Machine Translation vs. Common Language: Effects on Idea Exchange in Cross-Lingual Groups

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ABSTRACT

Diversity among members of international teams can be a valuable source of novel ideas. However, to reap these benefits, groups need to overcome communication barriers that stem from differences in members' native languages. We compare two strategies for overcoming these barriers: the use of English as a common language, and the use of machine translation (MT) tools that allow each person to communicate in his or her own native language. Dyads consisting of one English-speaking American and one native Mandarin-speaking Chinese participant exchanged ideas to perform brainstorming tasks, either through English or using MT. We found that MT helped the non-native English speakers produce ideas but that both native and non-native English speakers viewed MT-mediated messages as less comprehensible than English messages. The findings suggest it can be effective to support cross-lingual communication with asymmetric design, using MT technology to help people produce messages in their native languages, while leaving incoming messages untranslated and leveraging people's second language proficiency for comprehension.

Author Keywords

Machine translation; idea exchange; cross-lingual communication; computer-mediated communication

ACM Classification Keywords

H5.3 **[Group and Organization Interface]:** Computer-supported cooperative work

General Terms

Experimentation, Human Factors

INTRODUCTION

International groups perform various tasks that require idea generation, such as problem solving and design. Such teamwork can be found in numerous domains, such as the human genome project [4] and joint space exploration [5].

One important motivation for internationalizing work of this sort is the need to combine knowledge and expertise across cultures in order to diversify the knowledge accessible to groups and to better identify alternative ideas and solutions.

National and cultural diversity in global teams both provides benefits and creates obstacles. Diversity in concepts and ways of thinking can expand the knowledge base of a group and stimulate the generation of new ideas [28]. However, diversity in social norms, communicative styles, and languages spoken can be detrimental to communication. For tasks like problem solving and design, barriers in communication may interfere with the production and exchange of ideas, thereby eliminating the potential benefits of conceptual diversity for tasks.

Of the various constraints that can hamper idea exchange across nations and cultures, the language barrier is one that may be especially worth trying to overcome. Many global organizations have members who speak a wide variety of native languages [9][19]. People in these organizations have generally had training in the common language of the organization (often English), but they may have less than

Figure 1. Using machine translation to enable idea exchange between people using different native languages.

perfect proficiency that can negatively affect interpersonal and work processes [12][26]. Even when they are proficient, there is evidence that people find it cognitively taxing to communicate in a second language [24][25].

Technical work in natural language processing (NLP) suggests an alternative approach for bridging language gaps in international groups. Rather than making everyone use a common language, machine translation (MT) can be used to allow everyone to speak in his or her own native language. The integration of MT services and computer-mediated communication tools like instant messaging (IM) allows people to communicate, at least in principle, with others who speak different languages while producing and receiving messages in their native language (Figure 1).

However, as with second language use, MT imposes costs. Current MT services still sometimes produce erroneous translations or words unsuited to the communication context (e.g., by translating *computer bug* into the equivalent of *computer insect*), or by forming poor sentence compositions (e.g. by translating the Chinese sentence "还需要跟上海那边确认来不来得及," equivalent to "*Still need to confirm with the Shanghai side to see if there is enough time to make it*," into the English translation "*Need to keep Shanghai there confirm that I time*"). MT can make it difficult for group members to establish mutual knowledge or common ground [3], particularly when teams must refer to objects and entities in a workspace. As a result, studies have shown that when communication requires coming to agreement on objects of reference, using MT is less efficient than using a shared second language [29][30].

Previous comparisons of MT and second language use have focused primarily on overall outcomes of communication and collaborative work (e.g., agreeing on labels for objects). Less is known about which aspects of the communication process MT supports well or badly. For instance, MT might be differentially useful for message production versus comprehension. It may be easier for a native Mandarin speaker to produce "还需要跟上海那边确认来不来得及" than the English equivalent, but its translation could be very difficult to a native English speaking partner to understand.

