

FROM CULTURAL DIVERSITY TO GROUP CREATIVITY:
USING LANGUAGE-RETRIEVED PICTURES TO SUPPORT COMPUTER-
MEDIATED INTERCULTURAL BRAINSTORMING

A Dissertation

Presented to the Faculty of the Graduate School
of Cornell University

In Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy

by

Hao-Chuan Wang

August 2011

© 2011 Hao-Chuan Wang

FROM CULTURAL DIVERSITY TO GROUP CREATIVITY:
USING LANGUAGE-RETRIEVED PICTURES TO SUPPORT COMPUTER-
MEDIATED INTERCULTURAL BRAINSTORMING

Hao-Chuan Wang, Ph. D.

Cornell University 2011

International and intercultural groups increasingly perform various kinds of knowledge work that require groups to brainstorm or generate new ideas, such as problem solving, intelligence analysis and design. One observation based on the understanding of cultural differences and group idea generation suggests that cultures, or socially shared systems of concepts and practices among communities of people, introduce both benefits and obstacles to intercultural brainstorming. Cultural diversity in concepts and ways of thinking is in general beneficial, while cultural discrepancy in social norms, communication styles and language can be detrimental to idea sharing and brainstorming outcomes.

The major goal of this dissertation is to reconcile the tension between the benefits and obstacles of intercultural collaboration. In this dissertation, I investigate how people with different cultural backgrounds communicate to perform brainstorming. I further propose brainstorming support tools accordingly, and evaluate the designs in the contexts of cross-cultural and cross-lingual brainstorming. The dissertation considers that using computers to retrieve and display language-retrieved pictures, which are pictures relevant to the ongoing conversation, can effectively support intercultural brainstorming. As individuals from different cultures vary in terms of how they perceive and interpret image content, the design attempts to present

pictures to elicit diverse thoughts from members of intercultural groups. A study confirms the usefulness of this design for American-Chinese intercultural groups. The dissertation further considers to bridge cultures at the language level, using machine translation (MT) to allow group members to produce and read ideas in their native languages. Another study shows that MT supports the production of ideas but not the comprehension of ideas. The results point to the need to further investigate the detailed processes for producing and comprehending ideas in intercultural groups to inform future designs.

The dissertation contributes to the understanding of computer-mediated intercultural brainstorming with behavioral studies and design work, and shows the need for technical designs to take understanding of various aspects of culture, such as social and communicative norms, cognition and languages spoken, into consideration.

BIOGRAPHICAL SKETCH

Hao-Chuan Wang completed his Ph.D. in the Department of Information Science at Cornell University in 2011. Between 2006 and 2008, he was a Ph.D. student at the School of Computer Science, Carnegie Mellon University, where he conducted research at the Language Technologies Institute and the Human-Computer Interaction Institute. Between 2004 and 2006, he worked as a research assistant at the Institute of Information Science, Academia Sinica. He received his M.S. in Computer Science from National Chengchi University in 2004 and his B.S. in Earth Sciences from National Taiwan Normal University in 1999.

Hao-Chuan's primary research interests lie in the areas of human-computer interaction, social computing, artificial intelligence and educational technology. He also maintains a general interest in other interdisciplinary topics across computing, social sciences and natural sciences, such as science education, cognitive science, and the social aspect of scientific knowledge and communities. His recent projects include designing and evaluating systems for supporting group creativity, investigating the effects of culture on online communication, and supporting collaborative learning with automated text processing and computer agents.

In Memory of My Mother, Ping-Chen Hsu

茲以紀念我的母親徐萍真

ACKNOWLEDGMENTS

First of all, I would like to thank Susan Fussell for her great support and advice for my research work, career development and everyday life. I am grateful for having her as my mentor both at Carnegie Mellon University, where I started my PhD study, and at Cornell University, where I completed this dissertation. Without her insightful guidance, I would not be able to learn and accomplish as much in the past four years. I would like to thank Dan Cosley for being my co-advisor at Cornell. It was extremely helpful and reassuring to discuss with him, and to receive his thoughtful comments on my work all the time.

I would like to thank my committee members, Claire Cardie and Jeffrey Hancock. It has been a wonderful intellectual experience to work with them to explore this exciting yet challenging interdisciplinary research space. Their thoughtful comments have increased the completeness and the breadth of this dissertation, leading me to look at my research topics from multiple angles.

Many thanks to professors and senior researchers who have been teaching or working with me in the past few years. In particular, I would like to thank Sara Kiesler, Tsai-Yen Li, Chun-Yen Chang, Tyng-Ruey Chuang, and Carolyn Rosé for their inputs and help at various stages of my PhD study. I would like to thank all the graduate students in Susan Fussell's group. I especially thank Leslie Setlock for her assistance and many inspiring discussions that we had. Thanks to research assistants working with me. I especially thank Meaghan Frank, Johna Seo, Rebecca Flewelling, Kristie Lee, Akshay Bapat, Hau-yu Wong, and Andy Echenique for their work and contributions to projects that I managed.

I must also thank colleagues in the ACM SIGCHI community for their inputs and discussions at various situations, such as conferences and doctoral colloquiums.

Special thanks to Hao-Hua Chu, Laura Dabbish, Jodi Forlizzi, Wai-Tat Fu, Darren Gergle, Saul Greenberg, Toru Ishida, Gloria Mark, Leysia Palen, Mary Beth Rosson, Phoebe Sengers, Diane Sonnenwald, Loren Terveen, Ravi Vatrapu, Steve Whittaker, Naomi Yamashita, Qiping Zhang, and Chen Zhao (in alphabetical order). I thank my academic and personal friends for their support along the way: Yi-Chia Wang, Kai-Min Kevin Chang, Pablo-Alejandro Quinones, Patti Bao, Brian Y. Lim, Min Kyung Lee, Tawanna Dillahunt, Cristen Torrey, Gilly Leshed, Hyunyoung Song, Shaomei Wu, Nicholas Chen, Hrönn Brynjarsdóttir, Tina Yuan, Nanyi Bi, Xuan Zhao, Duyen Mary Nguyen, Sophia Wang and many others that I won't be able to enumerate at once here. Special thanks to all the faculty members and PhD students in the Department of Information Science at Cornell University for jointly building and maintaining such a great environment for research.

I would not be able to accomplish these without the enduring love and support from my family. My greatest appreciation goes to my beloved wife Yi-Chuan Chen, my son Morris Chenyuan Wang, my father Min-Chung Wang and my sister Ying-Jen Wang. This dissertation is especially dedicated to my mother Ping-Chen Hsu. She passed away and left the world in 2004. The great love, support and encouragement she gave to me continue to be a source of inspiration for my work

This material is based upon work supported by the National Science Foundation under Grants No. IIS-0325047, CNS-0551554, IIS-0803482, IIS-0845351, and OCI-1025425. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

TABLE OF CONTENTS

BIOGRAPHICAL SKETCH.....	iii
DEDICATION.....	iv
ACKNOWLEDGEMENTS.....	v
TABLE OF CONTENTS.....	vii
LIST OF FIGURES.....	ix
LIST OF TABLES.....	x
INTRODUCTION.....	1
Overview of Group Brainstorming.....	3
Intercultural Group Brainstorming.....	6
Supporting Intercultural Brainstorming.....	8
Supporting Cross-Lingual Brainstorming.....	12
Summary of Research Contributions.....	13
Outline.....	16
THEORETICAL BACKGROUND AND RELATED WORK.....	18
Group Brainstorming: A Socio-Cognitive Perspective.....	18
Cultural Variation and Group Brainstorming.....	24
Computer-Mediated Communication as Group Brainstorming Support.....	28
Automatic Feedback as Brainstorming Support.....	32
UNDERSTANDING COMPUTER-MEDIATED INTERCULTURAL GROUP BRAINSTORMING.....	35
Method.....	40
Measures.....	43
Results.....	46
Discussion.....	51
IDEA EXPANDER: AGENT-AUGMENTED BRAINSTORMING.....	57

Design Criteria.....	58
Using Language-Retrieved Pictures as Brainstorming Support.....	60
The IdeaExpander Model.....	63
Prototyping.....	67
EVALUATING IDEA EXPANDER IN CULTURAL CONTEXTS.....	72
Method.....	74
Measures.....	75
Results.....	78
Discussion.....	85
CROSSING LANGUAGE BOUNDARIES.....	90
Using Pictures to Support Machine Translation-Mediated Brainstorming.....	94
IdeaExpander-ML: Multilingual Brainstorming with Language-Retrieved Pictures.....	97
The Current Study.....	103
Method for the Study.....	106
Results.....	110
Discussion.....	118
GENERAL DISCUSSION.....	124
Summary of Results.....	125
Discussion.....	128
General Limitations and Future Work	135
Conclusion.....	136
APPENDIX A.....	138
APPENDIX B.....	141
APPENDIX C.....	142
REFERENCES.....	144

LIST OF FIGURES

Figure 1. Pictures containing the concept of “car”	11
Figure 2. A simple semantic network.....	21
Figure 3. Illustrations for the “extra eye” and “extra thumb” tasks.....	41
Figure 4. The video-enabled chatroom used in the study.....	42
Figure 5. Talkativeness (logarithmically transformed) per trial by individual cultural background and media condition.....	48
Figure 6. Responsiveness per trial by individual cultural background and type of cultural group.....	49
Figure 7. Cognitive and socio-cognitive processes mediated by IdeaExpander.....	64
Figure 8. IdeaExpander screenshot and high-level architecture.....	68
Figure 9. Validating picture selection methods.....	70
Figure 10. Illustration for the “having wings” brainstorming task.....	76
Figure 11. Adjusted productivity by group composition and picture support.....	80
Figure 12. Breadth of concepts by group composition and picture support.....	82
Figure 13. Breadth of concepts by individual cultural background and type of cultural group when using the Stimulus picture selection method.....	84
Figure 14. Using picture retrieval to repair a translation error.....	96
Figure 15. The architecture of IdeaExpander-ML.....	98
Figure 16. Productivity by individual cultural background, mediation condition and picture support.....	112
Figure 17. Breadth of concepts by individual cultural background, mediation and picture support.....	113
Figure 18. Effect of socially exchanged ideas, showing how similar an idea is to the previous idea proposed by the brainstorming partner.....	115
Figure 19. Perceived task load and comprehensibility of messages.....	117

LIST OF TABLES

Table 1. Definitions and examples of main coding categories.....	44
Table 2. List of words strongly associated to the queries (words in bold) retrieved from the semantic space.....	78
Table 3. Counts and percentages of utterances in different languages receiving pictures from IdeaExpander-ML.....	103
Table 4. Modes of language processing for American and Chinese over English- and MT-mediated communication.....	121

CHAPTER 1

INTRODUCTION

International and intercultural groups increasingly perform knowledge work for research and development. Examples of this type of collaboration can be found in numerous domains, such as human genome project (Collins et al., 2003), joint space exploration (Culhane & Worms, 2001), monitoring of environment and climate change (Haeberli et al., 2000), disease control (Heymann & Rodier, 1998) and international efforts on literacy education (Jones, 1990). There can be many reasons leading to the wide practice of international knowledge work, such as the need to combine expertise and resources located at different countries, or the need to popularize experience and information from one country to another. Among these factors, one observation is that the high availability of computer-mediated communication (CMC) tools built upon information and computing technologies, such as email, instant messaging and video conferencing, can play an enabling role, making it possible for people to perform international collaboration to fulfill various needs on a regular basis.

Pragmatically, using CMC tools to communicate and collaborate has become part of people's professional life. For example, the software company MathWorks holds annual "virtual conferences" by using a mixture of CMC tools including text chat and video conferencing tools for MATLAB users to share their use experience of the software¹. National Science Foundation also has also started to hold review panels online for reviewing research proposals by using Second Life (<http://secondlife.com>), an online world that allows panelists to use their avatars to discuss the proposals and

¹ <http://www.mathworks.com/matlabvirtualconference>

interact with each other (Bohannon, 2011). CMC thus has become a strategic tool that groups leverage to enable remote collaboration at a low monetary and time cost. There is a clear economic motivation for people to communicate with each other without having to travel physically and to meet face-to-face.

However, it is noteworthy that physical distance is not the only possible boundary between people in distributed groups (Olson & Olson, 2000). People collaborating across national and geographical boundaries also introduce systematic variation such as styles of working and communication, which can be best described as cultural differences. As a broad definition for the purpose of this dissertation, a culture is defined as *a system of concepts, norms, values and practices shared by a community of people through processes such as imitation and teaching* (Brumann, 1999; Fussell et al., 2008). Culture introduces differences along both cognitive (e.g., concepts) and social dimensions (e.g., norms and values), adding complexities to processes of group work. One observation is that the existing technical infrastructure of CMC is primarily designed for helping people work across physical distance but not across cultural boundaries. It is straightforward to develop and evaluate CMC tools in intracultural rather than intercultural contexts. This observation raises the needs to further investigate how culture influences intercultural group work and to consider whether the effects of technologies generalize across cultures.

Among various tasks that groups perform, group brainstorming, or conversing to generate ideas, is central to much work that requires novel thoughts or creative solutions (McGrath, 1984; Kraut, 2003), such as designing interactional methods to promote people's pro-environmental behaviors or identifying strategies for running a new business. It is thus of both theoretical and practical interest to study intercultural group brainstorming. On the one hand, on the theoretical side, intercultural group brainstorming represents a class of knowledge work in which culture can introduce

diversity in concepts, which in turn is potentially useful for the development of alternative solutions. Studying intercultural group brainstorming informs the general understanding of how people from different cultures collaborate to develop new ideas, and whether the creative potential of the intercultural structure occurs when cultural differences in social norms and communication styles make it more difficult for people to communicate. On the other hand, communicating to produce ideas is a practical task that distributed intercultural groups can reasonably perform with existing technologies and may encounter frequently in their work, raising the practical need to understand and support this activity.

1.1. Overview of Group Brainstorming

Generating ideas is an integral component to work in many domains. Designers propose designs of products with improved functions or appearance. Engineers think of strategies to solve technical problems. Scientists generate hypotheses and models to advance understanding of phenomena. One common aspect of these tasks across various domains is the need for people to produce novel and useful ideas. Creativity can be difficult as its criteria involve both novelty and feasibility (Amabile, 1983). It is necessary for new ideas to be not only different from existing ones, but also meaningful with respect to the requirements and constraints associated with the problem to be solved. When a problem to be solved involves requirements and constraints, such as designing a product that needs not only to be functionally feasible but also aesthetically pleasant, individuals may not be able to solve the problem well due to the limits in their knowledge, perspective, experiences and overall cognitive resources. As a strategy for breaking the limitations of individual cognition, distributed social and technological support that shares the agency of ideation and creativity can be useful (Amabile, 1983; Fischer, 2005; Osborn, 1957).

Group brainstorming is one widely practiced approach that uses social means to address individuals' limitation in creativity (Osborn, 1957; Paulus & Yang, 2000). Defined in its broadest sense, group brainstorming refers to a class of collaborative activities in which multiple individuals communicate with each other, most typically in language, to generate and share ideas. The normative paradigm of group brainstorming asks group members to follow certain rules for collaboration, which primarily encourage group members to generate a large quantity of ideas without concern for their quality during brainstorming. The rules also ask group members to build new ideas upon ideas proposed earlier, and discourage them from evaluating or criticizing ideas prematurely (Osborn, 1957). Although studies show that real world groups often do not strictly follow these rules and can simply "brainstorm" in a flexible manner where quality judgment and criticisms are common (Jackson & Poole, 2002), the normative brainstorming paradigm is still insightful in suggesting that openly sharing ideas can be beneficial for helping people generate ideas productively.

In theory, there are two potential mechanisms by which groups may perform idea generation better than individuals: aggregation and synergy (Kraut, 2003). First, using groups as the unit of idea generation aggregates group members' cognitive resources and ideas they think about, and thus can produce more ideas than separate individuals. Nevertheless, simple idea aggregation does not necessitate individuals to communicate interactively; offline pooling of individually generated ideas can also fulfill the same purpose. Aggregation explains the benefit of recruiting multiple individuals to generate ideas, while this mechanism predicts no unique benefit associated with the feature of interactivity of groups.

Synergy, or the increase of effectiveness through joint action, further explains why interactivity in brainstorming groups can be highly valuable (Kraut, 2003). One observation is that group brainstorming involves more, and more complex, processes

than individual idea generation. Beyond the mere aggregation of individuals' ideas, processes of individual thinking and group communication can affect each other and interact to shape task outcomes. There can be at least two types of synergistic effects in brainstorming groups. First, hearing others' unique ideas can help people think of concepts that they cannot easily access or think of on their own efforts (Nijstad & Stroebe, 2006; Paulus & Brown, 2007). Therefore, ideas contributed by people are not just products. Rather, they can serve as inputs to subsequent thinking. Second, individuals can also combine existing ideas with personal knowledge to synthesize new ideas that no one can develop individually. Social interactions thus open up the possibility of integrating knowledge originally distributed among the minds of different individuals. The opportunities to support other people's ideation and to socially co-construct ideas make interactive groups potentially powerful information processing units for generating ideas (Hinsz et al., 1997).

However, simply working in groups does not guarantee effective aggregation or synergy. Prior work has shown that people interacting with one another in groups do *not* necessarily generate more or better ideas than the same number of non-interacting individuals (Diehl & Stroebe, 1987). Structural factors, such as the composition of a group (individuals that make up the group), and process-oriented factors, such as the overlap of ideas contributed by group members can further influence brainstorming outcomes positively or negatively. Consider a group of people possessing exactly the same knowledge and generating ideas in the exact same manner (e.g., proposing ideas in the same order). Collaboration in this case is unlikely to enhance creativity because group members will not be able to access extra concepts beyond those already accessible individually. Though this is an extreme example, it highlights the crucial role of diversity in thoughts for brainstorming. Studies also show that when ideas received by people are semantically similar to each other, such as

those from only a few homogeneous topics, the performance of idea generation is worse than when ideas received are distributed across many heterogeneous topics (Nijstad et al., 2002; Stroebe et al., 2010). One understanding derived from recent work on group brainstorming suggests that the effectiveness for individuals of generating ideas in groups depends on how different the ideas shared by others are to one's own thoughts. Consistent with the synergistic aspect of group work, when ideas shared in groups are more different from each other, there are more possibilities for these ideas to facilitate the retrieval of rare thoughts, and to provide a broader basis for the construction of synthetic ideas.

1.2. Intercultural Group Brainstorming

Different cultures in intercultural groups introduce different systems of concepts and social norms, raising questions regarding how these differences affect mechanisms of group brainstorming such as aggregation and synergy.

First, culture provides a systematic source of variation in conceptual knowledge among people, such as varying saliency of particular concepts or meanings of particular words. Work in anthropology and psychology has shown various ways that individuals of different cultural backgrounds differ in their conceptual knowledge. For example, people from different national cultures can possess knowledge about specific social customs (e.g., Thanksgiving as a special event to North Americans but not East Asians), different definitions of certain conceptual categories (e.g., what people are covered by the kinship category “aunt”) (D’Andrade, 1981), varying interpretations of images and visual pictograms (Cho et al., 2008; 2009; Chua et al., 2005), and different associations between concepts (e.g., perceived similarities between the notions of “bored” and “sad”, or “arm” and “finger”) (Burton & Kirk, 1979; Romney et al., 1997).

The diversity in concepts between people in intercultural groups is potentially beneficial to group creativity. In terms of the aggregation of ideas, it is likely that members of intercultural groups would have a greater potential to produce different ideas jointly. Similarly, in terms of group synergy, as people from different cultures may contribute different ideas, hearing others' ideas can facilitate access to remote concepts that individuals cannot access on their own. The availability of diverse ideas creates opportunities for developing new ideas through combination. Recent work supports the benefit of cultural diversity on creativity. Studies show that intercultural experience (e.g., exposure to stimuli from other cultures) enhances individual creative performance like storytelling and creativity-supporting processes such as the retrieval of unconventional concepts (Leung et al., 2008).

Second, for intercultural groups to realize the benefit of creativity associated with diversity in concepts, group members must externalize and share their ideas with one another effectively. However, cultural differences in social norms and communication styles can lead to inefficient communication and idea sharing. For example, people from some cultures (e.g., East Asians) have greater tendency to conform to others' opinions, and thus be more apprehensive about sharing their thoughts (Huang et al., 2005; Zhang et al., 2006). Similarly, people from different cultures exhibit different degrees of conversational indirectness (whether to state one's intent directly) (Holtgraves, 1997) and rely to different extents on the context (social or visual) for communication (Hall, 1976; Veinott et al., 1999), which can add burdens of comprehension (e.g., difficulty in interpreting others' language and behaviors) and coordination (e.g., difficulty in placing requests to partners in appropriate ways). The observation that people from different cultures might also speak different native languages also becomes a potential barrier for communication.

What's becoming clearer from the previous discussion is a tension between the potential advantages and disadvantages of cultural differences in intercultural groups. On the positive side, as discussed earlier, cultural differences in thoughts can become a valuable input to idea generation and knowledge work in general. On the negative side, inefficient communication and idea sharing in intercultural groups may make it difficult to aggregate ideas and to synergistically develop new ideas. The tension between the positive and negative sides of intercultural group brainstorming raises not only the need to better understand the tension but also a design challenge— how to address the communication costs of intercultural brainstorming and realize the creativity of intercultural groups.

1.3. Supporting Intercultural Brainstorming

I base my solution for this design task to a basic understanding of cultural differences and the characteristics of the task of group brainstorming. I propose to support intercultural brainstorming with *language-retrieved pictures*, an interaction technique leveraging CMC's computational ability to monitor ongoing conversation and augment it with relevant pictures retrieved based on the content of verbal messages (Wang et al., 2010). The basic idea of the technique is use pictures as extra representations of meaning, and to visualize concepts originally conveyed in conversations. This approach presents concepts to be communicated in multiple communication channels (language and pictures), and aims to support intercultural brainstorming by leveraging distinct properties and communicative processes afforded by different channels. The design aims to be not only effective for supporting the task, but also simple and natural for people to use. Here I describe how the use of multiple channels may in general fulfill these requirements.

Among the two communication channels, language is a versatile and socially shared tool that supports both the production and exchange of ideas. People employ linguistic resources at various levels of processing (e.g., words, syntax, socially shared knowledge of language use) to represent and convey ideas (Graesser & McNamara, 2010; Holtgraves, 2002). When a common language is shared among group members, using conversation to communicate ideas has the benefit of imposing little cost for group members to learn ways of exchanging information in teamwork. Also, conversation is an efficient method of communication because it is a joint activity where participants collaborate to help each other produce and comprehend messages (Clark, 1996; Garrod & Pickering, 2004). Patterns of question answering illustrate this property. Consider the situation in which one person asks “what time is it?” and another responds to it with “it’s three thirty.” The question proposed by the first person calls for an answer of a particular type, which essentially helps the conversational partner formulate his or her response. Similarly, producing and asking the question also prepares the speaker to accept answers of a certain range, facilitating the comprehension of incoming messages. Therefore, conversation is an easy and natural way to communicate through collaboration (Garrod & Pickering, 2004). In practice, conversation is also a common way of communicating during brainstorming (Jackson & Poole, 2002).

Pictures, on the other hand, provide richer yet ambiguous presentations of concepts in visual form. It is efficient to convey certain information or concepts through visual forms (pictures, drawings) if the concepts to be communicated have a visual correspondence, such as those concepts denoting physical and concrete objects (e.g., “desk”, “chair” or “car” etc.) Recent work in cognitive psychology has noted that the nature of mental representations of concepts, especially for those visually perceptible ones, can be non-linguistic and image-like (Barsalou, 2008a, 2008b), so

that it can be cognitively more natural and efficient to communicate these concepts in visual than in verbal forms. Studies also show that replacing noun words in a sentence with pictured objects won't interfere with the judgment of sentence meaning (e.g., to decide the plausibility of a sentence) (Potter et al., 1986), implying that pictures can be useful representations of meaning if used appropriately.

In the context of brainstorming, one useful property is that pictures can provide rich information, which can be valuable for making abundant concepts available for ideation. For example, pictures of a car tend to provide information richer than a simple linguistic statement "this is a car." (see Figure 1). A car picture may contain information about the manufacturer (Ford or Nissan), its type (sedan) and its color (gray or purple) etc. Although it is also possible to express multiple concepts using language, it is not efficient to generate lengthy linguistic specifications to cover all the attributes of a car. Using pictures thus tends to be more natural for presenting and mediating these physically grounded concepts, and can also introduce relevant information without relying solely on the use of language.

There can also be individual and cultural differences in allocation of attention within a picture (which part of the picture a person focuses on) and picture interpretation (what people notice in the picture and what the whole picture is about) (Henderson & Hollingworth, 1999; Chua & Nisbett, 2005). The natural divergence of picture perception among people thus can serve as a useful mechanism for diversifying people's thoughts in intercultural groups. However, it is not feasible to use pictures as the sole representation of full ideas, which often also require people to use abstract concepts (e.g., values, associations and causality), perform semantic operations like negations and references, and combine multiple concepts to create complex expressions (Barsalou, 2008b). Pictures, such as everyday photos captured by cameras, do not constitute a socially shared symbolic system similar to language.



Figure 1. Pictures containing the concept of “car”. Rich attributes of cars can be verified directly from pictures (e.g., manufacturer, color etc.), but not from simple language statements like “this is a car”, which may fail to distinguish some apparent differences between the two cars in the pictures.

Pictures can be useful for conveying simple concepts and inspiring thoughts, but there is no socially agreed way to use pictures as symbols to denote meanings and to construct propositions for representing ideas.

By observing that language and pictures have distinct characteristics and thus different functions that can be either useful or detrimental to brainstorming, it is necessary to consider how to appropriately arrange and integrate the two media to leverage the beneficial aspects of each medium. I argue that using conversation as the driving force to retrieve and display relevant pictures, or the *language-retrieved pictures* approach, is a useful way to support intercultural brainstorming. This arrangement separates the communication of “concepts” from the communication of “ideas”. When people cannot communicate ideas effectively through the language channel due to intercultural communication problems, pictures retrieved by one’s language content may still mediate concepts, even though these might not be the ones intended by the speaker, and thereby facilitate other group members’ idea generation. Cultural differences in picture perception increase the likelihood of people perceiving diverse concepts from pictures, aiding in the production of ideas. Also, people do not

need specific language skills to decode and perceive concepts from pictures. This property can be useful for intercultural groups to reduce the reliance on using a common language (e.g., English) for the purpose of communicating concepts, as pictures can also share the agency of concept communication.

1.4. Supporting Cross-Lingual Brainstorming

In intercultural groups, the use of different native languages (e.g., English, Chinese, Japanese etc.) can be another barrier to the production and comprehension of ideas. Although using a common language (e.g., English) is a typical solution to intercultural collaboration, a lack of second language fluency is not uncommon in some countries (Butler, 2004; Man et al., 2004), which can impede thinking (Takano & Noda, 1993, 1995) and require people to exert more effort and attention to communicate (Schmidt, 1992). Consider the case of a Chinese participant speaking mainly Mandarin and some English working with an American participant speaking only English. When this intercultural dyad brainstorms in English, the Chinese participant may not be able to express certain thoughts or express them clearly enough in English, and may also fail to understand some ideas contributed by the American partner. As a result, a language barrier can emerge and lead to non-productive brainstorming.

One approach to managing language differences is to leverage machine translation (MT) tools, allowing people from different language groups to produce and read messages in their native languages (Hutchins, 1995). MT services have become widely available and inexpensive to regular users (e.g., <http://translate.google.com/>). Using MT to mediate cross-lingual communication is economically feasible today. In the context of brainstorming, using MT to release the language constraints of producing and comprehending ideas in intercultural groups implies the possibility of

further boosting brainstorming performance at a little cost. However, studies suggest that the translation quality of current MT systems is still insufficient for meeting the needs of certain kinds of teamwork, such as those requiring building shared knowledge of the work situation through communication (Yamashita & Ishida, 2006). It remains unclear how translation quality of MT impacts the task of group brainstorming, raising the need to investigate MT-mediated brainstorming.

One idea derived from the earlier discussion is the possibility of using language-retrieved pictures to counteract possible communication problems caused by MT. When pictures are retrieved independently with respect to the mechanisms of MT (e.g., retrieving pictures based on pre-MT messages rather than translation results), pictures can be helpful for visually representing key concepts in the messages, and supplementing the communication function of MT. For MT-mediated cross-lingual brainstorming, as with regular brainstorming, a tool might be designed to leverage individual and cultural differences in picture perception to provide visual stimulation for ideation even if verbal communication is not effective due to translation problems.

1.5. Summary of Research Contributions

The increasing demand and popularity of CMC-based international teamwork raises the needs for a deeper understanding of how properties of culture and technical mediation jointly influence intercultural group work. Along this line, the dissertation provides new contributions for understanding and supporting computer-mediated intercultural brainstorming, a common task that international groups perform for obtaining creative ideas required by work in various domains.

First, this dissertation contributes to our basic understanding of this type of intercultural work, by conducting a laboratory study to examine hypotheses derived from the current theories and understanding of cultural differences, CMC, and group

brainstorming activities. The study looks at how individual cultural background, group cultural composition, and medium (text-only chatroom versus video-enhanced chatroom) influence communication styles and idea generation performance in brainstorming sessions. The study shows that cultural factors and medium factors interact to shape people's conversational styles and brainstorming performance. In the study, Chinese participants were more talkative over text chat than video. Also, Chinese participants were more sensitive to whether other group members were from a different culture or not. Chinese participants' communication patterns were more responsive when working in mixed-culture groups than in same-culture groups. Media or group cultural composition, however, did not influence Americans' communication styles in terms of talkativeness and responsiveness.

The study also demonstrates that intercultural group composition has a negative effect on idea generation productivity. Individuals working in mixed-culture groups generated fewer ideas than those working in same-culture groups, regardless of individual cultural background. This observation suggests that the communication process is more of a problem than the intercultural group composition itself to intercultural brainstorming. This implies that it is possible to enhance intercultural brainstorming by improving the ways that people from different cultures interact to exchange ideas.

Second, to support intercultural brainstorming, this dissertation proposes to use *language-retrieved pictures*, an interaction technique that retrieves pictures relevant to the content of conversations, to visualize concepts introduced to group discussions as a brainstorming support. To achieve both productive brainstorming and naturalistic social interaction, this design presents relevant pictures as an extra visual communication channel to increase the amount and scope of concepts that group members can receive through group discussion. Results from a laboratory study show

that this approach enhanced intercultural groups' performance both in terms of productivity (number of original ideas) and in terms of diversity, or the breadth of concepts (average semantic distance between ideas generated). This dissertation also contributes a new and effective technical approach for supporting brainstorming in two-person groups. As a comparison, early brainstorming support tools were not effective for groups with less than four group members (cf. Gallupe et al., 1992). Another contribution from the design work is a way of thinking that considers cultural variation as a design component that can be leveraged to meet specific goals (e.g., brainstorming outcomes) at the level of socio-technical system design. This dissertation presents a view that cultural differences are not just "problems" to solve or design around; rather these differences can be useful elements that contribute to system outcomes when the benefits can be identified and elicited appropriately. In this work, cultural diversity in concepts and perceptual styles play a crucial role, making it possible to use language-retrieved pictures to enhance intercultural brainstorming.

