ UED team of 10 people, the establishment of a long time, more staff, experienced, but its internal IM tools do not face the market, just for internal staff use, and therefore does not have general applicability;

Group B: Enterprises ④ \_ Internet companies \_ UX team of 12 people, the establishment of a long time, more staff, experienced, market-oriented internal IM tools, many number of users.

Therefore, in the next depth analysis will be selected the enterprises ② and ④.

### Remote Collaborative \_ Team Mental Models Affecting Factors Discussed

The enterprises ② and ④ \_ Task flow model: Specific tasks expression as shown below:



According to the task flow model analysis, remote collaborative \_ Team Mental Models factors affecting roughly into the following categories:

- 1) Output performance, problem solving, customer satisfaction can be categorized as performance factors;
- 2) Skills upgrading, enhancing cognitive of teammates, team mental models, job satisfaction, and attitude change can be classified as mental factors;
- 3) Team tasks, basic flow, pay system, task cycle, output expectations can be categorized as task characteristics factors;
- 4) Team cohesion, number of team members, team experience can be categorized as the team factors;
- 5) Leadership qualities, team attitude, team skills, team members' characteristics can be classified as the individual factors;
- 6) The way of communication, communication environment can be

classified as environmental factors (technical factors influence this to some extent); 7) The design tools used in the process of task can be classified as device factors.

In the above factors in seven categories, equipment factors with less affected on team mental models building, for new equipment just adapt and learn to master; impact of environmental factors on build the model will be increasing to some extent by the technological development; the personal factors, as instability, with subjective component of attitude, character, personality and leadership qualities, to establish a model of greater impact; whether group factors stability comes from length of time the team founded, members of cognition, communication and understanding of each other, if there is a same consistent cognitive of the project, whether there had been experienced successful history, this factor will impact great on establish the model; task characteristics factors also affecting the mental model obviously, simple task make easier to build team mental model, the more similar cognitive by teammates of the tasks, the more easier to promote the models building; high-salary and short duty cycle directly influence the attitude of the team members sometimes, and the high output expectations can incentive and stimulus the team, also reflect the team members for their own requirements positioning; mental factors and performance factors are belong to the output, and therefore less affected on the models building, but these are important factors that will influence on the next team mental models building with iterative characteristics.

## CONCLUSIONS

In this paper, exploratory study of the mental model of the factors affecting the domestic Internet companies' team of designers in remote collaborative environment, the study found that at least seven types of factors that can affect different degrees of build remote collaborative \_ team mental models.

Due to the increasing globalization of the design will be an inevitable trend, the distribution of resources as well as off-site communication problems will be a key constraint to design. How to introduce the collaborative design mechanisms effective for this critical stage that generate the creative concepts, effective use of positive team mental models, to protect remote communication of designers, will also be the key to the future development of collaborative creative works. Looking at the results from previous studies, there are many places can be continued to dig deeper:

- Measurement of content: team mental models not only refer to the structure of knowledge, also include the attitudes and beliefs structure of team members, but now several methods used commonly for knowledge structure only rarely involve measuring belief system;
- Emphasize the similarity or accuracy of mental models of the measurement. In this study, more emphasis similarity on mental models, but the real situation may be although the team members reached a consensus, but it is wrong. Studies have shown that the similarities and correctness are two different targets, different effects on team performance (Marks, Zaccaro and Mathieu, 2000).

## REFERENCES

- Cannon-Bowers J A, Salas E. (1993), "Shared Mental Models in Expert Team Decision Making". In: Castellan N J Jr. (Eds.), "Individual and Group Decision Making: Current Issues", Hillsdale, NJ: Erlbaum.221~246.
- Cooke N J, Salas E, Cannon Bowers J A, et al (2000). "Measuring team knowledge". Human Factors. 42:151-173.
- David Meister. (1982) "The role of human factors in system development". Applied Ergonomics. 13(2), P119—124.
- Janice Langan-Fox, Anthony Wirth, et al (2001). "Analyzing shared and team mental models". International Journal of Industrial Ergonomics. 28:99-112.
- Klimoski R, Mohammed S. (1994), "Team mental model: Construct or metaphor Journal of Management", 20: 403-437.
- Kraiger K, Wenzel L H. (1997) "Conceptual development and empirical evaluation of measures of shared mental models as indicators of team effectiveness". In: Brannick M T, Salas E, Prince C (Ed.). Team Performance Assessment and Measurement, Mahwah: Erlbaum. 63~84.
- K. A Ericsson, H.A Simon (1984). "Protocol analysis - Verbal reports as data". London: MIT Press.
- Mohammed S. Klimoski R. Rentsch J R. (2000), "The measurement of team mental models: We have no shared schemas". Organizational Research Method. 3(2):123-156.
- Marks M A, Zaccaro S J, Mathieu J E. (2000) "Performance implications of leader briefings and team- interaction training for team adaptation to novel environments". Journal of Applied Psychology. 85: 971~986.

Ergonomics In Design, Usability & Special Populations III

- M.W van Someren, Y.F. Barnard, J.A.C Sandberg (1994). “*The think aloud method – A practical guide to modeling cognitive processes*”. London: The academic press.
- Robert J.K. Jacob, et al. (2008) “*Reality-based interaction: A framework for post-WIMP interfaces*”. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, P201—210.