A second unanswered question concerns the possible benefits of using one's native language in MT-mediated communication. Studies suggest native language use is more socially and cognitively advantageous than second language use [24][26]. However, it is unknown if *MT-enabled native language use* will also work well, because the advantages of using one's own native language use might be outweighed by the costs imposed by MT errors.

In this paper, we report results of a lab study comparing MT-enabled versus English language communication in conversations between native-English speaking Americans and native Mandarin speaking Chinese nationals. We ask people to perform a brainstorming task with a partner who speaks a different native language. This domain allows us to examine (a) whether using MT to enable native language use benefits idea production and comprehension for non-native English speakers, and (b) whether MT affects communication behaviors when the language used is unchanged but incoming messages are mediated by MT.

As we will show, MT influenced idea exchange for both Chinese and American participants. Allowing Chinese speakers to produce messages in their native language was indeed beneficial; they produced more new ideas when communicating in Chinese over MT than when using English. In addition, although American participants used English and produced similar numbers of ideas in both the MT and English-only conditions, MT changed the way they communicated. Americans were less talkative, producing fewer conversational turns and words, when using MT than when using English as a common language. Finally, Americans and Chinese participants saw MT as less comprehensible than English-mediated conversation.

These asymmetries between production and consumption, and between native and non-native speakers, advance current understandings of how MT affects teamwork and contribute to the design of cross-lingual communication that includes MT. Rather than seeing MT as categorically inferior to second language use, our results suggest that there are tradeoffs between MT-enabled and second language communication for certain processes and tasks. Understanding these tradeoffs can improve the design of CMC tools that leverage these asymmetries, interleaving MT and second language use to get the best of both worlds.

BACKGROUND

We begin by identifying two lines of research that are especially relevant to cross-lingual communication: one showing the costs of using a non-native common language to communicate, and the other revealing the detrimental effects of MT on the development of shared knowledge in groups. Neither of these lines of work has directly addressed using MT to enable idea exchange in multilingual groups. We review this literature to develop specific hypotheses for MT-mediated versus second language use in idea exchange and test them in the current study.

Costs of Using Non-Native Common Languages

People from different cultural backgrounds often speak different native languages. Global organizations often solve this problem by requiring people to speak a common language (e.g., English), but this may disadvantage group members who speak a different native language as well as negatively impact group work.

This is because second language use imposes communicative inefficiencies and cognitive costs. Because second language speakers tend to have more limited linguistic resources (e.g., constrained vocabulary size), they often have to use more complex communication strategies such as rephrasing or repeating previous utterances to bridge the gap between their second language proficiency

and their communicative intentions [7]. The extra effort required to manage these more complex strategies appears to decrease the cognitive resources people have available. Studies show that expressing messages in a second language leads to worse performance in a parallel problem-solving task [24][25]. Misunderstandings in communication caused by second language use can also lead to long-term consequences for group work, including reduced trust [13] and poorer interpersonal relationships at work [2][6].

Taking the communicative and cognitive constraints that second language use imposes, using a non-native common language such as English thus may not be ideal for international cross-lingual communication.

Effects of Machine Translation on Communication

The increasing availability of MT tools such as Google Translate (http://translate.google.com) makes it important to evaluate and assess the benefits and constraints of MT-mediated communication. In general, studies to date have shown that translation errors can hinder communication, especially when establishing joint understanding is key to the success of the task [14][29][30].

Yamashita and colleagues looked at Chinese-Japanese dyads using MT to collaborate on figure-matching tasks. 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"). Compared to using English as a common language, participants using MT couldn't efficiently use language to refer to the tangram objects or to understand others' referring expressions. MT mediation required participants to use longer sentences to accomplish their communication needs, even after multiple trials with the same objects, suggesting that people had difficulty establishing shared understanding over MT [29]. This is even more difficult in multiparty communication (e.g., three-person groups consisting of Chinese, Japanese, and Korean participants) [30] because translation errors and inconsistencies across multiple language pairs make it challenging for people to trace the status of understanding of other people, exacerbating communication problems.