Third, language can be a gap for the production and communication of ideas in intercultural groups because individuals from different cultures may speak different native languages. MT can be used to mediate cross-lingual brainstorming, allowing group members to express and read ideas in their native languages. However, MT also introduces translation errors, impeding communications. I consider that language-retrieved pictures can be useful for mediating concepts visually and thus addressing communication problems introduced by MT. To understand the joint effects of MT and language-retrieved pictures on intercultural brainstorming, a laboratory study manipulated type of mediation (English versus MT) and type of support (pictures versus no support), and looked at how the manipulations influenced brainstorming outcomes and comprehension. Results show that MT and pictures did not universally support every aspect of brainstorming. There is a tendency for MT to improve the

production of ideas. Chinese participants tended to generate more ideas when talking to their American partners over MT, using their native language (Chinese). However, MT also made it more difficult for people to comprehend each other's ideas, and reduced the diversity among ideas generated. Pictures did not further improve MT-mediated brainstorming, either in terms of performance or comprehension of messages.

The mixed patterns suggest a need to deliberately separate supports for idea production and idea comprehension, and to investigate the mechanisms behind different processes in MT-mediated work. This study points to the need of refining and improving picture retrieval methods for better representing verbal messages and supporting idea comprehension.

1.6. Outline

The rest of the dissertation consists of the following components: the theoretical background, a study for understanding the characteristics of computer-mediated intercultural brainstorming, a design for supporting intercultural brainstorming, and two studies looking at the effects of the design on intercultural and cross-lingual brainstorming respectively.

Chapter 2 will describe the theoretical background and work related to the dissertation research. I will review the literature pertinent to group brainstorming, cultures and computer-mediated communication. Chapter 3 will describe a behavioral study providing an initial understanding of computer-mediated intercultural brainstorming. In Chapter 4, I will describe the design rationale of the language-retrieved picture approach, and present IdeaExpander, a computer agent implementing this interaction technique. Chapter 5 will present a study looking at how IdeaExpander and group cultural composition (intracultural versus intercultural groups) shape

brainstorming outcomes, in terms of ideation productivity and diversity, when using English as the common language to work. In Chapter 6, I will describe a study extending the use of IdeaExpander in MT-mediated brainstorming, looking into the effects of MT and pictures on cross-lingual brainstorming. I conclude with a general discussion of theoretical and design implications of the work in Chapter 7.

CHAPTER 2

THEORETICAL BACKGROUND AND RELATED WORK

In this chapter, I will take a deeper look at important theoretical frameworks, empirical studies and technological designs in the areas of group brainstorming, cultural differences and CMC. To review related work, I will first describe characteristics and processes of group brainstorming tasks; then I will discuss cultural differences in cognition and social behaviors, and relate these cultural variations to group brainstorming. I will then review the uses of CMC tools to mediate and support group brainstorming and discuss how technical properties may influence group brainstorming and intercultural collaboration for obtaining insights useful for this dissertation's studies and design work.

2.1. Group Brainstorming: A Socio-Cognitive Perspective

Group brainstorming as a formal technique was first introduced by Osborn (1957) to enhance idea generation in groups. The key content of this technique is to introduce a set of “brainstorming rules” to regulate group members’ interactive behaviors during a brainstorming meeting, creating a group norm conducive to creative ideation. Brainstorming rules proposed by Osborn (1957) and variations used in many studies and workplaces include (1) the more ideas the better, (2) thinking outside of box no matter how strange ideas might be, (3) criticism is ruled out, and (4) combinations and improvements of ideas are sought (cf. Osborn, 1957; Paulus & Brown, 2007; Stroebe et al., 2010).

These rules have closely and rightly embodied a number of theoretical and empirical understandings about idea generation in groups. Rule 1 (focusing on

quantity) and rule 2 (welcoming wild ideas) may eliminate the tendency that group members would conform to a few opinions or ideas (“group think”) and fail to explore possible alternatives (Levine & Moreland, 1990). Similarly, rule 2 and rule 3 (no criticism) may address people’s concerns of evaluation apprehension, failing to express creative ideas due to social concerns. (Diehl & Stroebe, 1987). Rule 4 (collaborating to generate ideas) predicts a possible cognitive benefit of overhearing and making use of others’ ideas for triggering new ideas (Nijstad & Stroebe, 2006). These rules thus appear to have good rationales behind, and early studies also found that they were helpful for enhancing productivity, compared to groups receiving no rules (Parnes & Meadow, 1959).

However, when further considering whether working in groups can really help people to generate more or better ideas, studies have consistently failed to find so. In the opposite, individuals working in interactive groups tend to have lower idea generation performance than individuals working alone, either in terms of quantity or quality of ideas (Diehl & Strobe, 1987, 1991; Hill, 1982; Paulus & Yang, 2000; Paulus & Brown, 2007; Stroebe et al., 2010). This phenomenon is also termed *process loss* in the literature, as it turns out that individuals do not benefit from their interactions with their partners in groups, rather they lost their performance levels by engaging in the social interaction process.

Laboratory studies on group brainstorming stems from the motivation of trying to understand and explain the nature of process loss in idea generation groups. Early work focused extensively on factors at the social level, especially those structural and motivational issues in groups such as the negative impact of turn taking (having to wait to contribute ideas in groups), evaluation apprehension (fear of others’ evaluation of ideas) and social loafing (letting others do the work) (Diehl & Stroebe, 1987, 1991). More recent research has started to consider and cover factors both at the interpersonal

(social) and intrapersonal (cognitive) levels, trying to capture more details on idea generation in groups (Paulus & Brown, 2007; Stroebe et al., 2010). In this review, group brainstorming is decomposed to involve both the social process of idea sharing and the cognitive process of idea generation. This socio-cognitive perspective of group brainstorming provides a more complete picture of how interpersonal communication affects the cognitive process behind idea generation. Next I first describe the process of retrieving concepts from memory, and then discuss how social interactions may affect this cognitive process.

2.1.1. Cognitive Process of Concept Retrieval

At the cognitive level, one observation is that ideas, even very creative ones, cannot be generated out of nothing (Amabile, 1983). Ideas are meaningful propositions relevant to the given problem, and so idea generation requires individuals to use existing knowledge as the foundation. Thus, idea generation involves the process for retrieving knowledge from memory and combining multiple pieces of knowledge to full ideas (Paulus & Brown, 2007; Stroebe et al., 2010). The current understanding about the structure of semantic memory (i.e., the memory store that holds semantic knowledge) and the process of memory retrieval are therefore at the center of most cognitive models of idea generation (Brown et al., 1998; Nijstad et al., 2002; Nijstad & Stroebe, 2006)

In cognitive psychology, one class of broadly verified and accepted models of semantic memory posits that the human mind encodes and stores conceptual knowledge in a network structure, in which nodes of the network denote concepts, and links between nodes represent semantic associations between concepts (Anderson, 1983; Balota & Coane, 2008; Collins & Quillian, 1969; Collins & Loftus, 1976). Figure 2 illustrates a structure of semantic memory proposed by Collins & Loftus

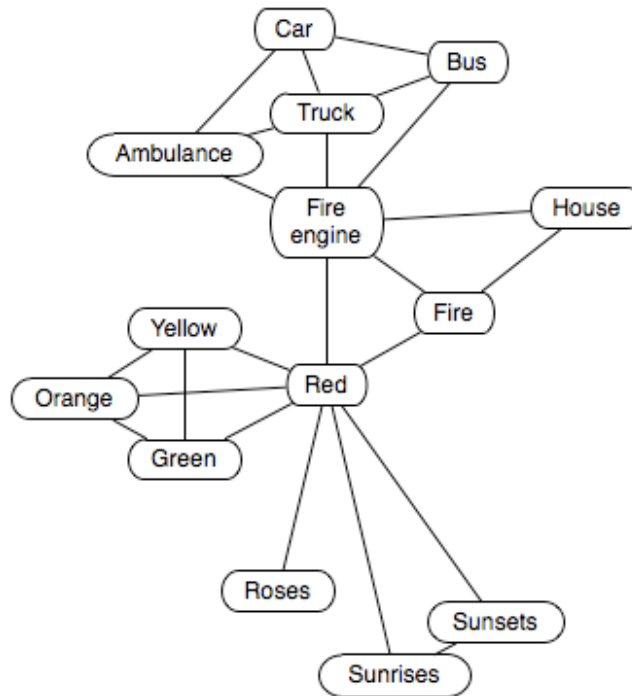


Figure 2. A simple semantic network model. The model represents partial relations among a set of concepts. Nodes of the network represent concepts, and the links represent associations among concepts. The length of links reflects strength of associations; the shorter the link, the stronger the association. Adapted from Balota & Coane (2008).

(1975). Note that the length of the links represents the strength of associations between concepts. Shorter links denotes closer, stronger associations. Network-like representations of conceptual knowledge help to explain and model the general observation that people can learn a great amount of information and use it in an efficient and flexible way, such as to establish the relation between concepts that were never experienced and learned together (Balota & Coane, 2008). Network-like structures permit abstraction and efficient use of information. For example, there is no need to represent the concept of “red” twice in the semantic memory for encoding and processing “fire is red” and “roses are red”. Studies in general found the approach of representing concepts in network structures useful for explaining phenomena related

to the processing of concepts, such as the reaction time in verifying the correctness of statements like “a canary is a bird” and “a canary is an animal” (Balota & Coane, 2008; Collins & Quillian, 1969). Although variations of this representational approach exist for better modeling a wider range of cognitive phenomena (e.g., Anderson, 1983; Raaijmakers & Shiffrin, 1981), most theoretical models preserve the key characteristic that the nature of semantic memory is *associative*.

There are a few important operational features common to different models. First, for being consistent with the observation that people can learn a great amount of knowledge yet can only process a limited amount of information at each time point, semantic network models posit that at any time only a relatively small subset of concepts can be retrieved or activated, becoming available for supporting higher order cognitive tasks such as language comprehension (e.g., Kintsch, 1998, 2001). Second, concept retrieval is not a standalone event. In semantic network theories, the accessibility of a concept can be represented as the level of activation for its corresponding node in the network model (e.g., Anderson, 1983). When the level of activation of a concept node exceeds a specific value, this node is retrieved and available for use. One feature relevant to idea generation is that the retrieval of one concept will contribute to the levels of activation of connected concepts and make them more accessible, facilitating a series of follow-up retrievals (e.g., Anderson, 1983; Balota & Coane, 2008; Raaijmakers & Shiffrin, 1981). For example, thinking about the concept “pears” elevates the activation level of the concept “apples,” which in turn subsequently contributes to concepts like “red” and “green.” Thus, the influence of retrieving one concept spreads throughout the network, with degree of influence attenuating over successive steps across nodes.

2.1.2. Implications to Group Brainstorming

The associative nature of semantic network models helps to explain why idea generation activities often produce a series of semantically related ideas as results (Stroebe et al., 2010). Because idea generation is driven by the retrieval of concepts from semantic memory, it is not surprising that thinking of one idea can influence the content of subsequent ideas, increasing the likelihood to generate conceptually similar ideas due to the higher accessibility of nearby concepts. The tendency to think of similar ideas with more accessible concepts implies that thinking alone may easily fall into pitfall of “cognitive fixation”, failing to explore alternative ideas grounded on less accessible concepts.

As thinking of and comprehending a specific idea both require retrieving and using the same concepts under that idea, it is reasonable to expect that either actively generating or passively hearing an idea can both contribute to the retrieval of interconnected concepts and the generation of relevant ideas (Brown et al., 1998; Nijstad & Stroebe, 2006; Paulus & Brown, 2007; Stroebe et al., 2010). Therefore, with the aid of ideas shared by others in brainstorming groups, it is more likely for individuals to explore and make use of less accessible concepts stored in their semantic memory by simply hearing and processing their partners’ diverse ideas. As a consequence, shared ideas are not only products of brainstorming, but also valuable social inputs that stimulate ideational thinking. From this socio-cognitive perspective, group brainstorming can be viewed as group members sharing ideas to support each other’s ideation and to collaboratively explore the concept space.

However, the potential advantage of idea sharing may not be realized if contributed ideas fail to stimulate thinking. This can happen when negative social effects, such as evaluation apprehension (fearing to express ideas because they might be viewed negatively) and production blocking (taking turns to speak up), reduce the quantity and quality of ideas (i.e., stimuli) shared (Diehl & Stroebe, 1987; 1991).

Failure to stimulate can also happen when group members possess overly similar knowledge. Socially shared knowledge, or *common ground*, is in general important to team collaboration for easing interpersonal communication (Clark & Brennan, 1991; Clark, 1996; Thompson & Fine, 1999). For example, for someone to instruct another person how to get to a location in the town, mutually shared geographical knowledge about the town is likely to save the instruction-giver's effort for expression (e.g., using less explicit instruction would be sufficient) and also the instruction-receiver's effort for understanding. However, it turns out that high similarity in knowledge between individuals in groups can be detrimental for group brainstorming. For example, for two people discussing about urban planning issues of a town, their ideas are unlikely to be very stimulating to each other if they both only know about this town, and have limited knowledge about other cities to share.

Therefore, when similarity among shared ideas is high, the overall value of these ideas for triggering novel thoughts can be lower due to redundancy. Group brainstorming as a group task is not all the same as other forms of interpersonal communication. Group members collaborate with the purpose to jointly explore different concepts diversely, rather than to align their perspectives. One message derived from the socio-cognitive perspective is the importance of ensuring conceptual diversity among group members for rich cognitive stimulation and productive brainstorming.

2.2. Cultural Variation and Group Brainstorming

To sustain group brainstorming, one important source of conceptual diversity is variation of *background knowledge* among group members. Different from domain-specific knowledge, such as abstract concepts and expert skills on specific subjects that requires focused training and education to acquire (e.g., knowledge of computer

programming or statistics), background knowledge can be defined as everyday concepts commonly shared by individuals in social groups and acquired naturally from the social context through participation (Lave & Wenger, 1991; Salomon & Perkins, 1998). For example, residents living in the same town for years tend to share richer knowledge about its geographies or stories. Studies show that individuals from specific cultural groups tend to possess unique definitions of concepts (e.g., D'Andrade, 1981) and unique interpretations of perceived information (e.g., Cho et al., 2008).

It is likely that individuals with similar developmental, educational and socializing backgrounds tend to also possess similar background knowledge due to similar histories and experience of learning in the social contexts. Given the increasing demand and popularity of international collaboration in workplaces, individuals developed and cultured in different national contexts may also introduce greater variation in everyday concepts to workgroups. For example, the concept of “turkey” is likely to be more central to Americans’ semantic memory than to Chinese due to the importance of Thanksgiving as an American holiday, while the Confucian concept of filial obedience may be absent from most Americans’ conceptual knowledge. National cultural background therefore may be a salient source of conceptual diversity that positively contributes to intercultural groups’ group brainstorming. Empirical work looking the effects of ethnic diversity, available in the same national culture, has similarity showed the benefit of diversity on the effectiveness and feasibility of ideas (McLeod et al., 1996).

Background knowledge is only one way that cultures diverge from each other and influence the outcomes of cognitive tasks like idea generation. Cultures also differ in cognitive styles, or the ways of thinking and processing information. Psychology research has showed that East Asians and Americans have broadly different cognitive

styles (Nisbett & Masuda, 2003). East Asians tend to allocate greater attention to contextual information, such as background objects in a picture (Chua et al., 2005; Masuda & Nisbett, 2001; Masuda et al., 2008). At higher levels of cognition, such as interpretation and categorization, East Asians often associate concepts based on ecological relations (e.g., associating cow and grass because cows eat grass) (Nisbett & Masuda, 2003; Peng & Nisbett, 1999). Americans, on the other hand, attend primarily to focal information, such as foreground objects in a picture, and to categorize based on shared properties (e.g., associating cows and sheep, because both are farm animals). Overall, the cognitive style of East Asians tends to be more holistic, and that of Americans tends to be more analytical. For brainstorming, it is unclear yet how each mode contributes to idea generation. However, it is likely that intercultural groups would be able to better explore diverse ideas than intracultural groups due to group members' flexibility in using multiple approaches of thinking to access and process information.

Cultures also differ in social orientations (Markus & Kitayama, 1991) and collaborative behaviors (Diamant et al., 2008; Setlock et al., 2004). East Asian cultures (e.g., Chinese) are generally more collectivistic and relationship-oriented (Markus & Kitayama, 1991; Triandis, 1995). When working in groups, Chinese may be less comfortable with dissent, and tend to conform to other people's opinions in order to avoid threats to interpersonal relations. In contrast, Americans are generally more individualistic and task-oriented. In teamwork, Americans may be more comfortable with sharing their thoughts directly without worrying as much about other people's opinions or feelings. Based on cultural differences in social orientations, one threat to intercultural group brainstorming is that certain negative social psychological factors related to social motivations and interpersonal relations like evaluation apprehension can be more prominent among some cultures (e.g., Chinese) and under

some conditions (e.g., talking about sensitive topics or communicating face-to-face) (Wang et al., 2009). The social norms of collectivistic cultures tend to promote individuals' conformity to authority and convergence of opinions of others (Huang et al., 2005; Powell & Anderson, 1994; Zhang et al., 2006).

Along a similar line, there can also be cultural difference in communication styles, ways people convey and interpret meanings in communication. Hall (1976) considers the role of context in communication as a crucial feature that differentiates cultures. In high-context cultures (e.g., Chinese, Japanese and Korean cultures), people tend to include context in the production of messages (e.g., conveying meanings in nonverbal ways), and also interpret others' messages with respect to a relevant context (e.g., looking for cues from the context for interpretation). On the other hand, people in low-context cultures (e.g., American and Germany cultures) tend to convey their meanings explicitly through the verbal channel, assigning a relatively minimal role to the context of communication during their production and interpretation of messages. Similarly, individuals from East Asian cultures, but not American culture, incline to speak more indirectly, look for indirect meanings during communication, and attend to indirect cues in the context (Holtgraves, 1997; Sanchez-Burks et al., 2003). In intercultural groups, group members practicing different communication styles can easily misunderstand each other because the divergence in styles can require them to exert greater cognitive efforts to recognize meanings or to repair communication. Cultural differences in communication styles therefore can be another barrier to smooth idea sharing in intercultural groups.

Overall, cultural differences along a number of dimensions appear to be relevant to idea generation and group brainstorming, some tending to be beneficial and some tending to be problematic. Cultural differences in background knowledge and cognitive styles can be quite useful for introducing diverse concepts to stimulate

ideation and enhance brainstorming performance. However, cultural differences in social norms and communicative styles can make it difficult for individuals in intercultural groups to effectively communicate and share ideas. Although similar kinds of social inhibition are common to all brainstorming groups (e.g., evaluation apprehension), intercultural group can be particularly susceptible to these obstacles due to the lack of shared norms and languages for performing group coordination at a meta-level. Therefore, it is especially necessary to design appropriate technical support for intercultural groups' brainstorming and knowledge work in general.

2.3. Computer-Mediated Communication as Group Brainstorming Support

One technological innovation in the context of group brainstorming is to introduce computer-mediated communication (CMC) as a means to support productive idea generation. CMC refers to the use of computer-based tools, such as video conferencing, email and instant messaging (IM) systems, to enable remote, non-collocated interpersonal communication. Although the original focus for designing and using CMC tools was mostly on the economic benefit of allowing people to deliver messages remotely, CMC is not the same as face-to-face communication, and so CMC tools can have secondary effects or functions other than quickly sending data from one end to another. For example, using a less realistic CMC tool with reduced social context cues available like email and IM, can make people to communicate more straightforwardly, more likely to express opinions in an uninhibited manner out of the social frame (Sproull & Kiesler, 1986). Properties of CMC thus can have pragmatic effects on group work, such as influencing interpersonal relations and effectiveness of collaboration. Research has noticed and shown that the matching task characteristics or needs with media properties is crucial to task outcomes (e.g., Connolly, 1993; Kraut et al. 2003).

Different CMC tools vary in *media richness* (Daft & Lengel, 1986), or the amount of communication channels available for conveying information and social cues. Instant messaging, for example, depends on only text as the means of communication, while video conferencing makes audio and video available, simulating aspects of face-to-face communication such as audibility and visibility. The theory of media richness states that when using a richer medium like video or face-to-face, people can convey information through more channels (e.g., verbal messages and non-verbal gestures), increasing the sense of social presence and making it more effective to communicate (Daft & Lengel, 1986). One general prediction is that CMC is a less useful mediation for group work, as communication over it tends to be less effective, taking longer to discuss one thing or requiring more efforts to accomplish communication goals. Theoretical analysis of how media influence language use also predicts that people establish common ground, or shared understanding about the situation, in communication more easily when multiple communication channels are available (Clark & Brennan, 1991). Studies supported the prediction of greater effectiveness for rich media when the goal of communication is to establish shared knowledge and the goal of collaboration is to negotiate and converge perspectives (e.g., Veinott et al., 1999; Kraut et al., 2003).

Although the reduction of social and contextual cues in CMC is unfavorable to many tasks (e.g., for establishing shared understanding), this can be a useful aspect for reducing social side effects in group brainstorming. As discussed earlier, individuals brainstorming in groups can suffer from the structural constraint of having to take turns to speak up (production blocking) and social concerns about how other people evaluate their ideas (evaluation apprehension) and how other people perform in the groups (social loafing, social comparison) (Diehl & Stroebe, 1987, 1991; Dugosh & Paulus, 2005). It appears that these negative effects of social interaction can override

the positive benefit of idea sharing and cognitive stimulation, motivating the design of leveraging CMC features to reduce the richness of social interaction, while preserving the function of idea sharing. Early designs such as group decision support systems (GDSS) and electronic brainstorming systems (EBS) (Connolly et al., 1990; Connolly, 1993; Nunamaker et al., 1991) use networked computer clients to enable parallel and anonymous idea contribution. Enforced anonymity can eliminate the concern of evaluation apprehension as the contributors of ideas become non-identifiable. Simultaneous idea contribution can decrease production blocking caused by turn taking in interactive brainstorming.

Studies found this type of CMC designs specialized for group brainstorming helpful for larger groups (e.g., groups consisting of more than four group members), but not useful for smaller groups (e.g., two-person groups) (Connolly, 1993; Dennis & Valacich, 1993; Gallupe et al., 1992). The results are not surprising as the main function behind these systems is to reduce evaluation apprehension with enforced anonymity and production blocking with parallel inputs, and these social side effects are likely to be more severe in large groups when there are more people available for competing conversational turns and for evaluating shared opinions. There remains a lack of effective solution for supporting idea generation during small group discussions between two or three key idea contributors, a common situation in project teams in academia and industries.

The actual adoption of EBS or similar kind of tools is low, while contemporary everyday CMC tools can actually replace most of its functional features at a lower cost. Anonymity or reduced social cues is available through the use of text-based IM. Simultaneous idea entry and asynchronous idea sharing are possible over a variety of web-based tools, such microblog (Twitter) and wiki etc. One observation is that it is not technically difficult to reduce social cues through by leveraging CMC properties,

while what may turn out to be an issue is whether a design approach focusing solely on the removal of social cues would make communication overly structured and constrained. One possibility is that people may find tools like EBS difficult to use if they prefer more naturalistic modes of social interaction such as free conversations.

A field study investigating naturally-occurring idea generation in a governmental agency shows that a deviation from the normative aspect of brainstorming (e.g., avoiding evaluation and other social factors harmful to performance) was common among real brainstorming groups and can still be functional (Jackson & Poole, 2002). Despite the consistent availability of GDSS tools, among all the brainstorming episodes, groups elected to use GDSS less than half the time. Further, using GDSS did not enhance idea generation outcomes. Group members spent limited amount of time on proposing ideas during brainstorming (15% of session time on average), while rich conversational activities constituted most of a brainstorming session, including acts of elaboration, tangent discussion and even criticism (Jackson & Poole, 2002). Similar patterns of rich language use were also observed in laboratory studies (Wang et al., 2009; Bao et al., 2010). One observation is that social interactions are crucial to group development, maintenance and long-term outcomes (Kraut, 2003). Rich conversational patterns may simply reflect people's parallel needs in maintaining both the task and social aspects of group work. Our understanding about the qualities of conversational interactions in brainstorming and their task- and social-oriented functions remain limited.

Given that group brainstorming tends to occur in a conversation-like format, the "social-cue-removal" approach to support brainstorming (e.g., GDSS) is considered less feasible because the strict regulation on social interaction imposed is not ideal for conversations. Another observation is that conversational interactions can provide socializing opportunities for remote, dislocated groups. In intercultural

remote teamwork, the opportunity to socialize is rare, and the inherent cultural divides would rely even more on unrestricted conversations at work time to socialize, to develop trust and to cultivate a social atmosphere conducive to collaboration.

2.4. Automatic Feedback as Brainstorming Support

The results from electronic brainstorming studies show that GDSS-like design failed to support small groups (e.g., two-person groups) (e.g., Gallupe et al., 1992). One reason may be that these designs did not attempt to actively supply stimuli to stimulate ideation, and therefore when social side effects like production blocking or evaluation apprehension were not severe, there were no other ways to support idea generation. This dissertation proposes an alternative observation and design approach. CMC opens up the opportunity to embed computer-based agents into communication channels for monitoring conversations and providing support in real time without the need of human interventions. Therefore, it is possible to use artificial agents to actively supply feedback as stimuli to support the cognitive aspect of group brainstorming, enhancing the overall brainstorming performance while maintaining the flexibility and naturalness of social interaction.

Automatic feedback as teamwork support varies in how sophisticated or “human-like” computer agents behave when interacting with people. Simple feedback mechanisms without complex AI programming involved can still be useful for supporting certain aspects of collaboration. For example, Leshed et al. (2009) shows that simple feedback in the form of using graphic visualizations to represent number of words typed into a chatroom or the extent of agreement between group members, can affect language use and guide groups to collaborate in a socially healthier manner. Another design provides a share display for visualizing group members’ percentages

of contribution with respect to all contributions made to groups, and can promote more equal participation among group members (DiMicco et al., 2004).

In the context of group brainstorming, Wang et al (2007) illustrates using machine learning (ML) techniques to detect topics of utterances, and provide automatic feedback in the form of sentence prompts to guide idea generation. Motivated by the socio-cognitive perspective of group brainstorming that external stimuli can have cognitive stimulation effect on ideation (cf. Nijstad & Stroebe, 2006; Stroebe et al., 2010), an artificial agent is designed to trace groups' ideation status and histories, and provide sentence prompts to explicitly guide individuals to explore relevant topics that they have not explored in the session. Evaluative studies showed that this design improved people's brainstorming productivity (Wang et al., 2007, 2011).

Note that existing designs diverge in terms of techniques used and design goals. Leshed et al. (2009) and DiMicco et al. (2004) provide topic-free visualizations that primarily aimed to regulate teamwork behaviors rather than directly influence the topics of individuals' thinking or groups' discussion. Also because the forms of feedback are peripheral and do not try to participate in the conversation, the smoothness and naturalness of conversational interaction can be better maintained. However, as this approach does not attempt to provide content-related feedback, it may have limited applicability to address the requirement of providing extra stimuli for sustaining ideation in brainstorming groups.

Wang et al. (2007, 2011), on the other hand, intervene in a brainstorming session by injecting topic-related sentence prompts, providing content-oriented stimuli for facilitating ideation. One concern is that this design may be too disruptive to ongoing conversation and collaboration because the artificial agent uses the same communication channel (i.e., the conversation) to provide feedback, and thus may

increase group members' burdens in managing verbal remarks coming from different sources (the agent and other group members). Also, this design relies on the agent's knowledge representation and reasoning procedure to provide artificial stimuli to support ideation. The practical scalability of this approach can be constrained, as it requires explicitly encoding and representing the knowledge structure relevant to the problem domain. It can be difficult to do so in practice as the goal of brainstorming activities is normally to handle novel problems, for which a priori knowledge engineering can be difficult or unpractical.

Another observation is that existing designs tend to consider groups as simple aggregations of multiple individuals, considering little about supporting the function of interpersonal interaction between group members for accomplishing specific task goals. In group brainstorming, one important benefit of social interaction is to exchange ideas, supplying stimuli for facilitating subsequent concept retrieval. It should be valuable to use automatic feedback to enhance the stimulating utility of shared ideas, empowering group members to better help each other retrieving diverse concepts from their individual memories, and collaboratively exploring the concept space. This dissertation will explore this design direction, proposing specific designs to augment the stimulating function of conversational interaction in intercultural brainstorming.

CHAPTER 3

UNDERSTANDING COMPUTER-MEDIATED INTERCULTURAL GROUP BRAINSTORMING

Common to the studies of different forms of online collaboration, such as the influence of email on people's language behaviors (Sproull & Kiesler, 1986) and the role of visibility of the partner's workspace in collaborative physical tasks (Kraut et al., 2003), existing componential, relevant knowledge play an important role to initiate hypotheses for obtaining more specific understanding of the target phenomenon. For example, existing knowledge and models of how people converse to build shared understanding and how technical properties make this process harder or easier to accomplish can be informative for making predictions about how different CMC tools affect teamwork. For computer-mediated intercultural group brainstorming, as discussed in Chapter 2, relevant knowledge comes from at least three aspects, including our understandings around computer-mediation, cultural differences and group brainstorming. The goal of the current chapter is to obtain a deeper and more specific understanding of the phenomenon by empirically examining hypotheses derived from the general knowledge.

I conducted a laboratory study to examine how factors of individual cultural background, group cultural composition and type of CMC tools affect participants' conversational styles and ideational productivity in brainstorming sessions (Wang et al., 2009). Different from earlier group brainstorming studies where the sole focus is on productivity measures (e.g., Diehl & Stroebe, 1987; Dugosh et al., 2000; Dugosh & Paulus., 2005; Gallupe et al., 1992), this study aims to obtain basic understanding of the conversational process of intercultural group brainstorming . Recent analyses of conversations recorded from group brainstorming sessions revealed that the

underlying communicative activities were more complex than expected (Jackson & Poole, 2002). Thriving conversational interactions were observed in the field. Although such conversation violates those normative brainstorming rules (e.g., no evaluation and criticisms) (Osborn, 1957), it is popular in real workplaces. Currently there is very limited understanding of this conversational aspect of group brainstorming from laboratory studies, which can be helpful to identify underlying causal factors and to inform the design of supportive tools.

At least two dimensions of brainstorming conversations are of interest: (a) *talkativeness*—how engaged and expressive group members are, and (b) *responsiveness*—the extent to which group members respond interactively to others' contributions. Conversational responsiveness is an established concept in linguistic studies of dialogue structure (Carletta et al., 1997). Utterances in dialogues are often categorized as initiations versus responses. In ordinary dialogues, initiations set up discourse expectations, and responses fulfill these expectations. In group brainstorming conversations, an initiation (e.g., suggesting an idea) does not necessarily call for any response (Jackson & Poole, 2003). As responding to others' idea proposals can reveal one's attitudes toward other people, decisions about whether or not to respond to another's idea may be based on cultural norms and concerns around interpersonal relations. People from an individualistic and independent culture may be more willing and comfortable to respond to others' thoughts during group brainstorming.