Production and Comprehension in Cross-Lingual Communication

Using a common language or using MT are two readily available options for cross-lingual communication if we do not consider options that involve a third person (e.g., manual translation) for reasons of cost and privacy.

The two options pose different tradeoffs. Using a non-native common language may make it harder to produce and share ideas to others and more cognitively taxing to think. Using MT, on the other hand, may hinder comprehension. Translation problems can make it hard for people to accurately understand what their partners mean and to repair misunderstandings. However, using MT

requires no second language proficiency, and may possibly avoid at least some of the costs of non-native language use.

Thus, MT—at least at its current level of sophistication—is most useful when reducing the cognitive costs of producing ideas is more valuable than the cost of misunderstandings. Determining this requires not just attention to overall outcomes, but to considering production and consumption separately. Previous studies used tasks that rely on referring expressions to align the perspectives of participants and achieve a well-defined solution (e.g., [29][30]). In such tasks, meaningful units of analysis are sequences of conversational turns (e.g., questioning-answering pairs) rather than individual utterances, and thus it is less feasible to use these tasks for the purpose of looking at aspects of production and comprehension separately.

THE CURRENT STUDY

To allow studying both the production and comprehension of messages, we chose to study the effects of MT on cross-lingual brainstorming groups. Group brainstorming tasks require groups to generate as many new ideas as possible [21][23]. Because the goal is ideational productivity, brainstorming tasks provide a natural driving force for group members to produce messages that externalize their ideas. The ideas shared by other group members may have a beneficial stimulation effect, helping people retrieve rare concepts from memory and think of ideas that they may not have generated alone [23][28]. Overall, idea exchange activities between group members, including both processes of production and comprehension, are central to group brainstorming. This makes group brainstorming an ideal task for our research purpose, because production and comprehension can be measured separately at the individual level through a combination of observed idea generation and questionnaires about comprehensibility.

Design of the Study

We asked American-Chinese dyads to brainstorm either in their native languages over MT (MT-mediated groups) or in English as a common language (English-mediated groups). The study recruited Chinese participants with Mandarin as their native language but who were also fluent or nearly fluent in English as a second language, possessing the proficiency for using English to communicate. From a participant-centric point of view, there is an asymmetry in language processing over these two types of mediation. Table 1 shows the modes of language processing (language for producing and consuming ideas) for American and Chinese participants under different mediation conditions.

American participants read and type in their native language in both English- and MT-mediated groups. However, Chinese participants read and type in a second language (English) over English mediation and in their native language (Chinese) when using MT. Using different types of mediation thus implies a greater change in language processing modes for Chinese participants.

Table 1. Modes of language processing for American and Chinese over English- and MT-mediated communication.

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

In this asymmetric configuration, comparing Chinese participants' behaviors and perceptions in MT-mediated versus English-mediated groups can reveal the effects of MT-enabled native language use on idea production and comprehension. Similarly, because American participants use their native language in both conditions, the difference between conditions is that MT mediation can affect the quality of incoming messages. Thus, we can examine how MT influences idea production and comprehension independently from native versus second language use.

Hypotheses
Based on the literature and the issues we discussed earlier, we pose a number of hypotheses. First, for the Chinese participants, who will produce and receive messages in Mandarin in the MT condition vs. English as the common language, we predict:

H1: Chinese participants will generate more ideas during brainstorming when using MT than when using English as a common language. Although poorly translated messages may be a burden, the benefit of being able to express ideas in one's native language may compensate for the cost. In other words, MT-enabled native language use will lead to higher idea productivity than second language use.