To initiate an understanding of how cultural factors influence brainstorming conversations, it is helpful to investigate cultures that are most likely to be different around some basic social and cognitive processes based on existing knowledge, so that it is possible to detect and inquire the role of cultural differences in more complex scenarios like computer-mediated intercultural brainstorming. This study compares

Chinese and American participants as previous work has suggested that individuals with these two cultural backgrounds tend to differ along several cultural dimensions relevant to group brainstorming (Markus & Kitayama, 1991; Triandis, 1995; Nisbett & Masuda, 2003; Hall, 1976). Studies have suggested that Chinese and Americans in general differ in social orientations that may influence teamwork motivation and behaviors (Markus & Kitayama, 1991; Triandis, 1995), cognitive styles that may influence perception and thinking (Nisbett & Masuda, 2003), and communication styles, most notably the extent to which context is used to convey messages (Hall, 1976).

As reviewed in Chapter 2, group brainstorming involves both cognitive processes for perceiving others' ideas and thinking of new ideas, and social processes for communicating and sharing ideas. Cultural differences in the social, cognitive and communicative dimensions thus may influence how individuals brainstorm in groups. There is also a practical function to study workgroups consisting of American and Chinese participants as the results will provide greater understanding about American-Chinese intercultural work, a form of collaboration that is becoming more and more common in organizations and workplaces.

In this study, three-person intercultural groups (i.e., mixed-culture groups consisting of both American and Chinese participants) and intracultural groups (same-culture groups consisting of participants with the same cultural background, either American or Chinese) performed two brainstorming tasks, one using a text-only chatroom, and one using a video-enabled chatroom that shows a view of other group members' faces. I chose these two media so that the input method could be held constant (typing), allowing a controlled comparison of how the visibility of group members influences the dependent variables.

This study tested several hypotheses derived from current theoretical and empirical understandings related to computer-mediated intercultural brainstorming. One observation is that there is a better *culture-task fit* between American individualistic cultural norms and task characteristics. Group brainstorming tasks require individuals to externalize their thoughts through verbalization. Americans may be more comfortable in sharing their thoughts because their individualistic tendency may drive them to focus on themselves and have less concern about how others perceive or evaluate their ideas. On the other side, Chinese participants may be less willing to share their thoughts due to the collectivistic tendency of evaluation apprehension (Kim et al., 2008) and conforming to others' opinions (Huang et al., 2005; Zhang et al., 2006). Cultural differences in social norms and the understanding that video-enabled chat mediates more social cues than text-only chat lead to hypotheses below.

In terms of talkativeness, I proposed that:

H1: American participants will provide more contributions to the brainstorming discussion than Chinese participants.

H2: Text-only chat will elicit more contributions from participants than video-enabled chat.

H3: The effect of medium on promoting contributions to the brainstorming discussion will be greater for Chinese participants than for American participants.

H4: Chinese participants will become more talkative when working in mixed-culture groups than in same-culture groups. I call such as a change of communication style due to group partners' cultures as cultural adaptation. I derived this hypothesis from the understanding that Chinese individuals tend to prefer coherence and harmony in groups due to their collectivistic tendency (cf. Markus & Kitayama, 1996). Therefore, noting an interpersonal difference in the social context, such as their

partners' more talkative communication styles, may motivate them to eliminate the differences through adapting their behaviors to their partners.

In terms of conversational responsiveness, I propose the following hypotheses:

H5: American participants, compared to their Chinese counterparts, will be more responsive.

H6: The use of video will lead to increased responsiveness. The heightened sense of others' presence and interactivity will compel participants to respond to each other's messages.

H7: Similar to H4, Chinese participants will become more responsive when working in mixed-culture groups because of being motivated to eliminate cultural differences in communication styles. They will attempt to reduce the discrepancy through adaptation. American participants will not exhibit as much cultural adaptation due to their individualistic tendency to maintain their own ways of communication regardless of how the group cultural composition changes.

I also looked at how cultural factors and media influence idea generation productivity, the number of non-redundant ideas proposed by individuals:

H8: Similar to H1, Chinese participants will express less non-redundant ideas than American participants.

H9: Text-only chat will elicit more non-redundant ideas from participants than video-enhanced chat.

H10: The effect of medium on the number of non-redundant ideas will be greater for Chinese participants than for American participants.

H11: Individuals will generate more ideas when working in mixed-culture groups than in same-culture groups. The rationale stems from the socio-cognitive model of brainstorming (cf. Nijstad & Stroebe, 2006), predicting that idea exchange between different cultures can be more diverse, useful for stimulating subsequent idea

generation. A competing hypothesis grounded on the cost and gap of cross-cultural communication, however, predicts that individuals will generate fewer ideas in mixed-culture groups because they may not be able to share and exchange ideas effectively.

3.1. Method

In this study, experimenters asked three-person groups to perform two structurally similar brainstorming tasks (see section 3.1.2), one via a text-only chatroom and one via a video-enhanced chatroom. One observation is that earlier research on intercultural collaboration tends to focus only on how CMC tools affect two-person groups (e.g., Setlock et al., 2004; Yamashita & Ishida, 2006), so more work is required to generalize this type of work to multiparty groups in order to increase the understanding of more realistic teamwork.

American and Chinese participants were assigned to one of four group compositions: three Americans (AAA), three Chinese (CCC), two Americans and one Chinese (AAC) and one American and two Chinese (ACC). Overall, the experiment was a 4 (group cultural composition) by 2 (medium) design. Group cultural composition was a between-subject manipulation. Media and brainstorming topics were within-subject manipulations and were counterbalanced to account for order effects.

3.1.1. Participants

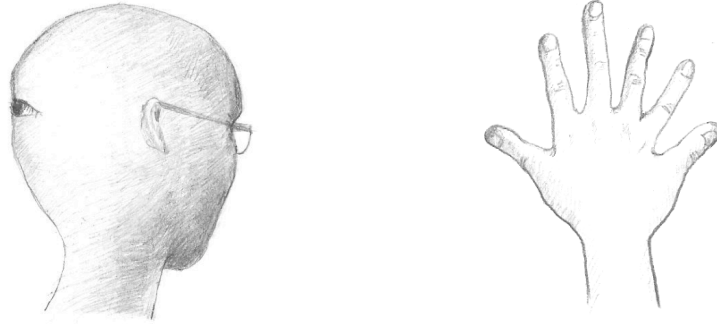


Figure 3. Illustrations for the “Extra Eye” (left) and “Extra Thumb” (right) brainstorming tasks used in the study. Participants were asked, “What are the benefits and difficulties if people had an third eye (or extra thumbs) in the future?”

Forty-eight participants were recruited from Carnegie Mellon University and the surrounding community. Among them, 23 participants were Americans born in the U.S. with English as their first language. The remaining 25 participants were international students born in China (80%), Hong Kong (5%) or Taiwan (15%) whose first language was Chinese. Although they were all currently studying at a U.S. university, the majority had been in the U.S. less than 2 years. The Chinese participants were all fluent or nearly fluent in English based on their self-reports and the understanding that international students are required to possess sufficient English proficiency (as proved by Educational Testing Service’s TOEFL exam) to enter undergraduate and graduate programs in the U.S. Experimenters randomly assigned participants to experimental conditions. A total of 16 brainstorming groups were formed (3 AAAs, 4 CCCs, 5 AACs, and 4 ACCs).

3.1.2. Tasks

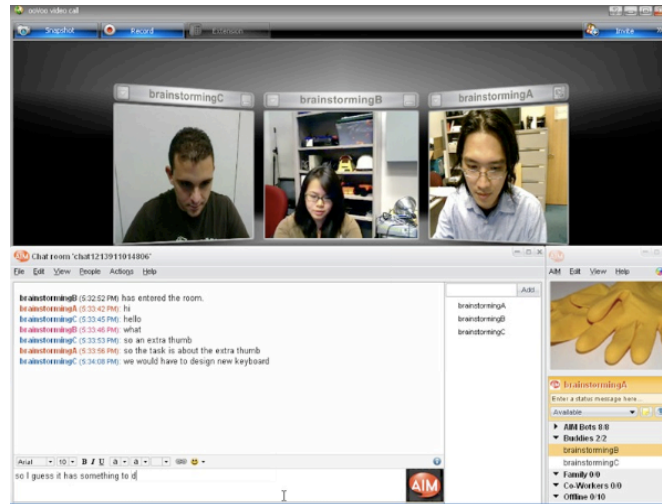


Figure 4. The video-enabled chatroom used in the study

I used two brainstorming tasks of equivalent difficulty: the “extra thumb” question and the “extra eye” questions (see Figure 3). The extra thumb question asked participants to generate ideas about the benefits and difficulties for people having a hypothetical extra thumb on each hand in the future. A number of previous brainstorming studies have used this task (e.g., Dugosh et al., 2000; Dugosh & Paulus, 2005; Ho, 1998), suggesting the appropriateness of using this task to study idea generation and group brainstorming. The extra eye question is a newly designed task that asked participants to generate ideas about the benefits and difficulties for people having an extra eye at the back of their heads in the future.

3.1.3. Equipment

In the text-only media condition, participants communicated via the chatroom function of AOL Instant Messenger (AIM, <http://www.aim.com>). In the video-enabled chatroom condition, participants were allowed to see themselves and the other two group members via a video conferencing client called ooVoo (<http://www.oovoo.com>) while using the same text chat client (see Figure 4). Audio was unavailable for both media conditions as a control for assuring that the availability of video is the only

source of variation. Participants in both conditions communicated by typing into the text-based chatroom. At the right hand side of the computer display, a series of images related to the current brainstorming topic were shown as cues for stimulating participants' idea generation. Research assistants preselected 40 images on concepts relevant to the two brainstorming tasks (20 pictures for each task; see the bottom-right of Figure 4 for a sample image on the concept of "gloves" for the extra thumb task). The computer clients showed images for 15 seconds to participants in a fixed sequence. After playing all the pictures, the clients repeated the sequence. Note that the purpose of showing pictures in this study is simply to promote participants' participation rather than to test specific hypotheses, therefore the study did not try to manipulate the availability or the order of pictures.

3.1.4. Procedure

Participants were brought to the laboratory and instructed about the brainstorming topics and rules. Four conventional brainstorming rules were provided to them (Osborn, 1957): (a) the more ideas the better; (b) the wilder the ideas the better; (c) combination and improvement of ideas are sought; and (d) avoid evaluating others' ideas. Groups were given 15 minutes for each of the two brainstorming tasks. Between tasks, we switched which version of the chatroom they were using (text only or video enhanced text). At the end of the whole experimental session comprising two tasks, participants then completed a post-experimental survey assessing their cultural tendency using the individualism-collectivism scale (see section 3.2.3) and collecting other demographic information. All the materials presented to the participants were in English, and participants were asked to converse in English.

3.2. Measures

Table 1. Definitions and examples of main coding categories

Category	Type	Definition	Example from Transcripts
Ideation	Active	Ideas offered for the first time in the brainstorming session	“(If having an extra eye,) I think it would be harder to concentrate...”
Meta-strategy	Active	Strategizing, orienting and coordinating brainstorming	“Any other ideas?” “What about privacy?”
Response	Reactive	Question, elaboration and opinion evoked by previous contributions	“(An idea about hard to concentrate was introduced earlier) Maybe people would close their third eye”
(Dis-) Agreement	Reactive	Acknowledgement and explicit consent/dissent	“Ya, I agree with you”
Explanation	Reactive	Explaining ideas	“(An idea about hard to concentrate was introduced earlier) I know I have to not have things to look at if I'm trying to study”
Picture	N/A	Mentioning pictures	“Look at the pictures on the right of the window. it seems that they are advertising about what we are talking”

The two sets of dependent measures, talkativeness and responsiveness, were derived from processing and coding participants’ conversations collected from the chat logs. I also analyzed brainstorming productivity by counting the number of non-redundant ideas generated by individuals.

3.2.1. Talkativeness and Responsiveness

Talkativeness was computed by counting the total number of words typed by each individual per brainstorming topic.

To measure responsiveness, we first coded conversational turns by applying a coding scheme consisting of seven categories: ideation, meta-strategy, response, (dis-)agreement, explanation, picture, and others. Table 1 shows the definitions and

examples of the main categories in our coding scheme. Two independent coders were recruited to perform the coding task. Inter-coder reliability based on 6% of the data was satisfactory (Cohen's Kappa=.69).

Among the coding categories, two general types of messages were identified, namely *active* and *reactive* utterances. Ideation and meta-strategy are active utterances featuring self-initiated contributions. They are proposals possibly initiating conversational threads and follow-up exchanges. On the other hand, response, (dis-)agreement and explanation are reactive or responsive contributions evoked and elicited by antecedents.

The measure of responsiveness is operationalized as the percentage of reactive utterances out of the total of active and reactive utterances:

$$\text{Responsiveness} = \text{Number of Reactive Codes} / (\text{Number of Active Codes} + \text{Number of Reactive Codes})$$

The higher the value, the more responsive a participant's messages are to the prior contributions by self or partners.

3.2.2. Productivity

To assess idea generation productivity, I used the strategy to first categorize participants' ideas into predefined categories of ideas for each brainstorming topic (e.g., "being able to grab more things" as an idea category for the extra thumb task), and then count the number of non-redundant ideas proposed by individuals in a brainstorming session. Research assistants and I collaboratively constructed a coding scheme of idea by carefully and iteratively reading and coding the conversational logs, and building it from the bottom up. The coding scheme contained 110 (thumb task)

and 118 (eye task) idea categories (see Appendix A for sample categories). Inter-coder reliability on this idea category coding task based on about 10% of the data was satisfactory (Cohen's Kappa=.79). Two coders then labeled all the conversational utterances with the coding scheme. Upon labeling utterances with idea categories, I operationalized productivity as the number of non-redundant ideas proposed by individuals.

3.2.3. Individualism and Collectivism

Participants completed Triandis' individualism and collectivism scale (see Appendix B)(Triandis, 1995). The instrument consisted of 6 items for collectivism (e.g., "what I look for in a job is a friendly group of coworkers," "aging parents should live at home with their children," Cronbach's alpha=.47) and 7 items for individualism (e.g., "I tend to do my own things, and most people in my family do the same," "what happens to me is my own doing," Cronbach's alpha=.65). I created a single composite score of individualism by averaging the scores on individualism items and the inverse scores on collectivism items.

3.3. Results

I used linear mixed models as the analytical approach for analyzing how cultural and medium factors influence the dependent variables (talkativeness, responsiveness and productivity) to account for the possible side effect of local interdependency between data points caused by repeated measures and social interactions within groups (Kenny et al., 2002). Note that the talkativeness measure was positively-skewed; that is, the distribution had a long tail on the positive side because a few people talked quite a lot. Therefore, a log10 transformation was performed prior to analysis. In all the linear mixed models, brainstorming trial was

nested within the variable of participant. Participant was a random variable nested within group, and group was set as a random variable. Individual cultural background (American or Chinese), communication medium (text-only or video-enabled chat), type of cultural group (working in same-culture versus mixed-culture group) and interactions among these variables were included as fixed effects. One analytical strategy used was to label “AAA” (all Americans) and “CCC” (all Chinese) groups both as same-culture groups, and “AAC” (two Americans, one Chinese) and “ACC” (one American, two Chinese) as mixed-culture group. This tactic decomposed group cultural composition to two specific factors, individual cultural background and type of cultural group, allowing a test of the interaction effect of the two factors.

Also note that in mixed model analyses, when tests of fixed effects involve a linear combination of variances at different levels of the model (e.g., group and individual), it is standard to estimate the degree of freedoms associated with the denominators by using Satterthwaite’s approximation. Therefore, non-integer degree of freedoms may occur in the analyses (see Littell et al., 1996).

3.3.1. Talkativeness

By using talkativeness as the dependent variable of a linear mixed model, we tested Hypotheses H1-4. The composite individualism score was included as a numeric covariate in this model for its role in hypotheses regarding talkativeness. Consistent with hypothesis H1, there was a main effect of culture on talkativeness. Participants with an American cultural background talked significantly more than those with a Chinese cultural background, $F[1, 24.14]=8.27, p<.01$. Contrary to Hypothesis H2, however, there was no medium main effect.

The individualism score covariate also had a significant effect on talkativeness. The higher the individualism score, the more talkative a participant was (regression

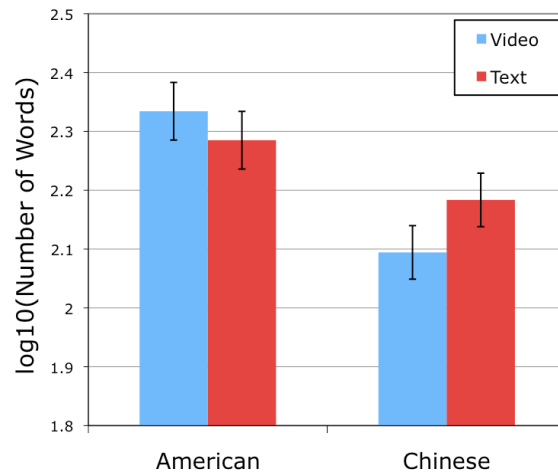


Figure 5. Talkativeness (logarithmically transformed) per trial by individual cultural background and media condition. Means and standard errors were estimated by the linear mixed model.

parameter=.13, $p<.05$). Thus individual differences in individualism further refine the effect of individualistic vs. collectivistic national culture.

A mixed model analysis of the log10 transformed data showed a significant interaction between individual cultural background and medium ($F[1, 44]=7.17$, $p<.05$; see Figure 5). Consistent with hypothesis H3, post-hoc t-tests revealed that Chinese participants talked significantly more in the text-only chatroom than in the video-enabled chatroom ($t=2.52$, $p<.05$). In contrast, there was no significant difference in talkativeness in the two media conditions for American participants. Also, it is interesting to note that in video-enabled chatrooms, American participants were more talkative than Chinese participants ($t= 3.71$, $p<.01$), but in the text-only condition, the difference between American and Chinese participants was not significant ($t=1.57$, *n.s.*). Leaner media (text) thus appears to equalize talkativeness across cultural background in this study.

Hypothesis H4 was not supported. There was no interaction effect between cultural background and type of cultural group on talkativeness, suggesting no individual-to-group adaptation of this aspect of communication style. Individuals

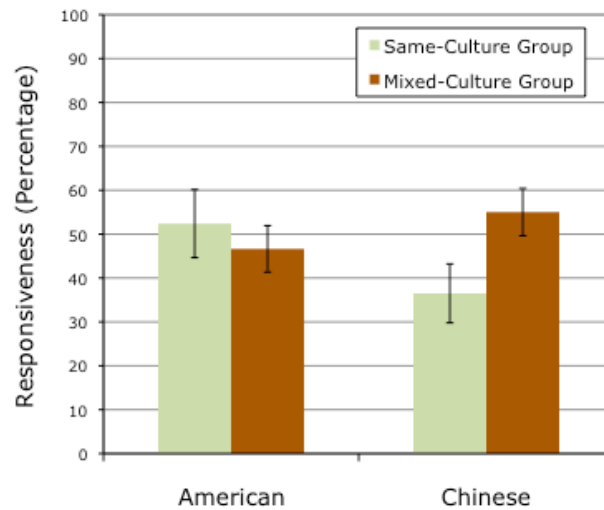


Figure 6. Responsiveness per trial by individual cultural background and type of cultural group. Means and standard errors were estimated by the linear mixed model.

regardless of cultural backgrounds did not appear to increase or decrease their talkativeness based on whether their partners were all from the same culture as them or not.

3.3.2. Responsiveness

I conducted a correlational analysis to ensure that talkativeness and responsiveness were stylistic properties of conversations independent to each other. The result confirmed that there was limited correlation between the two variables ($r=.17, n.s.$). I set responsiveness as the dependent variable of a linear mixed model to investigate hypotheses H5-7.

Contrary to hypotheses H5 and H6, there were no main effects of individual cultural background or communication medium on responsiveness. However, there was a significant interaction between individual cultural background and medium ($F[1, 44]=5.45, p<.05$). Post-hoc t-tests showed that Americans were more responsive in the video-enabled chatroom than in the text-only chatroom ($t=2.07, p<.05$). Medium did not influence Chinese participants' responsiveness.

In support of H7, there was a significant individual cultural background by type of cultural group interaction ($F[1, 21.06]=4.23, p<.05$). As shown in Figure 6, there was clearly cultural adaptation. When working in same-culture groups, Americans were the most responsive (on average, 52% of their utterances were responsive) and Chinese were the least responsive (only 37% of their utterances were responsive). Interestingly, when working in a mixed-cultural group, Chinese participants raised their level of responsiveness to that of the American participants (55% of their utterances were responsive). Post-hoc tests revealed that the effect of cultural adaptation was significant for Chinese participants (Chinese working in same-culture groups versus Chinese working in mixed culture groups, $t=2.15, p<.05$). Although from Figure 6, it seems that Americans were lowering their responsiveness in mixed-culture groups, this effect was not significant.

3.3.3. Productivity

I set the number of non-redundant ideas as the dependent variable of a linear mixed model to investigate hypotheses H8-H11.

I first examined the correlations between productivity and communication styles, talkativeness and responsiveness. I found that talkativeness and productivity had a moderately positive correlation ($r=.6, p<.0001$), while there was no correlation between responsiveness and productivity ($r=-.04, n.s.$). I included talkativeness as a covariate in the linear mixed model for productivity in order to separate idea productivity and talkativeness. The rationale of this analytical approach resides at holding the view that talkativeness is a stylistic measure of communication and productivity is a type of work outcome. Because it is unavoidable that people would have to talk in order to make idea contributions, as confirmed by the positive and

moderate correlation between the two variables, one way to separate the two aspects is thus to include talkativeness as a covariate in the statistical model.

Contrary to hypotheses H8 and H9, there were no main effects of individual cultural background or communication medium on productivity. Also, the results did not support H10, medium did not provide a greater support for Chinese participants to generate ideas. Culture and medium did not have a significant interaction effect on productivity, and Chinese participants did not generate more ideas in the text-only chatroom than in the video-enabled chatroom.

What is especially interesting is the test of H11. Type of cultural group indeed had a significant main effect on productivity. However, the result was in support of the direction opposite to what H11 predicted. Individuals worked in same-culture groups had higher productivity than those worked in mixed-cultural groups (adjusted means for same-culture groups=9.2 ideas, for mixed-culture groups= 7.0 ideas; $F[1, 12.6]=5.94, p<.05$).

3.4. Discussion

The study had three key findings: (a) Culture by medium interaction—Chinese participants were less talkative in general, but they were more talkative in a text-only chatroom than a video-enabled chatroom. (b) Cultural adaptation—In same-culture groups, Americans were high in responsiveness while Chinese were significantly lower. When working in mixed-culture groups, Chinese participants adapted their responsiveness, increasing it to the level of the American participants. (c) Intercultural productivity loss—mixed-culture groups generated fewer ideas than same-culture groups.

3.4.1. Culture by Medium Interaction

In this study, cultural background and medium interacted to influence talkativeness. Partly consistent with the perspective that CMC and lean media can reduce social inhibition in idea sharing, the use of text-only chatroom promoted talkativeness from Chinese participants. The result that Americans' talkativeness was not influenced by medium may reflect the behavioral characteristics of individualism and collectivism. Chinese as a collectivistic culture are more sensitive to the surrounding social context they perceive. The cultural emphasis on group harmony tends to foster conformity and withholding of contributions. Text-only chatrooms may simply reduce the number and the richness of perceptible social cues (e.g., the invisibility of partners' facial expressions). The reduction in social cues afforded by CMC may help Chinese more freely express their thoughts. Americans, because of their more individualistic culture, might not have had similar concerns. People thus might be relatively comfortable with expressing their opinions in groups. As a result, it may not be surprising that the manipulation of medium did not affect Americans' talkativeness.

3.4.2. Cultural Adaptation on Responsiveness

The sociolinguistic studies of communication accommodation show that people's communication styles, such as accent, word choices, and topic management, are adaptable when communicating with others from a different social group (e.g., gender, culture, age groups etc.) (Giles et al., 1991). One way to interpret the observed interaction effect between individual cultural background and type of cultural group on responsiveness might be from the perspective of accommodation memory. What is noteworthy is that intercultural accommodation in the brainstorming context appears to be asymmetrical. Chinese participants appeared to be more flexible in how they worked with partners in a group brainstorming session. They may either adopt a more

or less responsive communication style to communicate, possibly for the purpose of matching their style with their American partners' to maintain coherence and minimize interpersonal differences. In contrast, Americans appeared to have a more context-independent pattern of communication. No matter whether their partners were Americans or Chinese, Americans did not change their communication style, possibly due to their individualistic tendency.

From the view of small group interaction, it is not surprising that participants working in groups influence each other resulting in some mid-point between their individual communication styles (Levine & Moreland, 1990). But it is interesting that Chinese appeared to be more flexible than Americans in communication styles in this adaptation process. This asymmetrical pattern is important to the fundamental understanding of intercultural collaboration as it shows that cultural differences can also reside at a deeper level (flexibility in communication styles) but not only at a surface level (communication styles per se).

As individuals can express ideas via either high- or low-responsive conversations and there was no correlation between responsiveness and productivity in this study, the connection between cultural adaptation on responsiveness and brainstorming outcomes is not entirely clear. One conjecture is that responsiveness may still be relevant to the development of certain synthetic ideas that rely on social discussions and iterations (e.g., refining a prototypical idea into a mature form). This is an interesting aspect to investigate in future studies.

3.4.3. Intercultural Productivity Loss

The study further shows that type of cultural group, working with same-culture partners versus different-culture partners, significantly affected brainstorming productivity. One interesting observation is that individual cultural background

(Chinese or American) did not significantly affect productivity after controlling for talkativeness. The results imply that Chinese and Americans can essentially perform similarly well on idea generation, but what matters to their productivity levels in brainstorming groups would be whether they are working with partners from the same cultural background or from different cultures. The finding suggests that the communication process between different cultural groups, rather than cultural differences in ideation, is the primary cause of productivity loss.

3.4.4. Implications for Design

The results have implications for the design of tools for supporting intercultural group brainstorming, especially in terms of people's participation and work performance. First, the same communication medium is not necessarily equally effective for members of all cultures. Seemingly small differences in features, such as adding video to a text-based chatroom, can significantly impact the extent to which members of some cultures contribute to group work (i.e., the amount of talkativeness). To elicit contributions from individuals of all cultures in intercultural brainstorming, lean communication media like text chat is likely more useful than richer media like video conferencing or face-to-face communication. There is a need to match people's implicit and even culturally specific needs for performing tasks with the properties of communication media. CMC typically appears to be less useful than face-to-face communication due to the limited amount of communication bandwidth it provides. However, the current and earlier studies (e.g., Connolly et al., 1990; Connolly, 1993) converge to suggest that CMC or low-bandwidth communication can be quite useful and suitable for group brainstorming.

Second, the phenomenon of intercultural productivity loss highlights the important role of intercultural communication process on brainstorming outcomes.

Because individuals regardless of cultural backgrounds have similar levels of productivity when working with same-cultural partners, the mechanism behind mixed-culture groups' lower productivity cannot be simply explained by cultural differences alone. Rather, it appears that the communicative process of idea exchange that binds multicultural individuals to brainstorm in a group should be responsible for intercultural productivity loss. In other words, it is possible to enhance intercultural groups' brainstorming performance if one identifies and supports problems in intercultural idea exchange.

Informed by the socio-cognitive model of group brainstorming, as discussed in Chapters 1 and 2, one important function of brainstorming in groups is to exchange ideas socially for stimulating subsequent ideas cognitively. Intercultural groups should have a potential for brainstorming better due to the diversity of ideas and concepts that group members can possibly exchange (as H11 predicted). However, the study found an opposite pattern that intercultural groups actually performed worse. I consider that there can be two related problems. First of all, there might be difficulties for individuals working in intercultural groups to share ideas, and to comprehend and make use of ideas shared by others. Cultural differences in communication styles and patterns, such as high/low context communication (Hall, 1976), extent of conversational indirectness (Holtgraves, 1997) and degree of flexibility for adapting responsiveness situationally (this study), might increase the burdens for idea exchange due to the mismatch of styles between self and others and the need to deal with messages encoded and expressed in different manners. Holtgraves (1997), for example, identified that people inclining to talk indirectly also tend to look for indirect meanings in others' remarks, and are quicker at comprehending indirect meanings. Therefore, different cultural communication styles imply not only variation in preferred ways for producing ideas, but also preferred ways for consuming

information. All the mismatches of styles can make it difficult for intercultural group members to collaboratively brainstorm overall given the role of smooth idea exchange in productive brainstorming.

Second, there can be language barriers between different cultures. This study asked participants to communicate in English, which might still pose a higher threshold for Chinese participants to express their ideas and to read others' ideas because English is not their native language. There can be a gap between linguistic resources available to Chinese participants and their communication needs. Also, using a second language poses barriers not only on communication, but also thinking. Studies have shown that people can have worse thinking performance when using a second language in parallel, while there's no such problem when using their native language (Takano & Noda, 1993, 1995).

Overall, this study shows that simply grouping multicultural individuals together does not guarantee more productive and creative idea generation. There can exist mismatches of communication styles and language barriers, making it difficult for people to participate, exchange ideas and make use of shared ideas. To support intercultural brainstorming, it should be productive to consider ways of encouraging more equal participation from different cultures such as using a leaner medium, and more importantly, to consider ways of supporting effective idea exchange and sharing that cross the gaps of communication. As I will describe next, creating multiple communication channels, including visual and verbal ones, to reduce the sole reliance on language to exchange ideas can be a useful strategy.

CHAPTER 4

IDEA EXPANDER: AGENT-AUGMENTED BRAINSTORMING

The study presented in Chapter 3 showed that intercultural group brainstorming can be difficult, leading to poorer performance than brainstorming in homogeneous, same-culture group contexts. One further understanding is that individuals regardless cultural backgrounds can still brainstorm productively when working with other same-cultural partners, suggesting that the communication process between multicultural individuals rather than inherent cultural differences in the potential of ideation should be the source of the problem. This chapter aims to identify key design elements useful for supporting intercultural group brainstorming.

The previous study and also the literature have provided some design elements useful for aspects of group brainstorming. For example, using a lean medium (e.g., text-only chat without visibility of partners) is likely to promote Chinese participants' talkativeness. Similarly, studies on electronic brainstorming show that using CMC to enforce anonymity and parallel inputs can enhance brainstorming performance of large groups, but not small groups (e.g., Gallupe et al., 1992). Although these techniques are useful for reducing social side effects in brainstorming groups, as discussed in the last section of Chapter 2, there remains a lack of effective interaction techniques that can support the cognitive stimulation aspect of group brainstorming.

In this chapter, I explore the idea of supporting intercultural group brainstorming with technical designs that focus on enhancing the stimulation utility of interpersonal communication in groups. I will first present a number of criteria for supporting intercultural work in the context of group brainstorming. Then I will discuss displaying *language-retrieved pictures* as a candidate interaction technique

that supports these goals and may have other applications beyond group brainstorming.

4.1. Design Criteria

One observation is that computer-mediated intercultural group brainstorming is a complex setting of collaborative work, which is in need of support from multiple aspects. Because group brainstorming in workplaces can be a task nested in the context of other works (e.g., problem solving, design, decision making) and can serve particular organizational needs and goals (Jackson & Poole, 2002; Sutton & Hargadon, 1996), it is important for a design to consider ways of balancing multiple factors and addressing a number of key constraints to be relevant and useful to real remote intercultural brainstorming groups. I consider that there are three key design issues to address, including the *performance* of brainstorming, the *naturalness* of interaction, and the *feasibility* of enabling mechanisms.

First of all, one explicit goal of group brainstorming activities is to generate ideas that are original and useful. It is therefore important for technical designs to help improve the *performance* of brainstorming, such as the quantity and quality of ideas generated. As disclosed in the earlier discussion, this performance requirement drove the designs of earlier brainstorming tools (e.g., GDSS, EBS). But the techniques adopted were limited to the removal of social context cues. What's missing is an approach that can directly stimulate ideation and support group brainstorming. For intercultural groups, it is also necessary to take into account possible obstacles to collaboration associated with language gaps and cultural differences in social norms.

Second, field studies show that interactive discussions in brainstorming groups can have functions other than generating ideas (Jackson & Poole, 2002; Sutton & Haradon, 1996). Observations revealed that groups could use tangent discussions to

perform other work in parallel for the “big picture” or the higher level goal of teamwork (e.g., solving a problem). Similarly, the same research found that groups could discuss to narrow-down ideas during brainstorming sessions in preparation for future work (Jackson & Poole, 2002). Other field observations found that interactive brainstorming meetings can serve a number of critical functions important to organizations, such as supporting shared understanding about past and current ideas, and supporting the sharing of knowledge and expertise among group members (Sutton & Haradon, 1996). At the cognitive level, interactive conversation can also have the benefit of requiring relatively little cognitive efforts to communicate, comparing to non-interactive forms of communication (e.g., reading a paper) (Garrod & Pickering; 2004; Pickering & Garrod, 2004). The interactive alignment theory of conversation posits that the exchange of utterances help conversational participants align their mental representations about the situation through the unconscious mechanism of priming. The alignment of situational understanding between people makes communication more predictable and thus more *natural* to people, allowing people to understand each other even when information actually encoded literally in language is limited or fragmentary.

So overall, although interactivity in groups can be counter-productive because of negative social side effects discussed earlier (e.g., evaluation apprehension, production blocking etc.), interactivity among group members can be beneficial on other aspects of group work, and is also more natural to people’s communication. One implication is that designs of brainstorming support should enable naturalistic discussion (e.g. engaging in conversations), maintaining the functions and benefits that free-form interactions afford.

Third, after all it is important to take into account the *feasibility of mechanisms* for both people and technologies involved in the design. From a socio-technical

system point of view, technologies designed to support people can also require people to play certain constrained roles (e.g., following the instruction of electric brainstorming tools to interact with group partners in a restricted manner). To attain specific goals, technical designs can “configure” not only the behaviors of technical components but also their users, requiring people to follow the user manual to operate technologies in possibly unfamiliar ways (Woolgar, 1991). Therefore, there can be high cost associated with this type of design, requiring people to adapt to the designs and change their practices and norms of group work. Similarly, a design can be fragile if the underlying technical solution is difficult or expensive to implement (e.g., a computer agent that tries to propose full ideas). Therefore, I consider that a preferred design should also be simple and feasible with respect to existing understanding of technical solutions and the social and cognitive processes of people.

Although there can be other design criteria such as user satisfaction, one argument is that the three criteria proposed here represent components most crucial and relevant to remote intercultural teamwork. In group work, participants can be more satisfied with their experience of work and collaboration (and thus higher user satisfaction) if the group achieves performance goals and the system allows more flexible social interaction (e.g., Kraut, 2003). Therefore, the performance and naturalness goals may correlate with other aspects of well-being for groups.

4.2. Using Language-Retrieved Pictures as Brainstorming Support

As a design proposal, I consider that presenting *language-retrieved pictures* as peripheral cues can satisfy the key design criteria discussed above (performance, naturalness and feasibility). As first introduced in Chapter 1, language-retrieved picture is an interaction technique that uses a computer agent to monitor ongoing conversation and augment it with relevant pictures retrieved according to the verbal

content. The basic idea is to employ pictures as an extra representation of meaning, providing multiple communication channels (language and pictures) that can enhance the communication of concepts and cognitive stimulation, and to address communicative gaps caused by cultural and language differences. Next I discuss how the approach of language-retrieved pictures meets these requirements:

Performance. As discussed in Chapter 1, pictures and language have different properties and constraints for mediating concepts in group brainstorming. Using pictures as extra stimuli can provide easy-to-comprehend presentations of concepts and rich stimulation that language alone cannot afford, especially in intercultural settings. Picture-based concept mediation is independent of languages used. As a result, people speaking different native languages can still perceive and interpret the same picture to receive meaningful information, while flexible and diverse interpretations driven by individual and cultural differences become a way to diversify the conceptual space for ideation. Language, however, remains one powerful tool that people voluntarily use to express ideas and make contributions to the group. The design of language-retrieved pictures thus allows group members to express ideas in language, and at the same time receive rich stimulation from automatically retrieved relevant pictures that may enhance ideation and group brainstorming performance overall.

Naturalness. Field studies suggest that groups in workplaces prefer to converse and interact freely to generate and share ideas (Jackson & Poole, 2002). Cognitive theories posit that it is efficient and easy to use interactive conversation to communicate (Garrod & Pickering, 2004). In this design proposal, presenting language-retrieved pictures can be viewed as an ambient feedback using a different communication channel (i.e., visual perception) to preserve the naturalness of conversation. Pictures may not interrupt much people's ongoing conversations

occurring over the verbal channel. Theoretical models and empirical work in psychology and ergonomics support this observation. In ergonomics, Wickens's multiple resource theory (MRT) posits that there are separate pools of cognitive resources for supporting human visual processing and language processing, and thus cross-modal multitasking (i.e., processing visual and verbal information simultaneously) tends to be easy and efficient to people (Wickens, 2002). In psychology, one of the widely accepted models of working memory also supports the separation of temporary memory stores for visual and verbal information (namely the visuospatial sketchpad and the phonological loop) (Baddeley, 1992; 2003). Therefore, it is reasonable to expect that using the visual communication channel to supply pictorial stimuli can introduce extra cognitive resources (visual) to use and reduce the interference with ongoing conversations (a verbal process). The design is more likely to enhance the stimulation function of interpersonal communication while maintain the naturalness of conversational interaction than the alternative approach of presenting stimuli in a language form, competing for resources required by natural conversations.

Presenting language-retrieved pictures also embodies the naturalness principle in the sense of *natural concept mediation* and diversification. As discussed in Chapter 1, using pictures to represent concepts (e.g., pictures of "car") tend to convey richer information than language statements (e.g., a statement "this is a car") in a language-independent manner. Converting language to pictures can receive the benefit of letting people speaking different native languages to brainstorm together, and facilitating the process of ideation by sharing concepts through pictures.

Feasibility of mechanisms. At the end, it is important that the mechanisms proposed for reaching performance and naturalness goals are robust and easy to implement. At the human side, the design of language-retrieved pictures is intended to

leverage properties of visual perception for using extra cognitive resources and enabling language-independent concept mediation (naturalness) and also diversifying the conceptual space (performance). Because visual perception is more of a human capacity genetically endowed, there is presumably little need of instruction and cost of learning for people to benefit from the design. At the machine side, using conversations as the driving force for picture retrieval can free the system from the need for domain-specific knowledge such as pre-programmed domain models dictating what stimuli to present for what topics (e.g., Wang et al., 2007), widening the scope of tasks to which the design may apply. Now there is a rich pool of information retrieval (IR) techniques that can be used to retrieve relevant images for text inputs (cf. Datta et al., 2008), and large-scale image databases and search engines are increasingly available (e.g., Flickr.com, images.google.com). It is possible to build computer agents with IR techniques and open resources to implement the language-retrieved pictures approach.

4.3. The IdeaExpander Model

This section provides a precise specification of IdeaExpander, a concrete design implementing the notion of language-retrieved pictures for supporting group brainstorming. IdeaExpander adds a picture space that is shared by group members and is sensitive to conversational content. A computer agent chooses pictures related to ideas that have recently been discussed, and presents them to all group members as a shared visual representation of ideas.

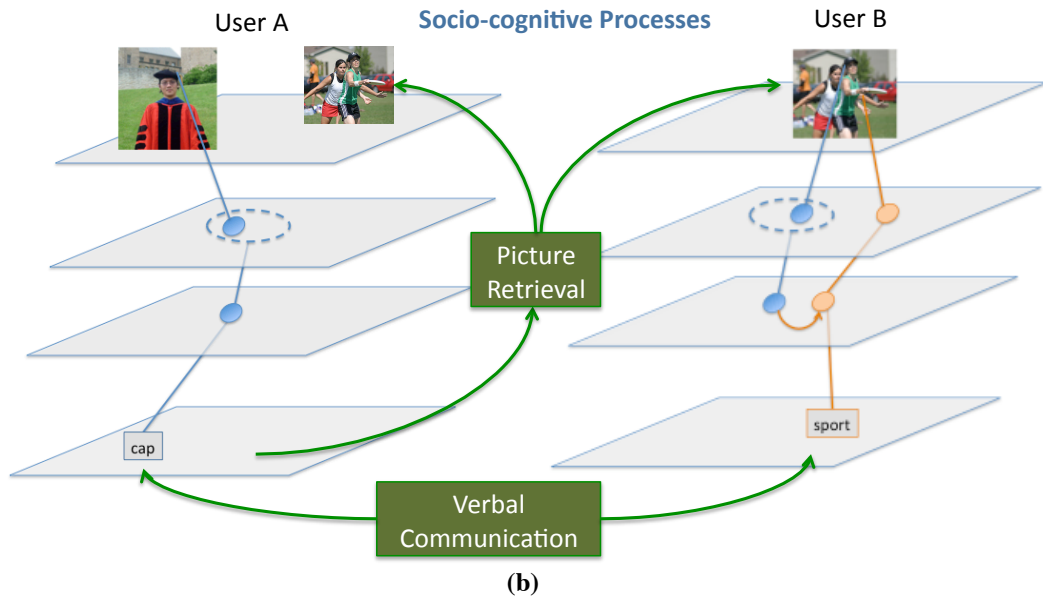
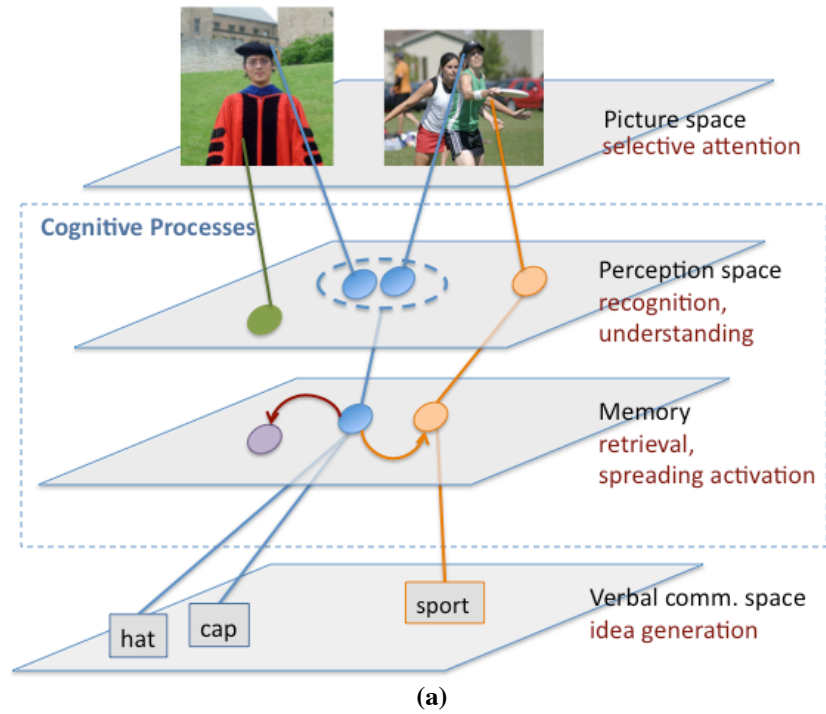


Figure 7. Cognitive and socio-cognitive processes mediated by IdeaExpander. (a) Cognitive processes of expanding ideas from picture stimuli. (b) Socio-cognitive processes of exchanging and expanding ideas with conversationally retrieved pictures.

As discussed earlier, individual and cultural differences in how people perceive pictures can be a useful source for diversifying the conceptual space for brainstorming. Here I use an example to describe how pictures promote conceptual diversity in groups. Figure 7(a)² shows the cognitive processes that bridge picture perception (perceiving pictures in a space of pictures) and idea generation (verbalizing and making ideas available to others through verbal communication). Figure 7(a) will be explained from top to bottom, starting at seeing pictures in the picture space to contributing verbal ideas to the verbal communication space. Because of individual and cultural differences in visual perception, some people tend to perceive mainly the focal or salient objects in a scene, while others tend to distribute the attention to both the foreground and the background (cf. Nisbett & Masuda, 2003). In Figure 7(a), when seeing the picture of a person throwing a frisbee (the picture at the top-right), some people thus may first notice the frisbee while others may notice peripheral or minor visual elements like the baseball caps or the building in the background.

Second, after selectively attending to specific visual elements of a scene, individuals then recognize the element by mapping them to candidate categories of concepts in an internal perception space (Palmeri & Gauthier, 2004). There could also be cognitive variability at this level. People interpret what they attend to differently based on prior knowledge, cultural experience and current framing. Variations in interpreting visual illusions (Gregory, 1997) and recognizing non-prototypical objects such as images of cat-like dogs or dog-like cats (Palmeri & Gauthier, 2004) are examples that demonstrate this variability.

Third, after object recognition and understanding, these perceptions enter the space of associative memory, followed by spreading activation of interconnected

² Creative Commons-licensed photos embedded in Figure 7:
<http://www.flickr.com/photos/akeg/1357992988/>

concepts (cf., Balota & Coanne, 2008). As discussed earlier in Chapters 1 and 2, people might differ in their semantic knowledge, or how concepts are organized and stored in their memory, due to different learning, social and cultural experiences. In Figure 7(a), thinking of “cap” by viewing the picture at the top left may lead the person to think of “sport” via the associative link between concepts, even though the picture at the top left has nothing to do with sports.

At the bottom of the Figure 7(a), verbalization externalizes ideas as knowledge products, and also feeds into the cognitive process. Words from the chat can also serve as thinking stimuli, contributing to the retrieval of concepts and the generation of new ideas. The IdeaExpander model thus employs both language and pictures as sources of stimulation, promoting variability of ideas through multiple channels.

4.3.1. Collaborative Idea Expansion

The power of this perceptual-cognitive processes can be fully unleashed when we connect multiple individuals through both visual and verbal communication channels, because this would further leverage interpersonal variability, including cultural differences. Figure 7(b) shows the scenario of connecting two people as a social creativity system. In Figure 7(b), when User A attends to the picture on the top-left, and expresses a verbal idea containing the concept of “cap”, the agent will perform picture retrieval to present a new picture (on the top-right of the figure) to both participants to enhance the stimulation utility of the idea. When User B attends to this new picture, perceptual and cognitive processes triggered by the picture may lead to the generation of an idea relevant to “sport”.

By using concepts currently present in the chat to select pictures, the agent can take advantage of interpersonal variation on concepts expressed to retrieve a wider range of pictures. There can be some pictures non-retrievable when individuals

working alone as they might only express ideas limited to a few conceptual categories. Applying IdeaExpander in groups thus may lead to divergent chains of spreading activation in each participant, reducing the chance that the conversation will become fixated and increasing the chance of creative ideation. In short, the system helps people to see what other people have said in new ways and to expand their ideas using multiple pathways.

One characteristic of collaborative idea expansion is thus the preference of greater interpersonal variation on concepts for increasing the coverage of pictures retrieved. As discussed in Chapters 1 and 2, cultures can be one prominent source of diversity for conceptual knowledge, and thus multicultural group composition can be an ideal “driver” of this collaborative idea expansion mechanism. IdeaExpander and culture form a reciprocal relationship to bolster each other. Pictures retrieved by the computer agent help to stimulate ideation in intercultural groups, and cultural diversity in concepts becomes *part of* the design to make the mechanism more effective.

4.4. Prototyping

To evaluate the usefulness of IdeaExpander, I have implemented a functional prototype. Figure 8³ shows a screenshot and the high-level system architecture. Participants brainstorm in a chat window on the right, while the system displays pictures it chooses based on the conversation on the left. The implementation uses a combination of machine learning (ML) and information retrieval (IR) techniques. I draw on a prior experiment in which participants brainstormed in a chatroom about the benefits and drawbacks of having an extra eye or thumb (tasks described in Chapter 3) or pair of wings (a similar new task that will be described in Chapter 5) to initiate a

³ Creative Commons-licensed photo embedded in Figure 8:
<http://www.flickr.com/photos/estherbester/1317549963/>

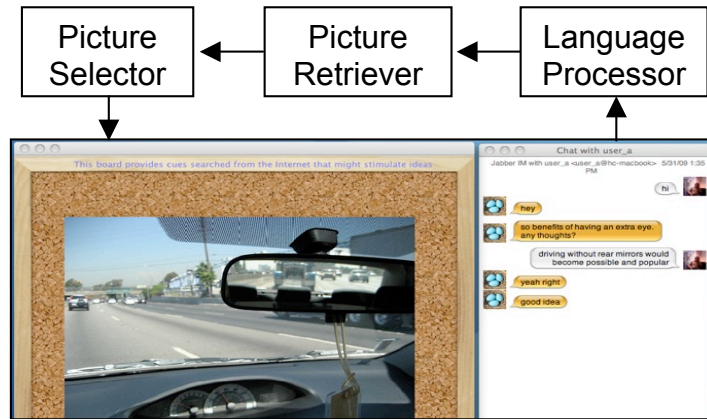


Figure 8. IdeaExpander screenshot and high-level architecture. The system monitors the group conversation (right) and selects pictures to display to the group (left).

ML classifier that can automatically classify whether a conversational remark consists of ideas or not. The system consists of three main components, a language processor, a picture retriever and a picture selector.

Language processor. IdeaExpander monitors the chat conversation to identify currently activated concepts. Because brainstorming conversations include both on-task and off-task exchanges, to avoid interrupting conversations abruptly (for naturalness) and to avoid including non-content words as cues for picture retrieval to increase the relevance of retrieved pictures (for performance), the language processor module filters out off-task remarks. I used a ML classifier trained by conversational data from the study described in Chapter 3 to determine whether a remark contains an idea or not. The ML algorithm used is support vector machine (SVM) for its generally high classification performance in text categorization tasks (Joachims, 1998; Cristianini & Shawe-Taylor, 2000). I used an SVM implementation included in an open source ML toolkit, Weka (Witten & Frank, 2005), to train a classifier with 5,391 labeled conversational turns. Accuracy of this binary classification (a conversational turn having an idea or not) is 80% (Cohen’s Kappa=.61).

Picture retriever. IdeaExpander uses remarks classified as containing ideas to retrieve candidate pictures to show. The initial prototype used a labeled picture

database specific to tasks of the study for control and analysis, while the underlying idea of language-retrieved pictures is general (e.g., using open datasets like Google images to scale). Previous coding of brainstorming logs resulted in a coding scheme containing 110 (thumb), 118 (eye) and 112 (wings) idea categories (see Appendix A for sample categories). Research assistants collected 60 pictures for each task from Flickr.com and coded each picture with the applicable idea categories (Krippendorff's $\alpha=.5$). Each picture was then labeled with the tags it already had from Flickr and the words contained in the codebook descriptions of the idea categories. The agent matches conversational turns it classifies as containing ideas against the texts of pictures (tags and codebook descriptions) in the database using TF-IDF, a standard model for indexing and retrieval in IR (Salton et al., 1975; Grossman & Frieder, 2004), to retrieve a set of relevant pictures. In the current prototype, the system retrieves the four most relevant pictures for each idea remark.

As a brief introduction, the TF-IDF approach represents “documents”, including conversation remarks and texts of pictures, as word vectors in a multidimensional space (i.e., each dimension denoting a word), and then computes similarity between two documents as the cosine value between their corresponding vectors. The weight for each word in a word vector is determined by the word's term frequency (TF) (i.e., number of times the word appearing in this document) and document frequency (DF) (i.e., number of documents containing this word). This weighting scheme gives higher weights for words with higher TF and lower DF (i.e., higher inverse-DF or IDF). A word occurring more times in a document and rarely found in other documents is considered more representative about the gist of this document (cf. Grossman & Frieder, 2004).

Picture selector. IdeaExpander then selects pictures to display based on specific interventional strategies. Because brainstorming performance and naturalness,

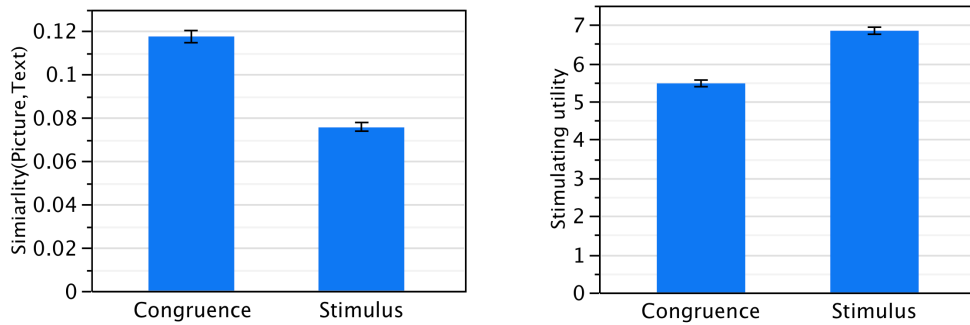


Figure 9. Validating picture selection methods. Left: Similarity score (TF-IDF) between pictures and conversational contents. Right: Stimulating utility score.

as discussed earlier in this chapter, are two major design criteria, it is possible to devise different picture selection strategies to determine which picture to show from the retrieval results for emphasizing either performance or naturalness.

I compared two plausible strategies. One strategy, *Congruence*, simply follows the common IR method, returning the picture labeled with the set of keywords *most similar* to words of the input conversational turn. *Congruence* should be a more naturalistic approach as these pictures tend to be more accurate visualizations of verbal ideas, and thus can better play the role of natural mediation of concepts. The other strategy, *Stimulus*, attempts to increase the functional usefulness of the stimuli for ideation. Like *Congruence*, it finds a set of relevant pictures based on keyword similarity first, but instead of just choosing the most relevant picture, it considers both the picture’s similarity to the ongoing discussion and the rarity (infrequency) of the keywords the picture is labeled with. Based on the socio-cognitive model of brainstorming, pictures labeled with statistically rare keywords are more likely to contain unconventional concepts, and thus can be more stimulating for ideation. This approach should be more performance-oriented, although as a cost people might perceive some stimulating pictures as less relevant and unnatural.

To implement the strategies, *Congruence* emphasizes similarity between pictures and recent ideas, retrieving the picture with the highest TF-IDF score from the

list of four relevant pictures. For the *Stimulus* method, I defined a stimulating utility score that prefers pictures that contain multiple idea categories or categories that are less commonly discussed (i.e., rare ideas). An earlier dataset was used to estimate the probability of generating each idea, and weighed each idea i as $\log(1/\text{probability of idea } i)$. The utility score for a picture is the sum of weighted scores of the ideas pertaining to it. The *Stimulus* method selects the picture from the relevant set with the highest utility score. In both methods, pictures that have already been shown are excluded.

To validate the manipulation of picture selection, Figure 9 shows the mean TF-IDF similarity and stimulating utility of pictures selected by each algorithm in an evaluation study that I will present in Chapter 5. As expected, pictures selected by *Congruence* were more similar to the ideas that triggered them than pictures selected by *Stimulus* ($t[1744]=-12.98$, $p<.0001$), while pictures selected by *Stimulus* had higher stimulating scores than pictures selected by *Congruence* ($t[1744]=10.84$, $p<.0001$).

For both versions, the computer agent updates the picture space (the board on the left of Figure 8) with a new picture—if available—every three seconds. The current design only chooses one picture for each conversational turn. While it is technically possible to choose and present multiple pictures for a turn or one picture for multiple turns, if the socio-cognitive mechanism used to bolster the design is correct, we should be able to see an effect of language-retrieved pictures on brainstorming performance with showing only one picture per turn. As an initial exploration of the design space, this dissertation starts from the most straightforward design (showing one picture for each idea-laden turn), putting the proposed mechanisms into a riskier, and therefore more valuable, hypothesis testing.

CHAPTER 5

EVALUATING IDEA EXPANDER IN CULTURAL CONTEXTS

In Chapter 4, I described the design rationale and the prototype of IdeaExpander, a tool that presents language-retrieved pictures to support group brainstorming. One general observation is that IdeaExpander may be especially effective for intercultural groups because cultural variation in picture perception and conceptual knowledge can lead to diverse interpretations of pictures, beneficial to idea generation and also the retrieval of pictures.

To evaluate the usefulness of IdeaExpander for intercultural group brainstorming, I conducted a laboratory study to examine the effects of different types of picture support (picture selected by the Congruence method versus the Stimulus method), group cultural composition (intracultural versus intercultural groups) and their interactions on brainstorming outcomes.

I operationalize the notion of “usefulness” along two dimensions, productivity and diversity of ideas. First, I evaluate a group’s productivity, defined as the number of original ideas generated by the group. I also evaluate the diversity or breadth of a group’s ideas, defined as the average semantic distance between any two ideas measured from a high-dimensional semantic space constructed using statistical techniques. The diversity of ideas is an important outcome measure as one purpose of group brainstorming is to produce alternatives for later decision making (Amabile, 1983; Paulus & Yang, 2000). Therefore, conceptually duplicating or similar ideas will not be very useful with respect to this task goal. Based on the work described in Chapter 4, I hypothesize how group cultural composition and language-retrieved pictures as brainstorming support (referred as *picture support* hereafter) will jointly

influence productivity and breadth of concepts covered. The study compares two picture selection strategies, *Congruence* and *Stimulus*, putting emphases on either the naturalness or performance of brainstorming respectively.

In terms of productivity:

H1: Both types of picture support, *Congruence* and *Stimulus*, will enhance productivity compared to no support; further, the *Stimulus* method will lead to better productivity than the *Congruence* method, because better concept communication and diversity introduced by pictures will improve stimulation.

H2: Intercultural groups will have better productivity than intracultural groups because cultural diversity in concepts will stimulate group members' ideation. Note that in the study reported in Chapter 3, individuals working in intercultural groups had poorer performance than intracultural counterparts possibly due to intercultural communication barriers. There is a tension between the possible benefit of being diverse in accessible concepts and the possible drawback of being different in communicative styles and languages used. This hypothesis still prefers the positive effect of intercultural collaboration to re-examine the previous finding in a different experimental context.

H3: The effect of picture support on productivity will be greater for intercultural groups than intracultural groups, because cultural differences in picture perception and conceptual diversity heighten the utility of picture support.

In terms of breadth of concepts:

H4: The *Stimulus* method will result in greater breadth of concepts than *Congruence* because the *Stimulus* method emphasizes choosing pictures that contain multiple or rare topics, and thus ones that semantically diverge from topics the group already explored.

H5: Intercultural groups' ideas will cover broader concepts than intracultural groups' ideas because of conceptual diversity in concepts between cultures.

H6: The effect of the *Stimulus* method in broadening conceptual coverage will be larger for intercultural groups than intracultural groups because cultural differences in picture perception and conceptual diversity make the *Stimulus* support more powerful.

5.1. Method

Experimenters asked two-person groups to perform three similar brainstorming tasks with three types of picture support: *Congruence*, *Stimulus*, and *None*. *None* is a baseline of providing no pictures to participants, simulating the common status of conversational brainstorming in workplaces. Three types of cultural groups were formed: two Americans (AA pairs), two Chinese (CC pairs), and one American and one Chinese (AC pairs). Cultural composition was a between-groups manipulation, while picture support and brainstorming tasks were within-subject manipulations. Their orders were counterbalanced using Latin squares.

Experimenters brought participants to the laboratory and instructed them about the brainstorming topics and provided with four conventional brainstorming rules (the more ideas the better, valuing every ideas even for wild ones, seeking to combine and improve ideas, avoiding idea evaluation), which are identical to the prior study (see Chapter 3).

5.1.1 Participants

There were 54 participants (65% female) recruited from Cornell University and the surrounding community. Of these, 29 were self-identified Americans living in the U.S. or Canada who had grown up in the U.S. or Canada and spoke English as

their native language. The remaining 25 participants were self-identified Chinese speaking Chinese as their native language but who were fluent in English. Although they were all currently studying or working in the U.S., the majority of them grew up in China, Hong Kong or Taiwan and had been in the U.S. for less than 2 years. Similar to the study in Chapter 3, the key principle behind this operationalization of culture (identifying participants as Americans or Chinese) ties cultural background to socializing experience rather than genetic origins. For example, this study considers an individual with a Chinese genetic origin but living and socializing in the U.S. for more than 10 years as having an American cultural background.

Participants were randomly assigned to brainstorming groups and experimental conditions. The majority of the participants (83%) reported that they did not know their fellow group members prior to the study. There were a total of 27 two-person groups formed (10 AAs, 9 ACs and 8 CCs).

5.1.2. Tasks

Two of the three brainstorming topics used were the same as the prior study in Chapter 3, the “extra thumb” and the “extra eye” questions asking about the benefits and difficulties for people having a hypothetical extra thumb or an extra eye at the back of their heads in the future. The third topic, the “having wings” task, is a newly designed task that asked participants to brainstorm about the benefits and difficulties for people having a pair of wings in the future (see Figure 10).

5.2. Measures

Groups outcomes were evaluated with two measures, productivity and breadth of ideas. Productivity addresses outcomes: the quantity and originality of the ideas that are generated. Breadth of ideas addresses both outcomes—one goal of brainstorming



Figure 10. Illustration for the “Having Wings” brainstorming task, asking participants to propose possible benefits and difficulties for people having a pair of wings in the future.

is to generate a variety of ideas—and process, in the sense that ideas generated may stimulate further ideas during the conversation by activating a wider variety of concepts among group members.