H2: Chinese participants will consider messages exchanged in MT-mediated groups to be less comprehensible than those exchanged in English-mediated groups due to translation problems introduced by MT. That is, MT-enabled native language use will lead to poorer comprehension because the cost of translation errors will outweigh the benefit of receiving messages in one's native language.

For American participants, who will produce and receive messages in English in both conditions, we predict:

H3: American participants will generate fewer ideas in MT-mediated groups than in English-mediated groups. This is because American participants won't receive the benefit of native language use in MT-mediated groups. However, receiving translated messages may require more effort to process and lead to lower idea productivity.

H4: American participants will consider messages exchanged less comprehensible in MT-mediated than in English-mediated groups because of translation errors.

METHOD
Two-person groups consisting of one American participant with English as a native language and one Chinese participant with Mandarin as a native language performed group brainstorming using a text-based instant messaging (IM) chat client. Each dyad was assigned to one of two conditions: using MT to communicate (*MT-mediation*) or using English to communicate (*English-mediation*). The dyads performed two structurally similar brainstorming tasks, to allow for better generalization to different brainstorming topics. The task order was counterbalanced.

For MT-mediation groups, participants typed messages in their own native languages (English or Chinese), with the IM server translating the messages using Google Translate and displaying the messages in their partners' chat windows in the partner's native language. Google Translate was accessed through the API during the period of time of the study (February to April 2011). For English-mediation groups, participants typed and saw all messages in English.

Procedure
Participants were brought to two separate rooms and instructed about the brainstorming topics and provided with four conventional brainstorming rules: (a) the more ideas the better; (b) the wilder the ideas the better; (c) combination and improvement of ideas is better; and (d) avoid evaluating others' ideas [21]. They were instructed to brainstorm with their partners over a text chat. They were not informed about their partner's identity or background. Groups brainstormed for 15 minutes for each task.

Participants
Participants consisted of 64 students (70% female) from a large U.S. university and the surrounding community. Half were self-identified Americans who had lived in the U.S. or Canada for more than 10 years and spoke English as their native language. The other half were self-identified Chinese who spoke Mandarin as their native language but who were fluent or near-fluent in English. Although the Chinese participants were all currently studying or working in the U.S., the majority had grown up in China (97%) and been in the U.S. for less than 2 years (77%). Note that although some degree of bilingual ability is common in the multilingual organizations we aim to support, the time spent in the U.S. means that this population might have better English skills than other native Chinese speakers. This works against our hypotheses that MT will affect message production and comprehension, thus creating a conservative test of the hypotheses.

Participants were randomly assigned to brainstorming groups and experimental conditions. All groups were dyads, consisting of one American participant and one Chinese participant. In total, there were 32 two-person groups (17 MT-mediated groups and 15 English-mediated groups).

Tasks
Teams performed two brainstorming tasks of equivalent difficulty. The "extra thumb" and the "extra eye" questions,

which have been used in many studies [27][28], ask participants to brainstorm 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.

Measures

Our key dependent measures were the productivity of ideation (H1 and H3) and the comprehension of messages (H2 and H4). To enable an exploratory analysis looking at how type of mediation influences message production overall, we also measured talkativeness during the tasks.

Because the study involved Chinese participants typing in Chinese in the MT-mediated groups, not all conversational data was in English. To enable analyses and comparisons of outcomes across conditions, a Chinese-English bilingual translator manually translated the Chinese utterances into English. A second bilingual speaker read the original Chinese inputs and corresponding translations and decided that the overall translation quality was satisfactory. This allowed further English-based data coding and analyses.

Productivity

To measure productivity, we adopted a two-level coding strategy proposed in a previous study [28]. At the first level, coders classified whether each conversational turn contained an idea or not. Turns coded as containing an idea were then coded as either duplicates (minor variations of an idea already contributed) or having originality (ideas not yet proposed in the session).