5.2.1. Productivity

To account for both quantity and originality aspects of idea generation, I coded the brainstorming data using a two-level strategy. At the first level, I asked coders to classify whether each conversational turn contained an idea or not. Turns that were coded as containing an idea were then coded as either duplicates (minor variations of an idea already contributed) or original ones (ideas not yet proposed by the group).

Two coders coded conversations from three randomly selected brainstorming groups (about 13% of the data) to assess reliability. Inter-coder agreement was satisfactory both at the first level (coding idea versus no-idea, Cohen’s Kappa= .95) and the second level (coding duplicate versus having originality, Cohen’s Kappa= .80).

I used the number of turns coded as containing original ideas as my measure of productivity.

5.2.2. Breadth of Concepts

Breadth of concepts was conceptualized as the average semantic distance between any two original ideas generated in a brainstorming session. Intuitively, semantic distance is how far apart the concepts expressed by the ideas would be in a semantic network. For example, “cow” and “sheep” would have a lower semantic distance than “cow” and “electron” in most people’s semantic networks.

To operationalize this idea, I started from a semantic network based on a database of word association norms (Nelson et al., 1999) that was generated by empirical studies that asked people to explicitly associate words. For example, an experimenter might ask participants to say the first three things that come to mind when they see the word “music”. This procedure generates a set of word association frequencies that does not, however, capture all possible word associations. These hidden associations can be uncovered by applying the statistical procedure of singular value decomposition (SVD) to map sparse raw data into a multidimensional space that represents words as vectors of numerical features, similar to what latent semantic analysis (Foltz et al., 1998). Using SVD on the word association frequencies results in a multi-dimensional word association space (WAS) (Steyvers et al., 2004).

Table 2 illustrates using some keywords (“bald”, “glasses”, “industry”, “music”, and “beauty”) as queries to retrieve the words most related to them from the semantic space. We see both associations that one might make directly, such as “bald” and “scalp”, but also associations uncovered by the SVD procedure such as “glasses” and “squint” that people would be unlikely to make directly.

Table 2. Lists of words strongly associated to the queries (words in bold) retrieved from the semantic space.

bald	glasses	industry	music	beauty
scalp	lens	employment	band	pretty
headband	contacts	career	instrument	beautiful
shampoo	blur	business	woodwind	attractive
beard	vision	occupation	oboe	gorgeous
comb	sight	corporation	flute	ugly
brush	squint	agency	viola	handsome
strand	eyelash	task	trombone	cute
mustache	eye	factory	tuba	model
forehead	blind	duty	guitar	elegant

With the WAS, it is straightforward to assess the strength of association between two ideas by computing the cosine similarity between word vectors representing each idea in the multidimensional space (Steyvers et al., 2004; Kintsch, 2007). Note that cosine similarity in high-dimensional semantic spaces ranges between 0 and 1 in most cases, where 1 represents perfect association (Kintsch, 2001). So I converted cosine to a distance metric where higher scores represent more diverse, by taking its inverse. And to generate a metric that represents the breadth of the whole set of ideas, I computed the average similarity between each pair of original ideas generated by a given group, and then invert it to a distance measure. I then took log-transformation for normality of distribution:

$$\text{Breadth-of-concepts} = \log(1/\text{avg. cosine of all idea pairs})$$

5.3. Results

The main units of analysis used in the analyses were groups, because the hypotheses primarily concerned how different types of picture support influenced the outcomes of different cultural groups. Same to the analytical approach used in Chapter

3, hypotheses were investigated by linear mixed models to account for possible interdependencies caused by repeated measures or social influences within groups (Kenny et al., 2002).

The basic model for analyzing group outcomes treated brainstorming trial and group as random variables. Brainstorming trial was nested within group. Group cultural composition, picture support, and the interaction between the two variables were included as fixed effects. Brainstorming topic was used as a covariate. To estimate effect sizes, we computed Cohen's d from the sample means and standard deviations (Cohen, 1988). For computing effect sizes of picture support, correction was applied to account for within-subject correlations (Cepeda, 2008; Morris & DeShon, 2002).

5.3.1. Talkativeness

Group brainstorming is a task relying on using language to verbalize ideas. Cultural differences in conversational behaviors (Setlock et al., 2004; Wang et al., 2009) and linguistic fluency (e.g., speaking a second language) thus are confounded with brainstorming performance. To examine this possibility, I looked at whether cultural groups differed in talkativeness using a linear model of the form outlined earlier and the number of words typed by pairs as the dependent measure.

Group cultural composition had a nonsignificant effect on talkativeness ($F[2,22.9]=2.18, p=.13$). Because this effect approached significance, we examined differences between groups further using post-hoc t -tests. AA groups typed more words than CC groups ($t[22.8]=2.06, p<.05$), but there were no significant differences between AA and AC or between CC and AC pairs. These results weakly suggest that cultural composition of a group influences overall talkativeness. I thus included this factor as a covariate in later analyses. Note that picture support did not affect

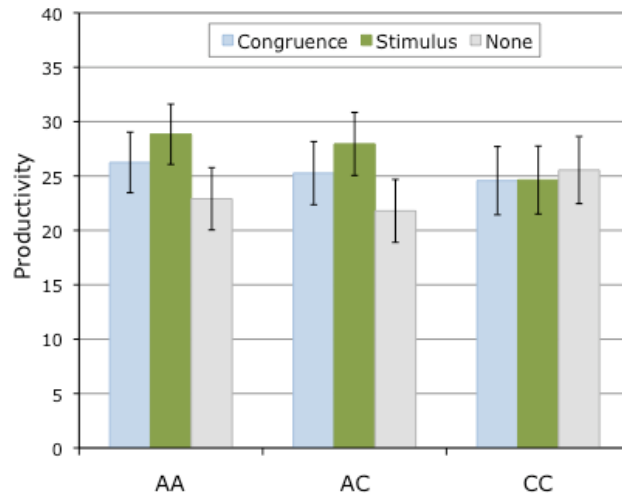


Figure 11. Adjusted productivity by group composition and picture support. Means and standard errors were estimated by the linear mixed model.

talkativeness. This suggests that if picture support were effective, its mechanism is unlikely to involve promoting talkativeness.

5.3.2. Productivity

To test H1, H2 and H3, I constructed a linear mixed model to evaluate the effects of cultural group and picture support on group productivity (number of original ideas by groups). Figure 11 shows adjusted productivity scores after accounting for the influence of talkativeness.

In support of H1, there was a main effect of picture support ($F[2,44.2]=8.04$, $p<.001$). Post-hoc t-tests showed that both the *Stimulus* method and the *Congruence* method led to better productivity than no picture support (*Stimulus* versus *None*: $t[43.3]=4.01$, $p<.0001$, Cohen's $d=.29$; *Congruence* versus *None*: $t[45.5]=1.99$, $p<.05$, Cohen's $d=.08$). There was also a trend for the *Stimulus* method to provide better productivity support than the *Congruence* method ($t[44.4]=1.88$, $p=.07$, Cohen's $d=.20$).

Hypothesis H2 was not supported by the analysis. Group cultural composition did not have a main effect on productivity ($F[2, 24.7]=.05, n.s.$). AC pairs did not produce more ideas than intracultural groups.

To test H3, I focused on how different cultural groups performed when picture support was available and not available. There was a significant interaction between group cultural composition and picture support on productivity ($F[4, 40.25]=3.37, p<.05$). As Figure 11 shows, intercultural groups generated more ideas when using either type of picture support than when using no support (AC & *Stimulus* vs. AC & *None*: $t[38.7]=4.00, p<.0005, \text{Cohen's } d=1.01$; AC & *Congruence* vs. AC & *None*: $t[40.5]=2.20, p<.05, \text{Cohen's } d=.28$). AA pairs also generated more ideas when using either type of picture support than no support (AA & *Stimulus* vs. AA & *None*: $t[43.7]=3.88, p<.0005, \text{Cohen's } d=.42$; AA & *Congruence* vs. AA & *None*: $t[46.3]=2.14, p<.05, \text{Cohen's } d=.09$). There was no effect of picture support on the productivity of CC pairs.

In support of H3, as indicated by effect sizes revealed in the previous paragraph, the effect of picture support on enhancing productivity was greater for intercultural groups (Cohen's $d=1.01$ for intercultural groups using *Stimulus*, and .28 when using *Congruence*) than for intracultural groups (Cohen's $d=.42$ for AA pairs using *Stimulus*, and .09 when using *Congruence*; no effects for CC pairs). However, the analysis did not detect differences across cultural groups for any picture support conditions. Intercultural groups had the greatest improvement when picture support was available, but still did not produce more ideas than intracultural groups.

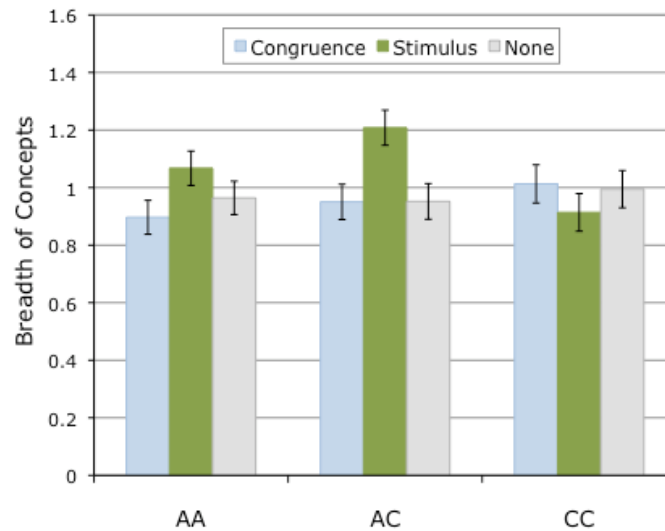


Figure 12. Breadth of concepts by group composition and picture support. Means and standard errors were estimated by the linear mixed model.

5.3.3. Breadth of Concepts

To test H4, H5, and H6, I used a linear mixed model with the breadth of concepts measure as the dependent variable. There was a moderate correlation between breadth of concepts and number of original ideas ($r=.27$). Although the correlation was not high, in order to ensure the results of concept breadth were independent of productivity, I included number of original ideas as a covariate in the model. Figure 12 shows the means of breadth of concepts estimated by the statistical model.

Picture support had a main effect on breadth of concepts ($F[2,45.9]=4.90$, $p<.01$). In support of H4, using the *Stimulus* method of picture selection resulted in broader concept coverage than using no pictures ($t[45.6]=2.47$, $p<.05$, Cohen's $d=.36$), or the *Congruence* method ($t[46.6]=2.89$, $p<.01$, Cohen's $d=.62$). The *Congruence* method, in contrast, did not help to increase breadth of concepts (*Congruence* vs. *None*, *n.s.*).

H5 was not supported by the analysis. Group cultural composition did not have a main effect on breadth of concepts ($F[2, 23.8]=.54, n.s.$). AC pairs did not cover broader concepts than intracultural groups (AA or CC).

The interaction effect between group cultural composition and picture support was significant ($F[4,44.5]=4.92, p<.005$). Intercultural groups had broader concept coverage when using the *Stimulus* method than no support (*AC & Stimulus* vs. *AC & None*: $t[46.2]=3.94, p<.0005$, Cohen's $d=1.16$), and than using the *Congruence* method (*AC & Stimulus* vs. *AC & Congruence*: $t[46.2]=3.98, p<.0005$, Cohen's $d=1.65$). AA pairs, when using the *Stimulus* method, had marginally broader concept coverage than no support (*AA & Stimulus* vs. *AA & None*: $t[44.8]=1.7, p<.1$, Cohen's $d=.48$), and broader coverage than using the *Congruence* method (*AA & Stimulus* vs. *AA & Congruence*: $t[46.5]=2.8, p<.01$, Cohen's $d=.98$). There was no difference in breadth of concepts for CC pairs across picture support conditions.

In support of H6, the *Stimulus* method had the greatest effect on broadening concept coverage when cultural diversity was available in the groups (i.e., intercultural group). What is especially noteworthy is the comparison between cultural groups. When the *Stimulus* method was used, AC pairs had greater breadth of concepts than both types of intracultural groups (*AC & Stimulus* vs. *CC & Stimulus*: $t[47.7]=3.28, p<.005$, Cohen's $d=1.26$; *AC & Stimulus* vs. *AA & Stimulus*: $t[47.5]=1.66, p<.1$, Cohen's $d=.53$). There was no difference between intercultural and intracultural groups for the other picture support conditions.

5.3.4 Agency in Broadening Concept Coverage

The analysis in section 5.3.3 reveals that *Stimulus* method helped intercultural groups (AC) achieve greater breadth of concepts than intracultural groups (AA and CC). This result raises questions as to whether individuals with different cultural

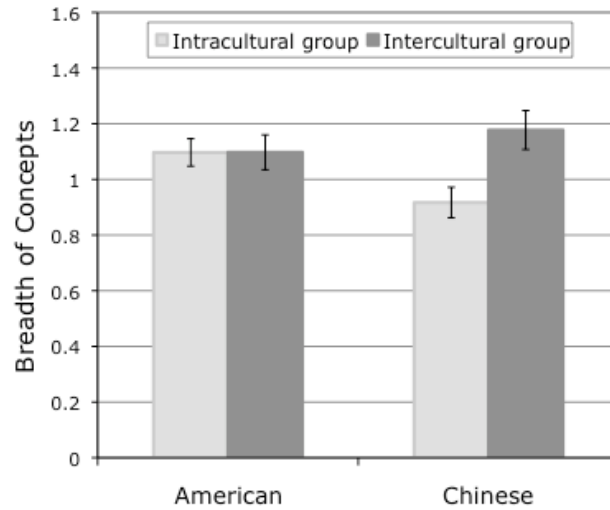


Figure 13. Breadth of concepts by individual cultural background and type of cultural group when using the *Stimulus* picture selection method.

backgrounds working in the intercultural group both contributed to concept coverage. That is, did the *Stimulus* method influence individuals of both cultures?

To address this issue, I computed breadth of concepts at the individual level to understand individuals' efforts in exploring the concept space when working under different conditions. The measure assessed the average semantic distance between any ideas generated by an individual on a brainstorming topic. To analyze, I used linear mixed modeling with individual-level breadth of concepts as the dependent variable. Individual cultural background (American or Chinese), types of cultural groups (intercultural or intracultural group), picture support and interactions of the three variables were set as fixed effects. Brainstorming topic and number of original ideas generated by individuals were included as covariates. Because the model fit was not ideal at the beginning ($R^2=.27$), I conducted an outlier analysis to exclude data with studentized residuals exceeding ± 2 . Ten out of 162 observations were excluded through this procedure. The revised linear model was reasonable in fit ($R^2=.72$).

Figure 13 shows when using the *Stimulus* method, how individual cultural background and group cultural composition affected breadth of concepts. Americans

and Chinese had similar breadth of concepts when working in *Stimulus*-supported intercultural groups (AC groups; the dark bars in Figure 13) ($F[1,100.9]<1$, *n.s.*). Under this specific condition, individuals from the two cultures proposed ideas with comparable breadth in concepts, and therefore, both appeared to take active agency to increase concept coverage.

As an interesting contrast to the result in intercultural groups, the *Stimulus* method did not appear to help Chinese individuals when they worked with other Chinese in intracultural groups (i.e., CC pairs). As Figure 13 shows, the difference between Chinese working in intercultural groups vs. intracultural groups was significant ($F[1,92.1]=8.55$, $p<.005$, Cohen's $d=1.12$). Americans, on the other hand, did not change depending on the cultural background of their partners ($F[1,80.9]<1$, *n.s.*). Under the *Stimulus* condition, Chinese also appeared to be more adaptable and susceptible to the cultural contexts in which they worked than Americans.

5.4. Discussion

In general, language-retrieved pictures emphasizing the quality of stimulation enhanced both the originality and the breadth of ideas. Pictures emphasizing contextual coherence supported productivity to a lesser extent than the *Stimulus* method, and did not facilitate breadth. Because the *Congruence* method selected pictures that were most related to the ongoing conversation, the pictures may not have been conceptually new or stimulating. Therefore, the failure to support the breadth of concepts may not be surprising. Overall, the general pattern with respect to picture support methods is consistent with the socio-cognitive view of brainstorming that conceptual diversity is crucial.

The influence of cultural diversity on brainstorming outcomes is a function of picture support. The *Congruence* method helped AC pairs generate more ideas than

the baseline of *None*, but did not make intercultural groups more productive or conceptually broader than intracultural groups. The *Stimulus* method, on the other hand, helped AC pairs cover broader concepts than both AA and CC pairs. It appears that this theoretically motivated design, grounded on the reasoning about the possible roles of cultural variation and language-retrieved pictures in intercultural brainstorming, helped groups leverage their cultural differences, thereby improving brainstorming outcomes.

5.4.1. Role of Cultural Accommodation

One interesting observation is the similarity of performance patterns between AC and AA pairs (see Figures 11 and 12). Picture support appeared to have similar influences on individuals working in AC and AA pairs, such as enhanced productivity and breadth of concepts, when brainstorming with the *Stimulus* picture support versus no support.

Motivated by the perspective of communication accommodation in intercultural encounters (cf. Giles et al., 1991), I suspect that Chinese participants' adaptation of communication behaviors may be responsible for the similarity between AC and AA pairs. The prior study in Chapter 3 also showed that Chinese are more likely to adapt their communication styles to partners from another culture than are Americans (Wang et al., 2009). This may explain the similarity of performance patterns between AC and AA pairs in the current study, as well as the dissimilarity between AC pairs and CC pairs. The individual level analysis displayed in Figure 13 provides some empirical support for the accommodation account by showing that Chinese individuals' brainstorming outcomes depended on the cultural backgrounds of their partners under the *Stimulus* condition.

However, it is not entirely clear yet what is the mechanism behind Chinese participants' adaptation of brainstorming outcomes. Note that earlier studies on communication accommodation mainly look at the styles of the process of communication (e.g., accent, word choice, topic management) rather than the output of communication (e.g., productivity in brainstorming). It is possible that some accommodation strategies such as word and topic choices can influence idea generation, as adjusting communication styles in ways related to content (e.g., words, topics) can further influence concept sharing and more concrete brainstorming outputs. The accommodation aspect should be worth of further investigation.

5.4.2. Second Language Use

One puzzle might be that the patterns of brainstorming outcomes for CC pairs were quite different from AA or AC pairs. Conversationally retrieved pictures did not enhance CC pairs' productivity and breadth of concepts in comparison to the baseline of showing no pictures. One possible account is the insufficiency of verbalized conceptual diversity, because the Chinese brainstormed in a second language (English). First of all, if Chinese participants did not express all of their ideas, naturally the group performance would be low even if language-retrieved pictures did help trigger new thoughts. Second, because our mechanism of picture support requires verbal input to trigger, fluent expressions of rich concepts are crucial to picture retrieval. Thus when ideas expressed were not rich and diverse, the agent also would not be able to retrieve a variety of pictures, limiting the usefulness of language-retrieved pictures as brainstorming support.

5.4.3. Implications for Design

The combination of the two sources of diversity, cultural differences and conversationally retrieved pictures, speaks to two general design questions pertaining to culture and collaborative work: whether the technology functions universally across cultures, and whether cultural differences can be used as a strategy to support certain work. These questions imply different stances with respect to the relationship between culture and technology.

The first question is essentially taking an evaluation stance, concerning whether the effects of a technology hold when moving to a different cultural context (e.g., Setlock et al., 2004; Wang et al., 2009). Seeing cultural differences in technology use or task performance is typically interpreted as requiring specialization of design to ensure better culture-technology fit (e.g., Marcus, 2001; Shen et al., 2006). Cultural differences are thus a target to be designed for, or around.

The second question takes the perspective that cultural differences are valuable resources that may become *part of* design. Cultural differences can introduce systematic diversity along many dimensions, such as language, social orientations, concepts, cognitive styles and life customs. In a group setting, interpersonal diversity may serve as a driving force to trigger positive group dynamics, such as promoting adaptation of behaviors so a desired effect can be attained (cf. the adaptation of Chinese in Figure 13), or increasing breadth of knowledge to attain more powerful collective intelligence (cf. the greater breadth of concepts covered by intercultural groups when receiving appropriate support in Figure 12). Cultural differences, in this view, become a design component, and may actually be the key to enabling certain technologies, such as enhancing group creativity through the combination of cultural differences and conversationally retrieved pictures.

I consider both views concerning the roles of cultural differences in design valuable. It is important to design for cultural differences and to make domain-general

intercultural collaboration easier to manage. It is also useful to consider the utility of cultural differences and incorporate it in design, such as naturally and systematically introducing diversity and dissent that stimulate thinking and reflection beyond what a homogeneous cultural context can afford.

As the next step of the dissertation (see Chapter 6), I propose to integrate picture support and machine translation to enable members of intercultural groups to speak their own native languages. Speaking in one's native language can make it easier to express diverse and rare concepts, and thus may better foster verbalized conceptual diversity.

CHAPTER 6

CROSSING LANGUAGE BOUNDARIES

The previous three chapters (Chapter 3, 4, and 5) have covered of the foundational behavioral, design and technical work of the dissertation. In Chapter 3, I presented a behavioral study investigating how cultures and communication medium affect the communication styles and the productivity of computer-mediated intercultural brainstorming. The results revealed not only cultural differences in communicative styles and sensitivity to the communication medium, but also confirmed that collaborating with partners from a different culture had a negative impact on productivity. Inferring from theories and the results, appropriate technological mediation that ensures conceptual diversity and concept comprehension or sensemaking is considered as one fruitful design direction. Chapter 4 presented the design of a computer agent that monitors brainstorming conversations and uses ongoing conversations as the driving force to retrieve pictures dynamically to stimulate idea generation. The underlying model posits that language-retrieved pictures can serve as a paralinguistic communication channel helping to communicate and diversify concepts and thus benefit idea generation. Chapter 5 described an evaluation of the system in intra- and intercultural brainstorming groups. Results from the study confirmed that the design helped intercultural groups to benefit from their multicultural composition. IdeaExpander-mediated intercultural brainstorming produced ideas with the greatest diversity that other configurations (intracultural groups with/without IdeaExpander, and intercultural groups without IdeaExpander) failed to obtain.

The dissertation so far has presented a big picture: using conversation to retrieve pictures to present at the side of a text chat, as a design motivated by theoretically and empirically identified characteristics of intercultural brainstorming, enhances intercultural brainstorming outcomes. The design prototype still poses certain constraints on intercultural groups, such as requiring groups to brainstorm using a text-based chatroom, discussing relevant topics to receive picture support, and using English as the common language to communicate. Among all these constraints, the “common language” assumption appears to be one that is especially worth releasing. The need to release this language constraint is not only because many people still don’t readily possess sufficient second language proficiency for communication (Butler et al., 2004), but also other negative effects associated with the use of second language in collaboration and knowledge work, as I will describe below.

People with different national cultural backgrounds often also speak different native languages (e.g., Chinese, English, Japanese, Korean etc.). Although it is a popular solution that people learn and use a common language to communicate (e.g., English), this approach may disadvantage people speaking a native language different from this common language and negatively influence group collaboration. For example, studies have shown that misunderstandings associated with second language use can lead to reduced trust (Henderson, 2005) and poorer interpersonal relationships at the workplace (Chevrier, 2000; DiStefano & Maznevski, 2000). During interpersonal communication, second language speakers also often have to use more complex communication strategies (e.g., rephrasing or repeating previous utterances) to bridge the gap between linguistic resources available to use and their communicative intentions (Dornyei & Scott, 1997). Finally, processing messages in a foreign language has been shown to decrease the cognitive resources available for

thinking tasks (Takano & Noda, 1993, 1995), and thus can be a non-ideal condition for knowledge work.

Research in artificial intelligence and natural language processing provides an alternative approach to cross the language barrier in multilingual groups. Rather than using a common language, it is possible using machine translation (MT) to enable cross-lingual communication. The integration of MT services, such as Google Translate (<http://translate.google.com>) or NICT's Language Grid toolbox (<http://langrid.nict.go.jp/>), and CMC applications can allow people to communicate with one another while producing and receiving messages in their native languages.

Recent studies revealed that current MT services do not always generate coherent and comprehensible translation results required for supporting certain types of collaboration (Yamashita & Ishida, 2006; Yamashita et al., 2009). For example, in communication tasks where referring expressions are important (e.g., to inform partners what objects to look at), MT can introduce errors and confusing messages, and thus impede establishing mutual knowledge or common ground about the world state. Yamashita & Ishida (2006) looked at one Chinese participant and one Japanese participant using MT tools to work on figure-matching tasks, where each of the participants has the same set of tangram figures but in different orders and they have to use language to communicate and match their orders of the figures (e.g., "your figure number 5 is my number 3"). Comparing to using English as a common language, one negative effect of MT-mediated collaboration is that participants failed to efficiently use language to refer to objects they tried to talk about, and also could not comprehend others' referring expressions well. When using MT, it required participants' efforts to take more conversational turns or use longer sentences to accomplish their communication needs (Yamashita & Ishida, 2006).

When shifting to MT-mediated multiparty communication (e.g., three-person collaboration consisting of Chinese, Japanese, Korean) where MT bridges the communications between any two participants speaking different languages (Chinese-Japanese, Japanese-Korean, Chinese-Korean), the negative effect of MT can be more salient and the difference between MT- and English-based communications can be larger (Yamashita et al., 2009). When one participant (*A*) speaking over MT, the other two participants (*B*, *C*) may encounter problems not only about *A*'s messages, but also around whether *B* or *C* understand *A* in the same way as translation inconsistencies and errors might be present. As a result, MT-mediated groups can suffer from being unable to abbreviate their referring expressions over time, which often naturally occurs in English-mediated groups when mutual knowledge about the situation establishes so that it is feasible to communicate efficiently with simplified utterances (Yamashita et al., 2009).

In contrast to communication tasks that rely on referring expressions to align the perspectives of participants (e.g., the figure-matching tasks discussed above), group brainstorming requires individuals to verbalize as many ideas as possible and use language to explore the conceptual space diversely. Previous studies on MT-mediated communication using referential-intensive tasks provide understandings on *convergence*-oriented collaboration in which people seek to achieve a well-defined task goal, such as unambiguously matching the order of a partner's figures to the order of one's own. The current chapter aims to introduce MT as a communication tool for group brainstorming, a *divergence*-oriented task in which alignment of mutual knowledge through communication is not the goal, but mutual stimulation is more of a purpose.

Because the diversity of ideas is important to brainstorming, either as an outcome of the task or as stimuli for triggering ideation, one potential benefit of MT is

allowing group members to express ideas in their own native languages, mitigating possible bottlenecks in multilingual brainstorming that are due to limited second language proficiency or reduced cognitive resources available for thinking.

Although MT can be beneficial for enabling idea sharing in native languages in intercultural groups, translation errors and noises associated with MT (e.g., wrong or inappropriate word choices and ungrammatical sentence construction etc.) might also have counteracting, negative influences on brainstorming. As shown by studies of MT-mediated collaboration, translation errors can impede the development of mutual knowledge (e.g., Yamashita & Ishida, 2006), implying that MT-translated messages can be difficult to comprehend. Thus it is possible that mistranslations can reduce the comprehensibility of socially exchanged ideas, and make them less useful for stimulating ideation.

6.1. Using Pictures to Support MT-mediated Brainstorming

As the study in Chapter 5 shows, adding language-retrieved pictures can promote productivity and diversify the scope of ideas generated. Here I further consider using language-retrieved pictures to similarly complement MT-based collaborative work when mistranslations arise.

To make MT a more useful tool to group brainstorming, the idea is to partially separate the semantic aspect of communication (the meanings of words and word combinations) and the pragmatic aspect of communication (the meanings and effects of utterances in the context of communication). One traditional focus of MT research is essentially on the semantic aspect, trying to achieve semantic equivalence between the source and the target languages. For example, classic evaluation metrics for MT systems focus on adequacy and fluency, preferring translations that convey complete and equivalent information contained in the original sentences in a fluent, human-like

manner (White & O'Connell, 1994). One MT evaluation method called BLEU, calculates the “translation closeness” metric between MT and human translators as how precisely a MT system chooses and orders words with respect to the human baseline (Papineni et al., 2002). These evaluation criteria reflect that the development and research of MT do not explicitly consider the actual influence of different MT designs on intercultural communication and collaboration.

One further observation is that, although syntactically and semantically precise translations can be quite helpful for collaboration, semantic equivalence is not necessarily a precondition for supporting intercultural work. Imperfect translation may be sufficient if key verbal and nonverbal resources are available to meet the practical need of communication. In the context of group brainstorming, as discussed and supported in previous chapters of this dissertation, enhancing the stimulation function of expressed ideas appears to be what really matters. A simple design such as showing language-retrieved pictures at the side of a text chat can be useful for eliciting cultural diversity in concepts and improving brainstorming outcomes. In MT-mediated brainstorming, it is possible that the language-retrieved pictures technique can provide non-verbal, visual representations of concepts to sustain brainstorming when poor translations impede language comprehension and thus possibly deteriorate the idea sharing function of the verbal channel.

I consider that pictures can influence MT-mediated brainstorming through two distinct and competing ways:

First, language-retrieved pictures might *increase* the saliency and influence of verbal messages that MT mediates. Because pictures selected are in close alignment with the linguistic content present in the ongoing conversation, pictures thus may have the function of duplicating concepts originally conveyed through the verbal channel also in visual representations. This multimodal duplication of information may support

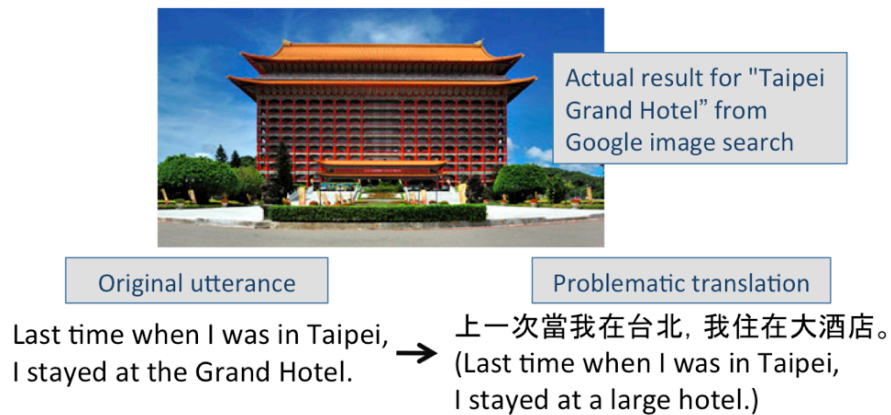


Figure 14. Using picture retrieval to repair a translation error.

the comprehension of messages. Consider the example in Figure 14, where “Grand Hotel”, a specific hotel in Taiwan, is mistranslated into Chinese literally as “large hotel”. Picture retrieval finds a picture that correctly represents that particular hotel, helping to repair translation errors and convey the intended, contextualized meaning. As another example, a translation of the English sentence “I had a difficult time in New York this winter due to the weather” such as “我有困難的時候在紐約, 由於今年冬季天氣” (a Chinese translation generated by translate.google.com, which approximately says “Because of the weather this winter, when I have difficulties in New York”) can be difficult to understand. However, using the same English sentence to retrieve pictures may return images of terrible snowstorms and bad traffic under such weather conditions, helping to convey the intended meaning in a richer visual context even though the implied concept of “snow” does not even occur in the original sentence or the translation.

Moreover, the duplication may let messages become more salient in conversation, garnering more attention and cognitive processing resources for processing each message. As a consequence, group members can have more focused discussions on each idea, leading to coherent conversational exchanges where a follow-up message tends to be more relevant to prior messages. In MT-mediated

brainstorming, language-retrieved pictures thus might foster the convergence of interpretations of received information among group members, and thus *reinforce* the influence of verbal messages even under the interference of MT errors or imperfections. This “convergence-facilitation effect” is similar to using simple, unambiguous images (e.g., line drawings) to replace individual words (e.g., “house”, “kitchen”, “read”, “book ” etc.) in sentences to enable language-independent cross-lingual communication (Cho et al., 2009; Mihalcea & Leong, 2008).

Second, language-retrieved pictures might convey richer concepts beyond language for stimulating ideation and thus *reduce* the saliency of verbal messages and associated mistranslations. In contrast to the convergence-facilitating role of pictures discussed above, pictures may on the other hand have a “divergence-facilitation effect” when pictures embody rich concepts and when people perceive and use these concepts in brainstorming. In the intercultural brainstorming study discussed in Chapter 5, pictures clearly played this role and served as a device for diversification, especially when the picture selection algorithm favored stimulation-oriented pictures. In MT-mediated brainstorming, both the convergence- and the divergence-oriented processes might occur. Also, both of them can be supportive through different processes. I consider that the source of stimulation can either come more from verbal messages with pictures playing a facilitating role, or from pictures directly with language and mistranslations having reduced influence on brainstorming.

6.2. IdeaExpander-ML: Multilingual Brainstorming with Language-Retrieved Pictures

To evaluate the influence of language-retrieved pictures on MT-mediated group brainstorming, I build a version of IdeaExpander for multilingual brainstorming

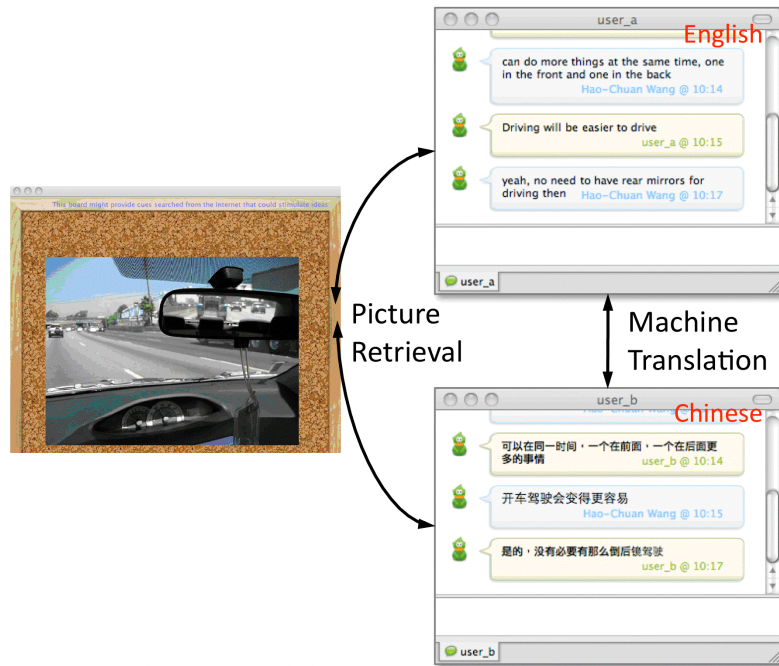


Figure 15. The architecture of IdeaExpander-ML. Performing picture retrieval independent of MT to retrieve pictures relevant to verbal messages for complementing MT-based communication.

called IdeaExpander-ML (“ML” denoting “multilingual”), integrating MT services and picture retrieval for computer-mediated brainstorming.

Figure 15 illustrates the high level architecture of IdeaExpander-ML. There are two main system modules, MT for translating text messages typed into the chatroom between different languages used by group members (e.g., Chinese and English), and the picture retrieval module responsible for retrieving relevant pictures for pre-translation, raw inputs. The key characteristic of this architecture is that the procedures for MT and picture retrieval are *independent* of each other. The mechanism of picture retrieval does not rely on MT services to function, and vice versa. This feature is important to support MT-mediated communication as it avoids the propagation of errors from one module (mistranslations) to another (picture retrieval)

and permits a non-confounded evaluation of the effects of pictures and MT on task performance.

6.2.1 Picture Retrieval Strategy

The system also must have a strategy for using multilingual conversations to retrieve pictures to display. I draw the general idea from research around multilingual information retrieval (MLIR), using queries in multiple languages (English, Chinese, etc) to retrieve candidate pictures from a shared picture database. The goal of MLIR is to retrieve, but not to translate, documents from multiple languages based on monolingual queries. For example, a Chinese language speaker might want to retrieve patents from the U.S., Japan, China, and so on by issuing a query in Chinese to an international, multilingual patent database. Although MLIR typically still uses MT for translating queries or indexing documents, this is simply a mediating step to discover and rank multilingual documents. This is a computationally more feasible problem than MT because the system does not have to generate comprehensible translations for human readers. (Hull & Grefenstette, 1996). Thus, translation errors may not have as large an impact as in conventional MT.

The picture retrieval module in IdeaExpander-ML has to solve a variation of the MLIR problem. Rather than issuing queries in one language to retrieve documents authored in multiple languages (using one language to retrieve documents in multiple languages), the goal is instead to use conversational turns typed in multiple languages as queries to retrieve relevant pictures (using multiple languages to retrieve relevant pictures). As discussed earlier, it is also necessary to address the requirement of the independence of mechanisms between picture retrieval and MT.

As the end solution for multilingual picture retrieval, I choose to index pictures with text descriptions in multiple languages (Chinese and English), and use the

standard IR model, TF-IDF, used in the earlier version of IdeaExpander (see Chapter 4) to compute similarity scores between a query and candidate pictures and select relevant ones. This approach simply considers simultaneously representing pictures as points in two separate vector spaces, one constituted by English words and another constituted by Chinese words, without assuming how the two multidimensional spaces relate to each other. Depending on the language of the input query, the system only uses one language-specific vector space to compute similarity scores. This solution meets the requirement of permitting using multiple languages to retrieve pictures, and is also independent of MT and straightforward to implement.

6.2.2. Prototyping

To implement IdeaExpander-ML, I modified the earlier version of the system in a number of ways, including adding MT to translate messages, indexing pictures with Chinese tags, and building a Chinese language processor for identifying keywords in Chinese utterances. Next I describe each of the changes in greater detail.

Machine Translation. In the current prototype, I use the MT service provided by Google (translate.google.com) to translate speakers' chat messages to a different native language (Chinese or English) used by their partners in real time. The system sends translation requests to Google's MT engine through a web-based programming interface that Google provides.

Picture Indexing. I revised the picture database by adding Chinese tags to pictures. Note that the pictures have been indexed with English texts as described in Chapter 4. Two Chinese native speakers provided Chinese tags on pictures for the extra thumb and the extra eye tasks (see Chapter 3 and Figure 3). The instructions asked them to tag each picture with any Chinese words or phrases that they considered descriptive or relevant. A total of 120 pictures (60 for the thumb task and 60 for the

eye task) were indexed with both Chinese and English texts, ready for IdeaExpander-ML to use. See Appendix C for sample pictures and their multilingual indexes. Note that the Chinese tags provided by the Chinese native speakers may also reflect their perceptions and interpretations of these pictures from the Chinese cultural perspective, which can be conceptually deviant from the English texts used to index the pictures. Because it is unclear whether all the English tags have a socially shared corresponding translation in Chinese and vice versa, and the current focus is to visualize verbal inputs with any relevant pictures, it is not crucial whether the Chinese tags and English tags are conceptually equivalent.

Chinese Language Processing. One important difference between Chinese and English is that there is no space or other delimiters between Chinese words in sentences. Also, so-called “words” in Chinese are essentially meaningful combinations of multiple Chinese characters. There can be multiple ways for segmenting sentences or grouping characters into words, adding complexity to Chinese language processing in general and keyword identification in the IdeaExpander-ML system in specific.

A common approach in natural language processing is to perform Chinese word segmentation (CWS) by using dictionaries for identifying boundaries of common words, or applying more sophisticated statistical techniques to perform segmentation adaptive to the sentence context (e.g., Ma & Chen, 2003). However, I consider that full-fledged CWS is not a necessary step for the purpose of keyword identification for picture retrieval. The requirement here is simply to project Chinese utterances typed by people (“queries”) as points in a multidimensional word vector space mentioned above (section 6.2.1) for computing similarities between input sentences and candidate pictures. Given that the total number of distinct Chinese tags used to index the picture database is not very large (1067 distinct tags for the set of 120 pictures), it is feasible to perform a series of substring matching against an input

sentence over the n tags to convert the input into a corresponding word vector representation. A straightforward algorithm for this sentence-to-vector conversion task is as the following:

Algorithm Sentence-to-vector conversion

Input: a sentence, s

Input: a set of Chinese tags used to tag pictures, T

$vector \leftarrow \{\}$ //initiate an empty vector

for all $t \in T$ **do**

$freq \leftarrow \text{SUBSTRING_MATCHER}(s, t)$ //count the frequency that t occurs in s

$vector \leftarrow \text{APPEND}(vector, freq)$ //append $freq$ to the end of the vector

end for

return $vector$

After representing input sentences as vectors in the Chinese tag-based vector space, it is permissible to perform standard IR, using TF-IDF to weigh the vectors and computing similarity scores with the cosine metric.

Another design decision to make is on how to decide whether a sentence contains ideas, so that the system should perform picture retrieval to visualize the sentence. For English inputs, IdeaExpander uses a statistically trained machine learning classifier to perform a binary classification, deciding whether a sentence has ideas or not (see Chapter 4). However, because IdeaExpander-ML is the first system involves using Chinese language on these brainstorming tasks, there are no labeled data available for applying the same machine learning technique on Chinese inputs. As a heuristic, when handling Chinese inputs, IdeaExpander-ML shows pictures only when the highest similarity scores between an input and pictures is greater than zero, implying that this sentence contains at least some tags of the pictures and can possibly be an idea worth visualizing.

Table 3. Counts and percentages of utterances in different languages receiving pictures from IdeaExpander-ML.

	Pictures retrieved	Utterances w/o pictures	Total
Chinese utterances	200 (58.5%)	142 (41.5%)	342
English utterances	218 (62.3%)	132 (37.7%)	350

To understand whether the new Chinese language processing mechanism can provide a similar degree of visualization support, matching what the English processing mechanism offers, I looked into the log data of an evaluation study that I describe in the next section, comparing the percentages of utterances in different languages receiving pictures from the system. As Table 3 shows, the log consists of 692 utterances produced by Chinese and English speakers in MT-mediated brainstorming, where 342 utterances were in Chinese and 350 utterances were in English. The system classified 58.48% of Chinese utterances and 62.29% of English utterances as consisting of ideas and retrieved pictures for them. The difference between percentages of utterances in different languages receiving pictures was not significant ($\chi^2=1, n.s.$), suggesting that the overall support for contributions in different languages were matched. The mechanisms of IdeaExpander-ML reasonably handle multilingual messages and provide potential support for MT-mediated brainstorming.

6.3. The Current Study

To gain understanding about how language-retrieved pictures and MT influence intercultural brainstorming, I conducted a laboratory study on intercultural dyads consisting of American and Chinese participants. This study manipulates two factors, type of mediation (communicating over MT versus English) and the

availability of language-retrieved pictures (using IdeaExpander-ML versus receiving no picture support), during intercultural brainstorming.

The earlier discussions in this chapter conjectures that although MT allows individuals to express ideas in native languages, mistranslations may impede comprehension and thus make it difficult for other group members to benefit from shared ideas. In other words, the stimulation function of idea exchange between group members may be weaker over MT-mediated communication. Language-retrieved pictures, if available, may strengthen this stimulation function, by either reinforcing the comprehensibility and saliency of verbal messages, or providing opportunities for individual and cultural differences in visual perception to diversify the conceptual space (see Section 6.1).

The study looks at effects of these technical interventions (MT, pictures) on two key brainstorming outcomes introduced in Chapter 5, productivity (number of original ideas) and the diversity or breadth of ideas (average distance between ideas). This study aims to examine a number of hypotheses with respect to the two dependent measures. In terms of productivity:

H1a: MT mediation will lead to higher productivity than English mediation (i.e., using English as a common language to communicate) because MT allows all participants to express messages in their native languages, beneficial for the production of ideas.

H1b: As a competing hypothesis to H1a, MT will lead to lower productivity, because mistranslations can impede comprehension and reduce the stimulation function of communication. The opposite predictions made between H1a and H1b are due to putting priority on different mechanisms. H1a assumes that the language of production is more important, while H1b considers that smooth idea exchange is more crucial.

H2: Language-retrieved pictures will enhance productivity compared to the baseline of having no support, because pictures can supply stimuli for stimulating ideation.

H3: The effect of pictures on productivity will be greater for MT than English mediation, because people can use their native languages to express ideas they glean through their visual perceptions of pictures. Also, pictures can mitigate the deficits of MT, enhancing the extent of stimulation available in groups.

In terms of breadth of ideas:

H4a: MT will lead to higher breadth of concepts due to the benefit of being able to express ideas in the native language.

H4b: Similar to the rationale behind H1b, a competing hypothesis considers that MT mediation will lead to lower breadth of ideas than English mediation because mistranslations can interfere idea exchange and therefore constrain the concept space that people can explore through collaboration.

H5: Language-retrieved pictures will increase breadth of ideas generated compared to no support because pictures can leverage cultural differences in perception and interpretation and elicit diverse ideas.

H6: The effect of pictures on eliciting diversity will be greater for MT than for English mediation, because MT permits expressing ideas in native languages, beneficial for multicultural individuals to share their diverse perceptions and thoughts around pictures. Also, pictures can mitigate the deficits of MT, enhancing the extent of stimulation available in groups.

Although the main focus is on task outcomes (productivity and breadth of concepts), the study also aims to explore and better understand the underlying processes that might be relevant to the observed outcomes, such as how people use

ideas shared by partners for ideation and their experience of efforts and communication during the session.

6.4. Method for the Study

Similar to the previous study discussed in Chapter 5, the study recruited participants with either American or Chinese cultural backgrounds, forming two-person intercultural groups for performing brainstorming over a text-based chatroom.

Experimenters randomly assigned each intercultural group to one of the two mediation conditions: using MT to communicate (MT-mediation) or using English to communicate (English-mediation). Each group consists of one Chinese participant using Chinese as native language, and one American participant using English as native language. For MT-mediation groups, participants typed messages in their own native languages (English or Chinese), and the system translated and displayed the messages in their partners' chat windows in the partner's native language. Each group performed two similar brainstorming tasks (the extra thumbs task and the extra eye task described in Chapter 3) using two different types of support: language-retrieved pictures provided by IdeaExpander-ML (referred to as the *Picture* condition), and a baseline of no support (referred to as *None*). Overall, type of mediation is a between-group manipulation, and type of support and brainstorming tasks are within-group manipulations. I counterbalanced the orders of picture support and brainstorming tasks.

The study in Chapter 5 shows that picture selection methods with different emphases, either on stimulating performance (*Stimulus*) or similarity to verbal messages (*Congruence*), would have varying effects. *Stimulus* pictures tend to better enhance productivity and breadth of concepts brainstorming outcomes overall, but *Congruence* pictures can still improve productivity though to a lesser extent than

Stimulus. Because for MT-mediated brainstorming, the functions of pictures for facilitating the interpretation of verbal messages and for providing direct stimulation can be both useful, the current study uses the *Congruence* picture selection method, choosing pictures most similar and relevant to the verbal messages.

6.4.1 Participants

The study recruited 46 participants (74% female) from Cornell University and the surrounding community. Among these, 23 were self-identified Americans living in the U.S. or Canada for more than 10 years and spoke English as their native language. The remaining 23 participants were self-identified Chinese speaking Chinese as their native language but who were also fluent in English. Although the Chinese participants were all currently studying or working in the U.S., the majority of them grew up in China (95%) and had been in the U.S for less than 2 years (73%).

Experimenters randomly assigned participants to brainstorming groups and experimental conditions. All groups are intercultural ones, consisting of one American participant and one Chinese participant. The majority of participants (98%) reported that they did not know their fellow group members prior to the study. There were a total of 23 two-person groups formed (12 MT-mediated groups and 11 English-mediated groups).

6.4.2. Tasks

The two brainstorming topics used were the “extra thumb” and the “extra eye” questions asking about the benefits and difficulties for people having a hypothetical extra thumb or an extra eye at the back of their heads in the future. The two topics have been used in earlier studies reported in Chapter 3 and Chapter 5. For each topic, a group brainstormed for 15 minutes by typing into a text-based chatroom.

6.4.3. Measures

The study adopted the operationalization techniques introduced in Chapter 5 to assess two main aspects of brainstorming performance, productivity and breadth of ideas. Note that study involves Chinese participants typing in Chinese in the MT-mediated condition. To enable analyses and comparisons of outcomes across cultures and conditions, a Chinese-English bilingual translator manually translated MT-mediated groups' Chinese utterances to English, allowing further English-based data coding and similarity analyses in a word association semantic space.

Specific measures used in the study for evaluating effects of interventions on brainstorming outcomes and processes include *productivity*, *breadth of ideas*, *similarity between adjacent ideas*, and *participants' experience*. Below I describe each of them:

Productivity. To assess intercoder reliability, two coders independently coded sample conversations six randomly selected groups, accounting for 30% of the data. Codes used the two-level coding strategy introduced in the study of Chapter 5, classifying whether each utterance contained an idea or not at the first level, and then deciding how original those idea utterances were, either “duplicate” (minor variations of an idea contributed) or “original” (ideas not yet proposed by the group). Inter-coder agreement was satisfactory both at the first level (Cohen's Kappa=.82) and the second level (Cohen's Kappa=.63). I then used the number of turns coded as containing original ideas as the measure of productivity.

Breadth of Concepts. I used the same operationalization of breadth of concepts introduced in Chapter 5 (Section 5.2.2), defined as the average semantic distance between any two original ideas generate by a group. The English-based WAS semantic space again served as the foundation for measuring the semantic distance

between ideas. Because WAS is an abstract representation of concepts, rather than word forms, one characteristic is that words expressing similar meanings tend to locate closely in this semantic space. Therefore, the translator's ad hoc word choice and sentence construction for a Chinese idea should not strongly influence the spatial location of this idea in the space and its distance to other ideas.

Similarity between Adjacent Ideas. Breadth of concepts is an outcome measure, capturing how diverse and how different ideas generated are to each other. The breadth of ideas measure, however, provides limited information about the working process, such as how group members influence each other through pictures and verbal messages when conversations unfold. I computed cosine similarities for ideas sequentially adjacent to each other in conversations with the WAS semantic space. This similarity measure captures how similar a new idea is to its antecedent idea, useful for inferring how individuals process external information and propose ideas under different conditions.

Experience. The study also asked participants to respond to a survey after working on each brainstorming task to capture their *perceptions* about their experience during the previous brainstorming session, especially on task effort required to brainstorm and comprehensibility of messages. To assess task effort, participants rated their mental demands using three items from the NASA TLX scale (Hart & Staveland, 1988). A sample item asked participants to rate "How much mental and perceptual activity was required to brainstorm (e.g., understanding the task, thinking, remembering, looking etc.)?" Ratings of the three items were averaged (Cronbach's alpha=.67).

To assess the general comprehensibility of messages under different conditions, participants rated three items developed for capturing this quality (e.g., "I could understand other members' ideas", "I am confident that other group members

understood my ideas”). Ratings of the three items were averaged (Cronbach’s alpha=.89).

6.5. Results

The main analytical strategy that I adopted is similar to previous studies, using linear mixed models to account for possible interdependencies due to repeated measures or social influences between group members within the groups (Kenny et al., 2002). Also, there can be between-group differences on performance driven by other mechanisms that are beyond the scope and interest of this study (e.g., innate creativity of group members). It is useful to consider group as a random factor that influences the dependent measures to clean up noises and obtain a more explanatory model.

One observation is that although there’s only one type of group composition involved in this study (American-Chinese intercultural dyad), experimental interventions, especially type of mediation, may not influence American and Chinese participants in the same manner. It is clear that Americans in the English-mediated and MT-mediated groups all read and express ideas in their native language (English); and Chinese participants read and express ideas in their native language (Chinese), only if working in MT-mediated groups. In other words, the impact of MT-mediation can be larger to Chinese participants, allowing them to type and read translated messages in Chinese. While to Americans, the main change from English- to MT-mediation is the quality of English messages they receive from MT. The asymmetry in how type of mediation influences language processing at the individual level raises questions concerning whether the hypothesized effects of MT and pictures further vary across cultures. To obtain more information in this aspect, the main units of analysis were *individuals* nested within groups, allowing us to look at how individuals’ cultural background affects the patterns of results.

Same to previous studies, I used linear mixed modeling to perform statistical analyses. The basic model configuration treated brainstorming trial, participant and group as random variables. I nested trial within participant, and participant within group. I included brainstorming topic as a covariate, and individual cultural background, type of mediation, type of picture support, and the full-factorial interactions between the three variables as fixed effects.

Note that unlike the study in Chapter 5, I did not include number of words as a covariate because the current data contained messages manually translated by the bilingual translator. It is unclear whether the number of English words fully represents talkativeness of individuals as the some of the contributions were originally inputted in Chinese. Also because of this lack of control for talkativeness (also see Chapter 5 for a discussion on this control), I consider it unsuitable to interpret the direct effect of cultural background on performance, which is also not a focus of this study.

6.5.1. Productivity

To test hypotheses H1 (a and b), H2 and H3, I constructed a linear mixed model using the number of original ideas as the dependent variable. Figure 16 shows productivity scores estimated by this model.

Between hypotheses H1a and H1b, the benefit of expressing ideas in the native language (H1a) appeared to be more influential than the difficulty of idea exchange over MT (H1b). There was no significant difference on productivity between MT- and English-mediated brainstorming ($F[1,21]<1$, *n.s.*). MT did not have a negative impact on productivity as H1b hypothesized. When looking into how this pattern varied across cultures, there was a trend that Chinese participants generated more original ideas using MT than using English ($F[1,41.9]=1.75$, $p=.19$), while there was no such pattern for Americans.

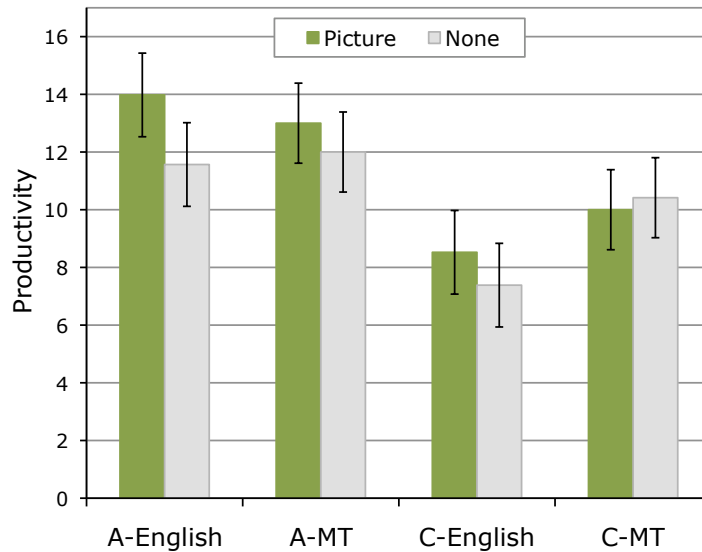


Figure 16. Productivity by individual cultural background, mediation condition and picture support. A denotes American, C denotes Chinese. Means and standard errors were estimated by the linear mixed model.

The results supported H2 to some extent. There was an overall trend toward significance that using pictures helped individuals generate more ideas than the baseline of providing no support ($F[1,41]=1.91, p=.17$). This pattern is similar to the previous intercultural study reported in Chapter 5 that *Congruence* pictures tend to have a smaller effect on productivity, though they remain helpful. It's also interesting to note that pictures *seem* to have a greater effect on Americans' performance, and the least influence for Chinese, especially those working in the MT-mediated groups (see Figure 16). Contrast analyses supported this observation, showing that the effect of pictures on productivity was nearly significant for Americans ($F[1,41]=2.6, p=.11$), and absent for Chinese participants ($F[1,41]<1, n.s.$).

The results did not support H3. Using pictures did not have a larger effect for MT-mediated groups. There was actually no significant difference between using pictures and no support under MT-mediation (*Picture-MT* versus *None-MT*: $F[1,41]<1, n.s.$), while the difference between pictures and no support under English-

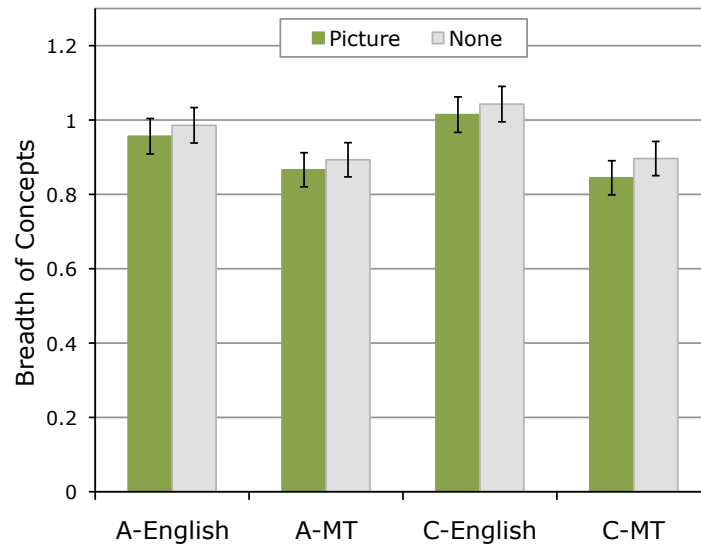


Figure 17. Breadth of concepts by individual cultural background, mediation and picture support. The measure is computed as the average semantic distance between ideas generated by an individual and all other ideas (either by self or the partner) contributed to the session. A denotes American, C denotes Chinese. Means and standard errors were estimated by the linear mixed model.

mediation was close to significance (*Picture*-English versus *None*-English: $F[1,41]=2.69, p=.1$). Picture support did not appear to be helpful to MT-mediated groups.

6.5.2. Breadth of Concepts

To test hypotheses H4 (a and b), H5 and H6, I used a linear mixed model with breadth of concepts as the dependent variable. Figure 17 shows the means of breadth of concepts by individuals estimated by the statistical model. Note that this analysis uses individual participants as the units of analysis. I defined breadth of concepts for an individual as the average semantic distance between ideas generated by this person and all other ideas, either by self or the partner, contributed to the brainstorming session. This measure captures how different or diverse an individual's ideas are in a

brainstorming session. For example, consider a group consisting of two individuals, *A* and *B* where *A* proposes two ideas: *a1*, *a2*, and *B* proposes another two ideas: *b1*, *b2*. The breadth of concepts for *A* is the average of distance scores for five pairs of ideas: *a1-a2*, *a1-b1*, *a1-b2*, *a2-b1* and *a2-b2*.

Between H4a and H4b, the result supported H4b. Brainstorming over MT lead to significantly lower breadth of concepts ($F[1,20.9]=11.1, p<.01$). This pattern was similar for American and Chinese participants (Figure 17) (American using MT mediation less broad than American using English mediation: $F[1,26.2]=5.06, p<.05$; Chinese using MT mediation less broad than Chinese using English mediation: $F[1,26.2]=15.12, p<.001$).

The results did not support H5. Pictures did not improve breadth of concepts. There was no main effect of type of support on breadth of concepts (*Picture* versus *None*: $F[1,40.6]=.85, n.s.$).

Similarly, the results did not support H6. Picture support did not have a larger effect for MT-mediated groups than English-mediated groups. In fact, pictures did not appear to help groups using either type of mediation (*Picture*-MT versus *None*-MT: $F[1,40.6]=.59, n.s.$; *Picture*-English versus *None*-English: $F[1,40.6]=.29, n.s.$). Also, the pattern of no effect was consistent across cultures (American-*Picture* versus American-*None*: $F[1,40.6]=.29, n.s.$; Chinese-*Picture* versus Chinese-*None*: $F[1,40.6]=.59, n.s.$).

6.5.3. The Influence of Socially Exchanged Ideas

The analyses above have revealed how MT and language-retrieved pictures influenced individuals' brainstorming outcomes. The observation that pictures did not seem to help Chinese participants in both productivity and breadth of concepts, but helped Americans to generate more ideas, raise questions about how external

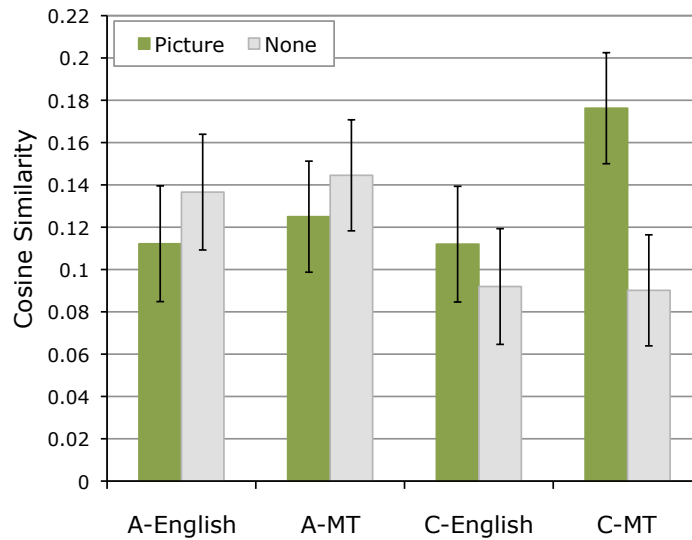


Figure 18. Effect of socially exchanged ideas, showing how similar an idea is to the previous idea proposed by the brainstorming partner. A, C denote the cultural backgrounds of the proposer of the current idea. Means and standard errors were estimated by the linear mixed model.

information influences people to collaborate and generate ideas during the brainstorming process.

In an exploratory analysis, I looked at the effect of *socially exchanged ideas* on subsequent idea generation, measuring how similar an idea is to another idea just proposed by the brainstorming partner (in this study, always with a different cultural background). This measure captures how individuals leverage socially exchanged ideas or ideas shared by their partners to generate ideas. For example, consider the case that group members *A* and *B* converse to generate a series of ideas and non-ideas in order: *a1, non_idea, b1, b2, a2, non_idea, b3*. In this sequence, idea pairs [*a1, b1*] and [*a2, b3*] capture how *B* processes *A*'s ideas to generate ideas *b1, b3*, and similarly, [*b2, a2*] provides information about how *A* uses *B*'s idea to generate *a2*, or how *B* influences *A* through idea sharing. When the average of this measure is high, one can infer that people take socially exchanged ideas more into account when generating new ideas, or a slightly varied interpretation can be that, those socially exchanged

ideas have greater influence on people. I computed cosine metrics between ideas in the WAS semantic space to measure semantic similarities.

I constructed a linear mixed model using individuals' average similarities between ideas and ideas just proposed by partners as the dependent variable. Figure 18 shows mean of this metric under different conditions.

Results showed that there was a significant interaction between cultural background and pictures on this similarity metric ($F[1,40.9]=4.26, p<.05$). Follow-up contrast analyses showed that language-retrieved pictures increased the similarity between Chinese participants' ideas and previous ideas proposed by their American partners (*Chinese-Picture* versus *Chinese-None*: $F[1,40.9]=4.26, p<.05$), but did not influence Americans in terms of this similarity metric (*American-Picture* versus *American-None*: $F[1,40.9]=.73, n.s.$). As Figure 18 illustrates, the effect of pictures is especially prominent for Chinese participants in MT-mediated groups (*Chinese-MT-Picture* versus *Chinese-MT-None*: $F[1,41.8]=5.86, p<.05$). Pictures seem to play a concept-highlighting function for Chinese, fostering the influence of socially exchanged ideas on follow-up contributions especially when using MT to work.

6.5.4. Participants' Perceptions

Finally, it is of interest to explore and understand participants' experience and perceived effects of MT and language-retrieved pictures. Figure 19 show participants' ratings on task load (NASA TLX) and comprehensibility of messages.

For task load, what's noteworthy is that Chinese participants working in MT-mediated groups considered it less effortful to brainstorm when receiving picture support (*Chinese-MT-Picture* versus *Chinese-MT-None*: $F[1, 41]=3.9, p=.05$) (see the rightmost bars of Figure 19 top). This pattern is consistent with the key idea behind the proposed hypotheses around brainstorming outcomes that MT alone is insufficient

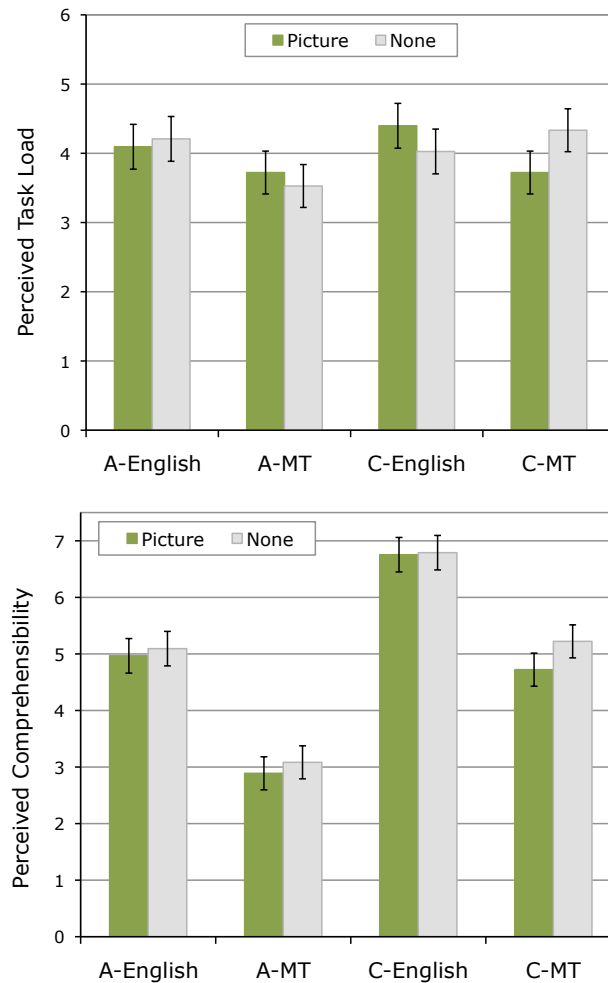


Figure 19. Perceived task load and comprehensibility of messages. A, C denote the cultural backgrounds of the proposer of the current idea. Means and standard errors were estimated by the linear mixed model.

while pictures can mitigate the deficits of MT. Also note that MT seemed to lower American participants' task load (American-MT versus American-English: $F[1,42]=1.84, p=.18$)

For comprehensibility of messages, participants rated English-mediated messages as easier to understand and comprehend than MT-mediated messages, regardless of individuals' cultural backgrounds (English versus MT: $F[1,42]=52.1, p<.001$) (see Figure 19 bottom). Pictures did not bolster perceived comprehensibility

in general. There was a tendency that pictures lowered comprehensibility for Chinese participants working in MT-mediated groups (Chinese-MT-*Picture* versus Chinese-MT-*None*: $F[1,41]=3.57, p=.07$).

Note that the analysis did not try to interpret cultural differences on subjective ratings here because the differences might simply reflect different response styles, rather than substantive differences in underlying perceptions (Hamamura et al., 2008).

6.6. Discussion

The study looked into how type of mediation (MT versus English) and type of support (language-retrieved pictures versus no support) influence intercultural brainstorming outcomes, including productivity and breadth of concepts. The study showed that language-retrieved pictures tended to increase the number of original ideas generated, but did not have an effect on the breadth of concepts among generated ideas. Type of mediation, on the other hand, in general did not have an effect on productivity but was influential to breadth of concepts. English-mediation fostered greater breadth between ideas than MT-mediation.

Note that the system's picture selection method chose pictures that were most similar to verbal messages (i.e., *Congruence* pictures as described in Chapters 4 and 5), rather than most stimulating for ideation (i.e., *Stimulus* pictures), for the possible secondary function of using pictures to complement MT for mediating verbal messages. Therefore, it is not surprising that the effect of pictures on productivity was positive in direction, but moderate in statistical significance. This pattern is consistent with the results of the previous study in Chapter 5. Another finding consistent with the previous study is that these *Congruence* pictures were not effective for broadening the breadth of concepts. What is probably more surprising is the lack of effect for pictures on MT-mediated groups' productivity. When communication is smooth

enough through a common language like English, pictures were useful for triggering more ideas, though not more diverse ideas. But when MT mediates messages, it appears that pictures might play a different role. It is necessary to understand the influence of MT on brainstorming first to further the discussion.

I consider that MT might have two impacts. In terms of language production, MT allows all participants to express ideas in their native languages, beneficial for brainstorming. However, in terms of language comprehension, MT can introduce translation errors and disrupt task outcomes due to problems of idea sharing and exchange. From the ratings of comprehensibility of messages, it is clear that MT made it more difficult for people to understand each other, and so smooth idea exchange was less likely to happen. However, it appears that poor comprehension did not harm productivity, people still managed to maintain the level of productivity over MT (i.e., no difference on productivity between MT- and English-mediation). Actually there was a trend that Chinese participants benefited from using MT and increased their quantity of ideas, supporting the view that expressing ideas in the native language is useful for brainstorming.

Although MT did not negatively impact productivity, on the other side, MT did lower breadth of concepts. This suggests that different brainstorming outcomes might depend on different processes. Productivity might be attainable by relying solely on language production, while breadth of concepts might require using interpersonal idea exchange to stimulate and to broaden the conceptual space available to explore. This is reasonable as quantity and diversity of ideas are likely to be two different dimensions of brainstorming outcomes.

So it appears plausible that translated messages are more of a hindrance to breadth of concepts but not productivity, possibly because people require quality external input to support them to retrieve diverse concepts from memory, and

translated messages fail to provide this stimulating function. One further question is why MT translations cannot play this stimulation role successfully. Here I propose that there can be two explanations.

One hypothesis extends the mediation role of *attention* in brainstorming to MT-mediated brainstorming. Prior studies show that to receive the benefit of cognitive stimulation in groups, it is necessary that people pay attention to others' ideas (e.g., Paulus & Yang, 2000; Paulus & Brown, 2007; Stroebe et al., 2010). In MT-mediated brainstorming, it is possible that translation errors lead people to adopt a "least effort strategy", focusing on producing ideas with their own means. Thus they may reduce their attention to translated messages as processing them would require more time and efforts, leading to the exploration of limited concepts within their own capacities.

Another hypothesis considers an alternative process, proposing that people require extra efforts to understand each other over MT, such as repairing the messages in various ways (e.g., Clark, 1996), thus reducing resources available for concept retrieval and ideation. In other words, translation problems can raise new needs for people to engage in communication acts irrelevant to task goals, and "distract" them from the task of brainstorming.

It is useful to reconsider the pattern that pictures tended to help English-mediated groups, but not MT-mediated groups, through the lens of the two hypotheses. The hypothesis that integrates the least effort principle and the role of attention probably will not be able to explain the lack of effect for pictures on MT-mediated brainstorming. As pictures leverage visual perceptions rather than language processing, adding an extra communication channel should make more cognitive resources available (e.g., Wickens, 2002), helpful for ideation especially when translated messages are less comprehensible. The second hypothesis focusing on the extra effort required to repair translation errors seems more explanatory here. It can

Table 4. Modes of language processing for American and Chinese over English- and MT-mediated communication.

	English-mediation	MT-mediation
American Participants	Type: Native (English) Read: Native (English)	Type: Native (English) Read: Native (Translated)
Chinese Participants	Type: Second (English) Read: Second (English)	Type: Native (Chinese) Read: Native (Translated)

be that people try to leverage pictures as representations of concepts to support their comprehension of translated messages. In this way, pictures no longer play the role to directly stimulate concept retrieval and ideation, thus have little or no effect on productivity as shown in this study.

6.6.1. The Role of Asymmetrical Language Processing between Cultures

If taking a participant-centric point of view for the communicative process in intercultural brainstorming, there exists an asymmetry in language processing for individuals from different cultures over different types of mediation. Table 4 shows the modes of language processing (language for typing and reading) for American and Chinese participants under different mediation conditions. For American participants, they read and type in their native language in both English- and MT-mediated groups. But the quality of English messages mediated by MT was less comprehensible, as shown by the results (see Figure 19 bottom). For Chinese participants, they read and type in a second language (English) over English-mediation, and in their native language (Chinese) when working over MT. Using different types of mediation thus implies a greater change in language processing modes for Chinese participants. This understanding helps explain certain results from the study.

One interesting pattern is that MT-mediation tended to moderately improve Chinese participants' productivity compared to English-mediation. This improvement demonstrates the benefit of using a native language to generate ideas. As it is considerably easier to read and produce ideas in a native language, MT-mediation helped Chinese participants to generate more ideas than English-mediation. Note that there was no such pattern for American participants possibly because MT did not change the language used to produce ideas. The contrast between how MT influences Chinese and American participants suggests that it is necessary to consider what benefits or obstacles MT introduce in terms of message production and comprehension. For American participants, MT actually introduced only disadvantages (i.e., possible translation errors), posing burdens on comprehension, while creating no extra benefits on production. For Chinese participants, the benefits of MT were more evenly distributed among production and comprehension.

It is also noteworthy that pictures raised the similarity between Chinese participants' ideas and ideas recently proposed by their American partners in MT-mediated groups (see Figure 18). There was no such pattern for Chinese participants working in English-mediated groups, or Americans working over any type of mediation. One possibility is that Chinese participants in MT-mediated groups strategically use pictures more as a device for supporting their comprehension of translated messages. The result that Chinese participants felt it less effortful to brainstorm with pictures rather than no picture over MT-mediation (see Figure 19 top) supports this view. On the other hand, pictures did not increase the influence of socially exchanged ideas for Americans, possibly due to culturally different ways of processing and using pictures in ideation. It can be that Americans treat pictures more as direct stimuli, and generate *new* ideas from their perceptions of visual components in the pictures, so pictures enhanced productivity but not the similarity to previous

ideas contributed by the partners. On the other hand, Chinese, especially when working over MT, may instead use pictures more as a message mediator, and generate *follow-up* ideas based on concepts intended by the verbal channel, increasing the similarity to previous ideas.

CHAPTER 7

GENERAL DISCUSSION

At a higher conceptual level, this dissertation attempts to answer two key questions for computer-mediated intercultural brainstorming. First, does culture matter? That is, how does multicultural group composition affect computer-mediated group brainstorming? And second, how should we design tools to effectively support computer-mediated intercultural groups. Allowing them to meet brainstorming goals and needs?

To investigate these two questions, the dissertation organizes studies and design work around the socio-cognitive model of group brainstorming, identifying that communicating to exchange and share ideas is crucial for stimulating ideation in groups, and then inquiring what roles culture and medium play in shaping brainstorming processes and outcomes. One key observation is that culture can have both positive and negative effects on intercultural brainstorming. On the positive side, cultural variation in background knowledge and cognitive styles (e.g., Nisbett & Masuda, 2003) has the potential to increase the diversity of ideas among group members, which is itself a desired outcome and also can be helpful to stimulating the process of subsequent ideation. On the negative side, cultural differences in communication styles (e.g., Hall, 1976; Holtgraves, 1997; Wang et al., 2009), social norms (e.g., Markus & Kitayama, 1991; Triandis, 1995) and linguistic fluency can hinder communication, and reduce the possible benefits of cultural diversity for stimulating ideation. Thus, there is a tension between the positive and negative influences of culture on brainstorming, and one central theme running through this dissertation is that we need to understand and address this tension. In the rest of this

chapter, I highlight key results from the preceding chapters, and then discuss how they contribute to the understanding of and resolution of this tension.

7.1. Summary of Results

Chapter 3 presented a study of how culture affects computer-mediated brainstorming. In a laboratory study, I looked into how individual cultural background (American or Chinese), type of cultural group (same-culture or mixed-culture group) and medium (text-only or video-enhanced chatroom) affect the communication styles (talkativeness, responsiveness) and outcome (productivity) of group brainstorming. Results show that American and Chinese participants exhibited different communication styles depending on the technical and cultural contexts of communication. Chinese participants were in general less talkative than their American counterparts, but using a text-only medium promoted Chinese participants' talkativeness and reduced this cultural difference. At the same time, Chinese participants were less responsive than American participants when working in same-culture groups, while Chinese and American participants exhibited similar levels of responsiveness when working in mixed-culture groups (i.e., intercultural groups). Stronger social cues mediated by video and the presence of multicultural composition in groups appear to foster Chinese participants' adaptation of different aspects of their communication styles, either talkativeness or responsiveness. Contextual factors did not have similar effects on American participants.

The study suggests that cultures differ not only in their styles of brainstorming conversation, but also in their flexibility and adaptability of their styles to the brainstorming contexts (here, the medium or the cultural background of their partner). Cultural differences in communication styles identified in this study and in previous work can increase the cost and difficulty of sharing ideas within groups and of

generating ideas collaboratively. My analysis of brainstorming productivity in this chapter further shows that multicultural composition led to lower quantity of ideas than uniform cultural composition. This pattern implies that communication bottlenecks might arise in intercultural groups' brainstorming, hindering the possible benefit of cultural diversity in concepts on creative brainstorming. There is a need to design supportive tools for unleashing the conceptual diversity and creative potential of intercultural groups.

Chapter 4 identifies key design requirements and proposes using language-retrieved pictures to visualize conversational content with relevant pictures and to enhance the stimulation utility of verbal messages. Cultural differences in communication styles, social norms and linguistic fluency may not be changeable in the short term. Thus intercultural communication problems can emerge when people from different cultures communicate through conversation, a form of interaction that is simple and natural, but also susceptible to cultural differences in social norms and communication styles.

As an alternative approach to addressing the tension between the goal of brainstorming performance and the goal of interactional naturalness, this dissertation proposes to consider enhancing the stimulation utility of natural conversation. Presenting language-retrieved pictures at the side of a chat is one design based on this consideration. In this design, a computer agent monitors ongoing conversations and performs picture retrieval to visualize verbal ideas with relevant pictures. Pictures can support brainstorming conversations in two ways: by either reinforcing the influence of verbal messages through the visual channel by duplicating the information in multiple channels, and by leveraging individual and cultural differences in picture perception (e.g., different loci of attention in a picture and different interpretations of a picture) to increase the diversity of concepts available in groups. Because the design

presents pictures only as peripheral cues, people can still maintain their flexibility to converse naturally.

Chapter 5 studies the effects of language-retrieved picture in cultural contexts. In a laboratory study, I investigated how the availability of pictures and type of cultural groups (e.g., intercultural or intracultural groups) affect brainstorming outcomes, including productivity and breadth of concepts among ideas generated. Results support the hypothesis that language-retrieved pictures can enhance intercultural groups' performance, eliciting diverse concepts from the multicultural composition. The availability of pictures is effective for supporting brainstorming in groups.

In Chapter 6, I focus on another important issue, the language boundary between cultures. Intercultural teamwork often requires participants to speak a common language, which adds constraints for those participants who speak a different native language and elevates the barrier for them to express and comprehend ideas due to insufficient linguistic knowledge. As a consequence, the language gap in intercultural groups can block idea sharing and reduce the cognitive benefit of using others' ideas as stimuli to facilitate ideation. In a laboratory study, I examined whether using MT and language-retrieved pictures releases constraints created by using a common language in intercultural groups because MT allows people to express and read ideas in their native language, and pictures may mediate concepts independent of language.

The study showed that MT moderately improved Chinese participants' productivity, supporting the theoretical benefit of expressing ideas in one's native language. However, MT reduced the comprehensibility of messages and the breadth of concepts among ideas for both Americans and Chinese participants, suggesting that the benefit of production may not be a key factor for these outcomes. Rather, language

comprehension and its impact on the process of idea exchange may be more influential to the diversity of ideas. Pictures, on the other hand, moderately enhanced productivity for English-mediated groups, but not MT-mediated groups. Displaying pictures did not further enhance the production of ideas in MT-mediated groups. This pattern suggested that translation problems might also influence the way people leverage pictures to work, raising needs of further investigation.

7.2. Discussion

As described earlier, one central theme of this dissertation is to understand and resolve the tension between the positive and negative influences of culture on group brainstorming. This dissertation contributes to this goal by looking at three key aspects of the problem: our basic theoretical understanding of how culture influences brainstorming (i.e., the behavioral science aspect), the design space of tools that incorporate language-retrieved pictures to augment the stimulation function of conversation (i.e., the design aspect), and our understanding of how technical features (e.g., MT) influence various brainstorming outcomes (i.e., the technological evaluation aspect).

7.2.1. Understanding Intercultural Communication

First, the dissertation enriches our theoretical understanding of computer-mediated intercultural brainstorming from the social and behavioral sciences. Culture introduces variation in communication styles, and the degree to which people flexibly adapt their styles to technical and cultural contexts, such as the type of medium used and the cultural composition of a group. Chapter 3 shows that Americans were not only more talkative and responsive in brainstorming discussions, but they were also less flexible (or more stable) in styles than their Chinese counterparts.

The high adaptability of Chinese individuals' communication styles is especially of theoretical and practical interests. Theoretically, the asymmetric adaptability between Chinese and Americans (i.e., Chinese being more adaptable) serves as an interesting case for examining earlier theories of related phenomena. The sociolinguistic theory of communication accommodation posits that people adapt their communication features (e.g., accent, speech rate, word and topic choices) when their conversational partners are associated with a different social group such as a different gender or culture (e.g., Giles et al., 1991). Thus the theory explains the adaptation of communication styles with social mechanisms, suggesting that intergroup relations and considerations are the driving forces for adapting ways of producing messages. Similarly, the psycholinguistic theory of interactive alignment posits that conversational utterances have priming effects, fostering the alignment of cognitive representations between interlocutors and leading to greater interpersonal similarity in conversational features such as word use, syntax and sentence structure (Pickering & Garrod, 2004). This theory thus considers the adaptation of communication features automatic, operating at an unconscious level.

What may deserve deeper investigation are the sociolinguistic and psycholinguistic mechanisms that lead to the observed intercultural asymmetry of communication adaptability. The conversational theories need to explain what leads Chinese participants to adapt their talkativeness or responsiveness, and why the same pattern did not occur for American participants. Does this imply that the social driving force for communication accommodation or the cognitive mechanism of priming is *not* universal? One conjecture is that cultural differences in certain basic social and cognitive psychological processes, such as East Asians' holistic perceptions (Nisbett & Chua, 2003) and interdependent social orientation (Markus & Kitayama, 1991) might be relevant, while there remains a lack of knowledge about how to

integrate cultural differences and conversational processes into a unified framework. For example, research that takes the communication accommodation perspective focuses on the relative relations between cultures, such as looking at how subordinate cultures adapt features of communication in order to converge to or diverge from the styles of the dominant cultures (Gallois et al., 1988). What is missing is an understanding of how individuals from different cultures vary in ways they communicate and handle intercultural relations, such as how Chinese and American individuals behave and converse when they are culturally subordinate.

The relative adaptability of Chinese participants' communication styles to technical and cultural contexts also has practical implications. Differences in communication styles can easily lead to miscommunication and reduce the effectiveness of information exchange in groups (e.g., idea exchange in brainstorming). For example, group members may experience difficulties in understanding each other if some of them talk directly while others talk indirectly, as there can be confusion about how to interpret the verbal and non-verbal cues. One way to resolve such a style mismatching would be the adaptation of communication styles. As it appears that Chinese individuals are more likely to adapt depending on the context, a designer taking this understanding into account could identify a way to foster the alignment of styles and reduce communication problems in workgroups. For example, it may be advantageous to assign Chinese individuals an information-brokering role in a multicultural group, since they could more easily align their styles with others and might facilitate the smooth communication of messages in the group.

7.2.2. Using Technological Agency to Address the Social-Cognitive Tension in Intercultural Work

Culture also introduces diversity in conceptual knowledge and thinking styles to groups, which can be beneficial for brainstorming and knowledge work that demands a broad knowledge foundation. However, Chapter 3 shows that intercultural communication led to productivity loss, obscuring the potential benefit of cultural diversity. Although it's not entirely clear how intercultural interaction leads to the loss of task performance, the result implies that it can be beneficial to enhance intercultural brainstorming by focusing on improving the process of communication and idea sharing in intercultural groups.

One contribution of the dissertation is to experiment with a design strategy that tries to detour around intercultural obstacles of being communicatively different, and to elicit the intercultural benefits of being cognitively diverse. In the context of brainstorming, my proposed solution is to create an extra communication channel that is more “cognitive-oriented”, such as pictures, which relies on individuals’ perception and interpretation to receive external information, while maintaining the “social oriented” channel, such as language, which affords desired social collaboration and facilitation, though the negative social and communicative side effects on performance may exist. In Chapter 5, the study of using IdeaExpander to support intercultural brainstorming confirms the usefulness of this “detouring-around-the-social” design strategy.

One lesson learned from studies of intercultural collaboration (e.g., Setlock et al., 2004; Wang et al., 2009; Setlock & Fussell, 2010) and the literature of computer-supported cooperative work (CSCW) is the nuanced nature of people and their interactions with artifacts (Ackerman, 2001). It is acknowledged that capturing every detail of how culture influences computer-mediated collaboration is challenging. For example, a switch of task can greatly change the relative talkativeness for American and Chinese individuals working in intercultural groups (Setlock & Fussell, 2010).

Therefore, one may argue that using technical designs to try to change people's social practice is not feasible, as people can easily adapt their strategies and behaviors in ways that technical designs may not always capture a priori. One field observation shows that people often opted not to use structural tools (i.e., GDSS) for performing group brainstorming, and even when they used the tools they did not have better task performance (Jackson & Poole, 2002). The finding supports the view that even workgroups can have multiple goals and needs. The understanding that there exist certain communicative and social barriers in intercultural groups is certainly useful, but it does not mean that it is easy to devise technical mechanisms to remove these barriers without sacrificing certain benefits or introducing new problems.

There is value considering the tool proposed by this dissertation not only as a specific design for intercultural brainstorming, but also as a case embodying the "detouring-around-the-social" design strategy that can be useful for the design of CSCW tools in other contexts. Besides group brainstorming, it is not unusual for other group tasks to involve both social and cognitive processes, such as collaborative problem solving and decision making (McGrath, 1984). Understanding and recognizing the role of individual cognition and its relation to social interaction in group work can help broaden the design space for supporting these tasks, and create opportunities to address multiple design constraints, such as enhancing the performance of idea generation while maintaining the naturalness of social interaction, with simple designs. The design of IdeaExpander provides an example of keeping the conversational channel unchanged or "as is", while using language-retrieved pictures to trigger diverse ideas and sustain brainstorming performance. In this design, technologies like language-retrieved pictures might be described as sharing the agency for supplying stimuli to stimulate ideation, which reduce the need to regulate social

interaction directly and resolve the tension between the social obstacles and cognitive benefits that culture introduces.

Further design research exploring this social-cognitive division and tension in different CSCW contexts can be helpful for examining the general usefulness of including this design strategy as a template solution in designers' toolboxes.

7.2.3. Evaluating the Usefulness of MT-mediated Communication

This dissertation also advances our understanding about the effects and usefulness of MT as a communication medium in the context of group brainstorming. Chapter 6 shows that MT helped release the production constraint (Chinese participants expressing more ideas over MT than English), but not the comprehension constraint (low comprehensibility of translated messages, and lower breadth of concepts). Pictures, on the other hand, increased productivity only for English-mediated groups, but not for MT-mediated groups. Note that pictures still enhanced productivity when using English as a common language (see Chapter 5), but they had limited influence when another technical mechanism (MT) came into play. These results constitute a practical understanding for applying MT to mediate international work, especially when people from different cultures do not share a common language so that MT is one economic solution for enabling interactive communication.

The asymmetries that MT releases one constraint (production) but not another (comprehension) and that pictures help only English-mediated groups but not MT-mediated groups pose further design and theoretical questions around using MT to mediate cross-lingual brainstorming. For Chinese participants capable of using English as a second language, forcing them to both type and read ideas in Chinese may not be the only option, especially since the study shows the low effectiveness of receiving ideas translated by MT. One refined design strategy would be to let

participants express ideas in their native languages, while the system only translates bilingual Chinese participants' ideas from Chinese to English and keeps American participants' ideas untranslated. This design would better match the languages skills of different cultures, and allows people to receive the benefit of producing ideas in native languages while avoiding the problem of comprehension introduced by MT at least for Chinese participants.

The asymmetrical effects of MT on production and comprehension require further theoretical exploration. One line of hypotheses proposed in Chapter 6 points to people's various strategies for handling poorly translated messages in interactive brainstorming, such as focusing on conversational repair rather than ideation or generating ideas solitarily without leveraging external inputs. However, an alternative theoretical perspective is that mistranslated messages can still be cognitively stimulating because they still contain keywords or cues useful for priming and facilitating concept retrieval (e.g., Bargh & Chartrand, 1999; McNamara, 2005). This "word-as-prime" or "word-as-retrieval-cue" theoretical approach also underlies the interactive alignment model of conversation (Pickerling & Garrod, 2004) and the socio-cognitive model of group brainstorming (Nijstad & Stroebe, 2006), positing that unconscious cognitive processing is fundamental to language use and idea generation. Although the results of the current work do not appear to support this perspective (e.g., reduced breadth of concepts over MT), it could be useful to consider the hypothesis that other factors are blocking the effects of this unconscious facilitation. For example, it might be possible to change ways of presenting translated messages, such as highlighting or increasing the size of keywords while de-emphasizing function words and syntactical errors in order to promote the unconscious aspect of cognitive processing. One area for future work is to identify presentation strategies of this sort in

order to increase the usefulness of MT for brainstorming and general communication, as significantly improving the quality of MT results can be technically more difficult.

7.3. General Limitations and Future Work

There are a number of general limitations of this dissertation research, which also point out some key directions for future work. First of all, the dissertation mainly adopts the paradigm of laboratory study, trying to establish a basic understanding around the causality between variables. The experimental setting can be viewed as a projection or simulation of key aspects of real-world remote teamwork, making it possible to isolate factors and identify the causal structure. However, it is inevitable that the setting might not capture all nuanced aspects of online groups in the wild. In the future, it would be useful to conduct research in the field, such as studying how people perform computer-mediated intercultural brainstorming in organizations and examining the effects of IdeaExpander on participants with realistic goals and needs to collaborate online with people from different cultures.

Also, another limitation is on the experimental design per se. The current work focuses on small groups. Each group consists of two or three people. Results of the studies thus advance the understanding of small group collaboration and interpersonal communication, while more work will be required to generalize the finding and design recommendations to larger groups. Consider, for example, whether IdeaExpander can be similarly effective for intercultural groups consisting of more participants. One possibility is that increasing group size may lead to more significant dominance of opinion, as the cost for taking turns and discussing everyone's ideas can be higher if there's no appropriate management. Although language-retrieved pictures might still be effective for stimulating people's ideation, it can be difficult to produce diverse ideas if people cannot obtain opportunities to express their ideas. Thus it might be

necessary to apply some structures for interaction to ensure more equal participation among people in large groups, although this type of structured interaction is considered less natural and preferred for small groups, as discussed earlier in the dissertation. Also, a larger group size might introduce more salient cultural asymmetry in group composition, so that there is a higher chance that some cultures may be of the majority while others may be of the minority. Clearly, it is not possible to have this type of asymmetry in two-person groups. Recent work looking at the effects of asymmetrical cultural composition in three-person groups shows that which culture is of the majority significantly influences people's conversational styles (Wang & Fussell, 2010). Further work is needed to understand the nature and implications of this cultural asymmetry in large groups.

Another direction to pursue is the application of the language-retrieved pictures approach to other tasks and contexts. The technical approach of visualizing conversational content with relevant pictures can be especially useful for tasks that demand diversity of thoughts or where fixation on a few ideas is problematic. Thus there is the potential to apply this approach to other open-ended tasks such as design and intelligence analysis. As mentioned earlier, the design thinking that tries to identify key technical features to resolve the tension between the social and cognitive processes in collaboration can also be valuable to the design of other group activities.

7.4. Conclusion

This dissertation considers how culture influences computer-mediated group brainstorming and how to effectively support intercultural brainstorming groups. Grounded on the understanding that intercultural work introduces the social barrier of intercultural communication problems and the cognitive benefit of diverse concepts, the dissertation investigates how intercultural composition affects online

brainstorming, and identifies technical mechanisms for resolving the tension between the barriers and benefits introduced by culture.

The dissertation proposes to use language-retrieved pictures, or pictures relevant to ongoing conversation, as stimuli to extend the stimulation utility of verbal messages without trying to directly regulate people's communication behaviors. This dissertation evaluates this design and shows its effectiveness on brainstorming performance. A further study integrating this design and machine translation (MT) within the context of cross-lingual collaboration enriches our understanding of how MT influences the production and comprehension of ideas in cross-lingual brainstorming. This dissertation contributes to behavioral science theory and technology design and evaluation within the context of intercultural brainstorming, and opens up new theoretical and design questions, such as the interconnection among culture, conversational processes and creativity as well as the use of simple technical features to share the key agency of group work.

APPENDIX A

Sample idea categories for the “extra eye” task

E-v-1	Vision	Better overall field vision/ like a superpower/ If you stand on top of a mountain you could see everything.
E-v-2		Too many incoming information, hard to process, mentally disturbing / distracting
E-v-3		You might be able to pay attention to the lecture while putting your head on the desk
E-v-4		Easy multitasking like cooking in front and watching TV behind, etc
E-s-1	Sport	Easier behind the back passes
E-s-2		Military might only hire people with that eye because having an eye on the back is useful in combat
E-s-3		New sports and games would also be invented to utilize the new eye.
E-ro-1	Redesign	Crazier glasses (including sun glasses and safety glasses)
E-ro-2		Helmets and hats with eye holes
E-ro-3		Ponchos and hoodies would have to be redesigned, making way for rain hats with holes in them.
E-ro-4		Classrooms could also be changed to have visual aid be shown simultaneously with the lesson to enhance it.
E-co-1	Change of convention	Surround-view movies / tv's
E-co-2		The band "Third Eye Blind" might have to change the name to "Fourth Eye Blind"
E-co-3		Putting the contact lens for the back eye will be challenging
E-co-4		People might cheat on HIDE AND SEEK
E-co-5		Running backward will be cool again; you could walk backwards better.
E-h-1	Hairstyle	Stranger hairstyles to keep hair out of eye; New hair style will be born (basically no hair around the eye)
E-h-2		People will probably try to hide it w/ hair for style issue
E-h-3		Haircuts would become trickier / hairdressers would need more education
E-h-4		It would be very dangerous to get your hair colored. Salons may go out of business
E-h-5		Shaving your head would be better than having hair because of the third eye/couldn't have long hair
E-d-1	Driving	No need for rear-view mirrors / car side mirrors
E-d-2		Number of people who die in car accident, etc might go down

Sample idea categories for the “extra thumbs” task

T-s-1	Sport	Bowling
T-s-2		Better tennis player
T-s-3		More frisbee throws
T-s-4		More balance when performing handstands
T-s-5		Martial arts would have to incorporate the new thumb.
T-s-6		Easier to grip a basketball
T-m-1	Music	New way of playing-play more keys once
T-m-2		New style of music be created
T-mo-1	Manipulation of object	Faster keyboard typing
T-mo-2		Enhancing productivity or communication that require typing
T-mo-3		Hard to hold small objects due to the bigger hand
T-co-1	Change of convention	Count more with hands
T-co-2		6/12-base system would be popular
T-co-3		Double thumb wars
T-co-4		High sixes (high five)
T-co-5		More extreme tickling
T-ro-1	Redesign	Redesign glove; old gloves no longer fit / use only mittens
T-ro-2		Pockets need to be redesigned/enlarged
T-ro-3		Jars will have to be made larger
T-ro-4		Keyboards
T-sc-1	Social consequence	Social discrimination between 5 and 6-finger populations
T-sc-2		Low self-esteem of 5 or 6-finger person
T-cq-1	Chance and quantity	Industrial accidents involving the hand

Sample idea categories for the “having wings” task

W-t-1	Transportation	People can fly instead of taking other forms of transportation; Able to travel more quickly
W-t-2		Danger of flying, e.g., getting hit by planes
W-t-3		Still faster to take plane than fly on your own
W-t-4		Able to travel as far and as fast as you want with breaks
W-t-5		More [difficult] air traffic monitoring control
W-sc-1	Social consequence	More spiritual references to angels, heaven
W-sc-2		Population in better shape or more healthy due to exercise
W-sc-3		New jobs, e.g., winged police and air traffic controllers
W-sc-4		Traffic license rules for people flying in the sky
W-sc-5		Criminals would be harder to catch because they can fly away more easily
W-f-1	Functionality	No need for shirts or upper body clothing, i.e., it would get in the way of the wings
W-f-2		Fold or unfold wings naturally
W-uo-1	Use of objects	New clothing to fit wings
W-uo-2		No need for umbrella
W-uo-3		Use more shampoo detergent
W-uo-4		Backpacks are useless; would have to be redesigned
W-m-1	Maintenance	Feathers will shed molt so you need to clean up more often
W-m-2		Method for cleaning the wings every day; keeping up good hygiene and smell
W-m-3		Fixing the wings when they are broken
W-m-4		New wing medicine doctors and science
W-c-1	Change in convention	Difficulty sleeping. People have to stand or sleep facedown
W-c-2		Save gas oil electricity
W-c-3		Build homes in the sky or in remote areas

APPENDIX B




Questions for assessing Individualism (Ind) and Collectivism (Col) adapted from Triandis (1995):

Please answer the following questions by choosing the option that most closely represents your personal beliefs. (scale 1-7).

- What I look for in a job is a friendly group of co-workers. (Col1)
- Children should live at home with their parents. (Col2)
- I like to live close to my good friends. (Col3)
- I tend to do my own things, and most people in my family do the same. (Ind1)
- When faced with a difficult personal problem, it is better to decide what to do yourself, rather than follow the advice of others. (Ind2)
- The most important thing in my life is to make myself happy. (Ind3)
- I like to live in cities, where there is anonymity. (Ind4)
- I would rather struggle through a personal problem myself than discuss it with my friends. (Ind5)
- Aging parents should live at home with their children. (Col4)
- When faced with a difficult personal problem, one should consult widely one's friends and co-workers. (Col5)
- I would help within my means if a relative told me he/she is in financial difficulties. (Col6)
- What happens to me is my own doing. (Ind6)
- Aging parents should have their own household. (Ind7)

APPENDIX C

Sample pictures⁴ with multilingual indexes (English and Chinese) in the database:

ID	Picture	English Index	Chinese Index
Eye-13 ⁵		<p>classrooms could also be changed to have visual aid be shown simultaneously with the lesson to enhance it reading would be tough as back eye would get distracted can read more books easier to cheat on tests teachers will have an easier time - watching catching cheating students students couldn't cheat anymore studying examination classroom students bcit british columbia intense problem work exam test binder pencil paper blackboard</p>	<p>考试 难 答卷 答题 作弊 偷看 道德 品行 教室 上课 考试 测验 练习 补习班 同学</p>
Eye-3 ⁶		<p>no need for rear-view mirrors car side mirrors overall easier safer to drive truck freeway car rearview mirror accident drive driving seatbelt seat seatbelts</p>	<p>后视镜 公路 仪表盘 追尾 事故 汽车 高速公路 轿车 后照镜 里程表 车路</p>
Eye-10 ⁷		<p>overall benefit to athletes null sports football ucla cal berkeley bruins college uclabruins bears calbears team manly muscle intense fight goal touchdown referee game</p>	<p>橄榄球 足球 撞击 对抗 受伤 比赛 观赏 球员 冲 得分 美式足球 比赛 球赛 冲撞 运动 球</p>

⁴ Licensed under Creative Commons

<p>Thumb -23⁸</p>		<p>redesign glove old gloves no longer fit use only mittens overall redesign objects used in society looks would change sewing knitting affected knitting knitted gloves cashmere pink soft winter</p>	<p>手套 魔术 冬天 温暖 保护 织 毛线 毛线手套 紫色 手势 树</p>
<p>Thumb -41⁹</p>		<p>hard to hold small objects due to the bigger hand toothbrush easier to hold more items at once or larger items easier to do delicate things sewing knitting affected embroidery electronic conductive thread floss needle weave</p>	<p>针线 缝补 手工 家政 家务 缝纫 刺绣 针线 手工艺 底稿 针线活</p>

⁵ <http://www.flickr.com/photos/dennissylvesterhurd/141183312/>

⁶ <http://www.flickr.com/photos/estherbester/1317549963/>

⁷ <http://www.flickr.com/photos/picdrop/2016903/>

⁸ <http://www.flickr.com/photos/snowdropsense/351888827/>

⁹ <http://www.flickr.com/photos/bekathwia/2531127747/>

REFERENCES

- Ackerman, M. (2000). The intellectual challenge of CSCW: The gap between social requirements and technical feasibility. *Human-Computer Interaction, 15*, 179-203.
- Amabile, T. M. (1983). *The social psychology of creativity*. New York: Springer-Verlag.
- Anderson, J. R. (1983). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior, 22*, 261-293.
- Baddeley, A. (1992). Working memory. *Science, 255*, 556-559.
- Baddeley, A. (2003). Working memory: Looking back and looking forward. *Nature Reviews Neuroscience, 4*, 829-839.
- Balota, D. A., & Coane, J. H. (2008). Semantic memory. In J. H. Byrne, H. Eichenbaum, R. Menzel, H. L. Roediger III, & D. Sweatt (Eds.), *Handbook of learning and memory: A comprehensive reference*. Amsterdam: Elsevier. 512-531.
- Bao, P., Gerber, E., Gergle, D., & Hoffman, D. (2010). Momentum: Getting and staying on topic during a brainstorm. *Proceedings of CHI 2010*.
- Bargh, J. A. & Chartrand (1999). The unbearable automaticity of being. *American Psychologist, 54*, 462-479.
- Barsalou, L. W. (2008a). Grounded cognition. *Annual Review of Psychology, 59*, 617-645.
- Barsalou, L. W. (2008b). Grounding symbolic operations in the brain's modal systems. In G. R. Semin & E. R. Smith (Ed.) *Embodied grounding: Social, cognitive, affective, and neuroscientific approaches*. New York: Cambridge University Press.
- Bohannon, J. (2011). National Science Foundation- Meeting for peer review at a resort that's virtually free. *Science, 331*(6013), 27.
- Brown, V., Tumeo, M., Larey, T. S., & Paulus, P. B. (1998). Modeling cognitive interactions during group brainstorming. *Small Group Research, 29*, 495-526.
- Brumann, C. (1999). Writing for culture: Why a successful concept should not be discarded. *Current Anthropology, 40*, 1-27.
- Burton, M. L., & Kirk, L. (1979). Ethn classification of body parts: A three-culture study. *Anthropological Linguistics, 21*, 379-399.

Butler, Y. G. (2004). What level of English proficiency do elementary school teachers need to attain to teach EFL? Case studies from Korea, Taiwan, and Japan. *TESOL Quarterly*, 38, 245-278.

Carletta, J., Isard, A., Isard, S., Kowtko, J. C., Doherty-Sneddon, G., Anderson, A. H. (1997). The reliability of a dialogue structure coding scheme. *Computational Linguistics*, 23, 13-31.

Cepeda, N. J. (2008). Effect Size Calculator.
<http://www.cognitiveflexibility.org/efficientsize/>.

Chevrier, S. (2003). Cross-cultural management in multinational project groups. *Journal of World Business*, 38, 141-149.

Cho, H., Ishida, T., Takasaki, T., & Oyama, S. (2008). Assisting pictogram selection with semantic interpretation. *Proceedings of European Semantic Web Conference (ESWC) 2008* (pp. 65-79). Berlin: Springer-Verlag.

Cho, H., Ishida, T., Yamashita, N., Koda, T., & Takasaki, T. (2009). Human detection of cultural differences in pictogram interpretations. *Proceedings of ACM International Workshop on Intercultural Collaboration (IWIC) 2009* (pp. 165-174). NY: ACM Press.

Cristianini, N., & Shawe-Taylor, J. (2000). *An introduction to support vector machines and other kernel-based learning methods*. Cambridge University Press.

Chua, H. F., Boland, J. E., & Nisbett, R. E. (2005). Cultural variation in eye movements during scene perception. *Proc. Nat'l Acad. Sci.*, 102, 12629- 12633.

Clark, H. H., & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127-149). Washington, DC: American Psychological Association.

Clark, H. H. (1996). *Using Language*. New York, NY: Cambridge University Press.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences*, 2nd Ed.. NJ: Erlbaum.

Collins, A. M. & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, 8, 240-247.

Collins, A. M. & Loftus, E. F. (1976). A spreading activation theory of semantic processing. *Psychological Review*, 82, 407-428.

- Collins, F. S., Morgan, M., & Patrinos, A. (2003). The human genome project: Lessons from large-scale biology. *Science*, *300*, 286-290.
- Connolly, T., Jessup, L. M., & Valacich, J. S. (1990). Effects of anonymity and evaluative tone on idea generation in computer-mediated groups. *Management Science*, *36*, 689-703.
- Connolly, T. (1993). Behavioral decision theory and group support systems. (pp.270-280). In L. Jessup & J. Valacich (Eds.). *Group support systems*. NY: Macmillan.
- Culhane, J. L., & Worms, J. C. (2001). Improving the effectiveness of international collaboration in space science. *Space Policy*, *17*, 179-186.
- Daft, R. L., & Lengel, R. H. (1986). Organizational information requirement, media richness and structural design. *Management Science*, *32*. 554-571.
- D'Andrade, R. G. (1981). The cultural part of cognition. *Cognitive Science*, *5*, 179-195.
- Datta, R., Joshi, D., Li, J., & Wang, J. Z. (2008). Image retrieval: Ideas, influences, and trends of the new age. *ACM Computing Surveys*, *40*, 5:1- 5:60.
- Dennis, A. R., & Valacich, J. S. (1993). Computer brainstorm: More heads are better than one. *Journal of Applied Psychology*, *78*, 531-537.
- Diamant, E. I., Fussell, S. R. & Lo, F-L. (2008). "Where did we turn wrong?" Unpacking the effects of culture and technology on attributions of team performance. *Proc. of CSCW 2008* (pp. 383-391). NY: ACM Press.
- Diehl, M., & Stroebe, W. (1987). Productivity loss in brainstorming groups: Toward the solution of a riddle. *J. Personality and Social Psychology*, *53*, 497-509.
- Diehl, M., & Stroebe, W. (1991). Productivity loss in idea-generating groups: Tracking down the blocking effect. *Journal of Personality and Social Psychology*, *61*, 392-403.
- DiMicco, J.M., Pandolfo, A., & Bender, W. (2004). Influencing group participation with a shared display. *Proceedings of CSCW'04*.
- DiStefano, J. J. & Maznevski, M. L. (2000). Creating value with diverse teams in global management. *Organizational Dynamics*, *29*, 45-61.
- Dornyei, Z., & Scott, M. L. (1997). Communication strategies in a second language: Definitions and taxonomies. *Language Learning*, *47*, 173-210.

- Dugosh, K. L., Paulus, P. B., Roland, E. J., & Yang, H-C. (2000). Cognitive stimulation in brainstorming. *J. Personality and Social Psychology*, *79*, 722-735.
- Dugosh, K. L., & Paulus, P. B. (2005). Cognitive and social comparison processes in brainstorming. *Journal of Experimental Social Psychology*, *41*, 313-320.
- Fischer, G. (2005). Distance and diversity: Sources for social creativity. *Proc. Creativity and Cognition*.
- Foltz, P. W., Kintsch, W., & Landauer, T. K. (1998). The measurement of textual coherence with latent semantic analysis. *Discourse Processes*, *25*, 285-307.
- Fussell, S. R., Zhang, Q., & Setlock, L. D. (2008). Global culture and computer-mediated communication. In S. Kelsey & K. St. Amant (Eds.) *Handbook of Research on Computer-Mediated Communication* (pp. 901-916).
- Gallois, C., Franklyn-Stokes, A., Giles, H., & Coupland, N. (1988). Communication accommodation in intercultural encounters. In Y. Y. Kim & W. B. Gudykunst (Eds.), *Theories in Intercultural Communication*, Newbury Park, CA: Sage.
- Gallupe, R. B., Dennis, A. R., Cooper, W. H., Valacich, J. S., Bastianutti, L. M., & Nunamaker, J. F. (1992). Electronic brainstorming and group size. *The Academy of Management Journal*, *35*, 350-369.
- Garrod, S., & Pickering, M. J. (2004). Why is conversation so easy? *Trends in Cognitive Sciences*, *8*, 8-11.
- Giles, H., Coupland, J. & Coupland, N. (1991). *Contexts of Accommodation*. NY: Cambridge University Press.
- Graesser, A. C., & McNamara, D. S. (2010). Computational analyses of multilevel discourse comprehension. *Topics in Cognitive Science*, 1-27.
- Gregory, R. L. (1997). Visual illusions classified. *Trends in Cognitive Sciences*, *1*, 190-194.
- Grossman, D. A., & Frieder, O. (2004). *Information Retrieval: Algorithms and Heuristics*. Springer.
- Hall, E. (1976). *Beyond Culture*. NY: Doubleday Anchor Books.
- Haeberli, W., Josef, C., Roger G., B. (2000). Glacier monitoring within the global climate observing system. *Annals of Glaciology*, *31*, 241-246.

- Hart, S. G., & Staveland, L. E. (1988). Development of a multi-dimensional workload rating scale: Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Ed.), *Human mental workload* (pp. 139-183). Amsterdam: Elsevier.
- Henderson, J. M., & Hollingworth, A. (1999). High-level scene perception. *Annual Review of Psychology, 50*, 243-271.
- Heymann, D. L., & Rodier, G. R. (1998). Global surveillance of communicable diseases. *Emerging Infectious Diseases, 4*, 362-365.
- Hill, G. W. (1982). Group versus individual performance. Are N+1 heads better than one? *Psychological Bulletin, 91*, 517-539.
- Hinsz, V. B., Tindale, R. S., & Vollrath, D. A. (1997). The emerging conceptualization of groups as information processors. *Psychological Bulletin, 121*, 43-64.
- Ho, L. (1998) The effects of individualism-collectivism on brainstorming: A comparison of Canadian and Taiwanese samples. Masters thesis, Concordia University.
- Holtgraves, T. (1997). Styles of language use: Individual and cultural variability in conversational indirectness. *Journal of Personality and Social Psychology, 73*, 624-637.
- Holtgraves, T. (2002). Language as social action: Social psychology and language use. Mahwah, NJ: Lawrence Erlbaum Associates.
- Huang, X., Van de Vliert, E. & Van der Vegt, G. (2005). Breaking the silence culture: Stimulation of participation and employee opinion withholding cross-nationally. *Management and Organization Review, 1*, 459-482.
- Hutchins, W. J. (1995). Machine translation: A brief history. In E. F. K. Koerner & R. E. Asher (Eds.) *Concise History of the Language Sciences: from the Sumerians to the Cognitivists* (pp. 431-445). Oxford: Pergamon Press.
- Hull, D. A., & Grefenstette, G. (1996). Querying across languages: A dictionary-based approach to multilingual information retrieval. *Proceedings of SIGIR 1996*.
- Jackson, M. H. & Poole, M. S. (2002). Idea generation in naturally occurring contexts: Complex appropriation of a simple group procedure. *Human Communication Research, 29*, 560-591.

- Joachims, T. (1998). Text categorization with support vector machines: Learning with many relevant features. *Proceedings of the European Conference on Machine Learning (ECML)*.
- Jones, P. W. (1990). UNESCO and the politics of global literacy. *Comparative Education Review*, *34*, 41-60.
- Kenny, D. A., Mannetti, L., Pierro, A., & Livi, S. (2002). The statistical analysis of data from small groups. *J. Personality and Social Psych.*, *83*, 126-137.
- Kim, Y-H., Chiu, C-Y., Peng, S., Cai, H., & Tov, W. (2008). Explaining East-West differences in the likelihood of making favorable self-evaluations: The role of evaluation apprehension and directness of expression. *Journal of Cross-Cultural Psychology*, *41*, 62-75.
- Kintsch, W. (1998). *Comprehension: A Paradigm for Cognition*. New York, NY: Cambridge University Press.
- Kintsch, W. (2001). Predication. *Cognitive Science*, *25*, 173-202.
- Kintsch, W. (2007). Meaning in context. In T. K. Landauer, D. S. McNamara, S. Dennis, & W. Kintsch (Eds.), *Handbook of Latent Semantic Analysis*. LEA.
- Kraut, R. E. (2003). Applying social psychological theory to the problems of group work. In J. Carroll (Ed.), *Theories in Human-Computer Interaction* (pp. 325-356). New York: Morgan-Kaufmann Publishers.
- Kraut, R. E., Fussell, S. R., & Siegel, J. (2003). Visual information as a conversational resource in collaborative physical tasks. *Human Computer Interaction*, *18*(1), 13-49.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York, NY: Cambridge University Press.
- Leshed, G., Perez, D., Hancock, J. H., Cosley, D., Birnholtz, J., Lee, S., McLeod, P. L., & Gay, G. (2009). Visualizing real-time language-based feedback on teamwork behavior in computer-mediated groups. *Proceedings of CHI 2009*.
- Leung, A. K-y., Maddux, W. W., Galinsky, A. D., & Chiu, C-y. (2008). Multicultural experience enhances creativity. *American Psychologist*, *63*, 169-181.
- Levine, J. M., & Moreland, R. L. (1990). Progress in small group research. *Annual Review of Psychology*, *41*, 585-634.
- Littell, R., Milliken, G. A., Stroup, W. W., & Wolfinger, R. D. (1996). *SAS system for mixed models*. SAS Inst.

Ma, W. & Chen, K. (2003). Introduction to CKIP Chinese word segmentation system for the first international Chinese word segmentation bakeoff. *Proceedings of the second SIGHAN workshop on Chinese language processing*.

Man, J. P., Weinkauff, J. G., Tsang, M., & Sin, D. D. (2004). Why do some countries publish more than others? An international comparison of research funding, English proficiency and publication output in highly ranked general medical journals. *European Journal of Epidemiology*, *19*, 811-817.

Marcus, A. (2001). International and intercultural user interfaces. In: Stephanidis, C. (Ed.), *User Interfaces for All: Concepts, Methods, and Tools* (pp. 47–63). Mahwah, NJ: Lawrence Erlbaum.

Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review*, *98*, 224-253.

Masuda, T., & Nisbett, R. E. (2001). Attending holistically versus analytically: Comparing the context sensitivity of Japanese and Americans. *Journal of Personality and Social Psychology*, *81*, 922-934.

Masuda, T., Ellsworth, P. C., Mesquita, B., Leu, J., Tanida, S., & van de Veerdonk, E. (2008). Placing the face in context: Cultural differences in the perception of facial emotion. *Journal of Personality and Social Psychology*, *94*, 365-381.

McGrath, J. E. (1984). *Groups: Interaction and Performance*. Englewood Cliffs, NJ: Prentice Hall.

McLeod, P. L., Lobel, S. A., & Cox JR., T. H. (1996), Ethnic diversity and creativity in small groups. *Small Group Research*, *27*, 248-264.

McNamara, T. P. (2005). *Semantic Priming: Perspectives from Memory and Word Recognition*. New York, NY: Psychology Press.

Mihalcea, R., & Leong, C. W. (2008). Toward communicating simple sentences using pictorial representations. *Machine Translation*, *22*, 153-173.

Morris, S. B., & DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychological Methods*, *7*, 105-125.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1999). The University of South Florida Word Association, Rhyme and Fragment Norms. <http://w3.usf.edu/FreeAssociation>.

- Nijstad, B. A., Stroebe, W., & Lodewijkx, F. M. (2002). Cognitive stimulation and interference in groups: Exposure effects in an idea generation task. *Journal of Experimental Social Psychology, 38*, 535-544.
- Nijstad, B. A., & Stroebe, W. (2006). How the group affects the mind: a cognitive model of idea generation in groups. *Pers. and Social Psych. Review, 10*, 186-213.
- Nisbett, R. E. & Masuda, T. (2003). Culture and point of view. *Proceedings of the National Academy of Sciences, 100*, 11163-11170.
- Nunamaker, J. F., Dennis, A. R., Valacich, J. S., Vogel, D. R., & George, J. F. (1991). Electronic meeting systems to support group work. *Communications of the ACM, 34*(7), 40-61.
- Olson, G. M., & Olson, J. S. (2000). Distance matters. *Human-Computer Interaction, 15*, 139-178.
- Osborn, A. (1957). *Applied Imagination*. NY: Scribner.
- Palmeri, T. J., & Gauthier, I. (2004). Visual object understanding. *Nature Reviews Neuroscience, 5*, 291-303.
- Papineni, K., Roukos, S., Ward, T., & Zhu, W-J. (2002). Bleu: A method for automatic evaluation of machine translation. *Proceedings of the 40th Annual Meeting of the Association for Computational Linguistics (ACL 2002)*.
- Parnes, S. J., & Meadow, A. (1959). Effects of “brainstorming” instructions on creative problem solving by trained and untrained subjects. *Journal of Educational Psychology, 50*, 171-176.
- Paulus, P. B., & Yang, H-C. (2000). Idea generation in groups: A basis for creativity in organizations. *Organizational Behavior and Human Decision Processes, 82*, 76-87.
- Paulus, P. B., & Brown, V. R. (2007). Toward more creative and innovative group idea generation: a cognitive-social-motivational perspective of brainstorming. *Soc. Personality Psych. Compass, 1*, 248-265.
- Peng, K., & Nisbett, R. E. (1999). Culture, dialectics, and reasoning about contradiction. *American Psychologist, 54*, 741-754.
- Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences, 27*.

- Potter, M. C., Kroll, J. F., Yachzel, B., Carpenter, E., & Sherman, J. (1986). Pictures in sentences: Understanding without words. *Journal of Experimental Psychology: General*, *115*, 281-294.
- Powell, R. G., & Andersen, J. (1994). Culture and classroom communication. In L. A. Samovar & R. E. Porter (Eds.), *Intercultural communication: A reader* (7th ed., pp. 322-331). Belmont, CA: Wadsworth.
- Raaijmakers, J.G.W., & Shiffrin, R.M. (1981). Search of associative memory. *Psych. Review*, *88*, 93-134.
- Romney, A. K., Moore, C. C., & Rusch, C. D. (1997). Cultural universals: Measuring the semantic structure of emotion terms in English and Japanese. *Proc. Natl. Acad. Sci.*, *94*, 5489-5494.
- Salomon, G., & Perkins, D. N. (1998). Individual and social aspects of learning. *Review of Research in Education*, *23*, 1-24.
- Salton, G., Wong, A., & Yang, C. S. (1975). A vector space model for automatic indexing. *Communications of the ACM*, *18*, 613-620.
- Sanchez-Burke, J., Lee, F., Choi, I., Nisbett, R., Zhao, S., & Koo, J. (2003). Conversing across cultures: East-West communication styles in work and nonwork contexts. *Journal of Personality and Social Psychology*, *85*, 363-372.
- Schmidt, R. (2002). Psychological mechanisms underlying second language fluency. *Studies in Second Language Acquisition*, *14*, 357-385.
- Setlock, L D., Fussell, S. R., & Neuwirth, C. (2004). Taking it out of context: collaborating within and across cultures in face-to-face settings and via instant messaging. *Proc. CSCW 2004* (pp. 604-613).
- Setlock, L. D. & Fussell, S. R. (2010). What's it worth to you? The costs and affordances of CMC tools to Asian and American users. *Proc. CSCW 2010* (pp. 341-350).
- Shen, S-T., Woolley, M., & Prior, S. (2006). Toward culture-centered design. *Interacting with Computers*, *16*, 820-852.
- Sproull, L., & Kiesler, S. (1986). Reducing social context cues: Electronic mail in organizational communications. *Management Science*, *32*, 1492-1512.
- Steyvers, M., Shiffrin, R. M., & Nelson, D. L. (2004). Word association spaces for predicting semantic similarity effects in episodic memory. In A. F. Healy (Ed.),

Experimental cognitive psychology and its applications: Festschrift in honor of Lyle Bourne, Walter Kintsch, and Thomas Landauer (pp. 237-249).

Stroebe, W., NIjstad, B. A., & Rietzschel, E. F. (2010). Beyond productivity loss in brainstorming groups: The evolution of a question. *Advances in Experimental Social Psychology*, *43*, 157-203.

Sutton, R. I., & Hargadon, A. (1996). Brainstorming groups in context: Effectiveness in a product design firm. *Administrative Science Quarterly*, *41*, 685-718.

Takano, Y. & Noda, A. (1993). A temporary decline of thinking ability during foreign language processing. *Journal of Cross-Cultural Psychology*, *24*, 445-462.

Takano, Y. & Noda, A. (1995). Interlanguage dissimilarity enhances the decline of thinking ability during foreign language processing. *Language Learning*, *45*, 657-681.

Thompson, L., & Fine, G. A. (1999). Socially shared cognition, affect and behavior: A review and integration. *Personality and Social Psychology Review*, *3*, 278-302.

Triandis, H. C. (1995). *Individualism and Collectivism*. Boulder, CO: Westview.

Veinott, E. S., Olson, J., Olson, G. M., & Fu, X. (1999). Video helps remote work: Speakers who need to negotiate common ground benefit from seeing each other. *Proceedings of CHI 1999* (pp. 302-309). NY: ACM Press.

Wang, H-C., Fussell, S. R., & Setlock, L. D. (2009). Cultural difference and adaptation of communication styles in computer-mediated group brainstorming. *Proc. CHI 2009* (pp. 669-678). NY: ACM Press.

Wang, H-C., Cosley, D., & Fussell, S. R. (2010). Idea Expander: Supporting group brainstorming with conversationally triggered visual thinking stimuli. *Proc. CSCW 2010* (pp. 103-106). NY: ACM Press.

Wang, H-C., & Fussell, S. R. (2010). Groups in groups: Conversational similarity in online multicultural multi-party brainstorming. *Proc. CSCW 2010* (pp. 351-360).

Wang, H-C., Rosé, C.P., Cue, Y., Chang, C-Y, Huang, C-C., & Li, T-Y. (2007). Thinking hard together: the long and short of collaborative idea generation in scientific inquiry. *Proceedings of Computer Supported Collaborative Learning 2007 (CSCL 2007)*.

Wang, H-C., Rosé, C.P., & Chang, C-Y. (2011). Agent-based dynamic support for learning from collaborative brainstorming in scientific inquiry. *International Journal of Computer-Supported Collaborative Learning (ijCSCL)*.

White, J.S., & O'Connell, T. (1994) The ARPA MT evaluation methodologies: Evolution, lessons, and future approaches. *Proceedings of the First Conference of the Association for Machine Translation in the Americas* (pp. 193-205).

Wickens, C. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*, 3, 159-177.

Witten, I. H., & Frank, E. (2005). *Data mining: Practical machine-learning tools and techniques*. Elsevier.

Woolgar, S. (1991). Configuring the user: The case of usability trials. in John Law (ed.) *A Sociology of Monsters: Essays on Power, Technology and Domination* (pp. 58-100), London: Routledge.

Haeberli, W., Cihlar, J., & Barry, R. G. (2000). Glacier monitoring within the global climate observing system. *Annals of Glaciology*, 31, 241-246.

Yamashita, N. & Ishida, T. (2006). Effects of machine translation on collaborative work. *Proceedings of CSCW 2006* (pp. 515-523). NY: ACM Press.

Yamashita, N., Inaba, R., Kuzuoka, H., & Ishida, T. (2009). Difficulties in establishing common ground in multiparty groups using machine translation. In *Proceedings of the 27th international Conference on Human Factors in Computing Systems* (pp. 679-688). NY: ACM.

Zhang, D., Lowry, P. B., Fu, X., Zhou, L., & Adipat, B. (2006). Cultural and media effects on group decision making under majority influence. *Proceedings of the 39th Hawaii International Conference on System Sciences (HICSS 2006)*.