To assess intercoder reliability, two coders independently coded sample conversations from six randomly selected groups, accounting for 19% of the data. Inter-coder agreement was very good at the level of whether or not there was an idea present (Cohen's Kappa=.82) and satisfactory at the second level of whether the idea was novel (Cohen's Kappa=.63). One useful criterion for interpreting Kappa considers Kappa values between .61 and .80 substantial, and above .81 almost perfect [8][16]. Thus we used the number of turns coded as containing original ideas as a measure of productivity.

Comprehensibility

To assess the general comprehensibility of messages in each condition, we asked participants to answer three questions after each brainstorming trial: "I could understand other members' ideas", "I am confident that other group members understood my ideas", and "I didn't understand what other group members said". Ratings of the three items using 7-point Likert scales were averaged as a single measure (Cronbach's alpha=.89).

Talkativeness

There are two straightforward measures for talkativeness during brainstorming: the number of words typed and the number of chat turns generated. Because our analytical strategy of manually translating Chinese utterances into English for the purpose of data coding might distort counts of the number of "words", we looked at both the number of

turns and the number of words in our analysis for ensuring the reliability of behavioral patterns observed.

RESULTS

The units of analysis were individuals, because the hypotheses concerned how MT influences individuals' production and comprehension. However, because they worked in dyads, we used mixed model ANOVAs to account for possible interdependencies caused by repeated measures or social influences between group members [15]. This type of mixed model adjusts the estimation of variance and typically provides more conservative results. Note that in mixed models, it is standard to estimate degrees of freedom by using Satterthwaite's approximation. Non-integer degree of freedom results may occur (see [18]).

Our basic analytical model, which we used across multiple dependent measures, treated brainstorming task, individual, and group as random variables. Brainstorming task was nested within participant, and participant was nested within group. Linguistic background (American or Chinese), type of mediation (MT or English), and brainstorming trial (first or second) were independent fixed variables.

Productivity

To test H1 and H3, we conducted a mixed model ANOVA using the number of original ideas as the dependent variable. Figure 2 shows idea productivity by American and Chinese participants in MT- and English-mediated groups.

Overall, there was a main effect of linguistic background: American participants produced more original ideas than Chinese participants ($F[1,30]=8.7$, $p<.01$). This difference may involve different communication styles, such as Chinese participants adopting a relatively "high-context" style and thus verbalizing fewer ideas [10]. However, this line of inquiry is not directly relevant to our hypotheses.

There was a marginal effect of brainstorming trial, where people tended to produce more ideas during the second trial than the first ($F[1,60]=3.3$, $p<.1$). There was also an interaction effect between trial and type of mediation ($F[1,60]=4$, $p<.05$). Participants in MT-mediated groups
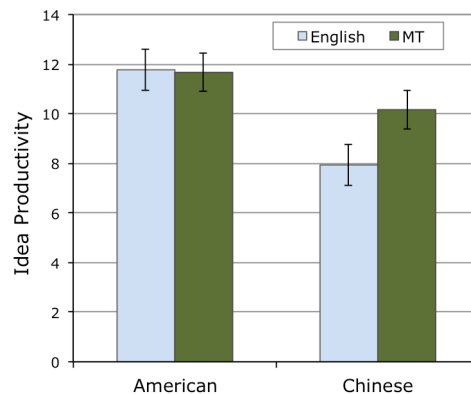

Figure 2. Idea productivity by Americans and Chinese in MT- and English-mediated groups.

produced more ideas in the second trial ($F[1,60]=7.8$, $p<.01$), while participants in English-mediated groups did not differ in idea productivity across trials ($F[1,60]=.01$, $n.s.$). There were no other main or interaction effects.

We then took a deeper look to test H1, which asked whether MT-enabled native language use was beneficial to idea production. A contrast analysis focusing on Chinese participants' productivity showed that there was a trend for Chinese participants in MT-mediated groups to produce more original ideas than those working in English-mediated groups (see Figure 2; $F[1,59.3]=2.6$, $p=.1$). This effect of native language was significant in the second brainstorming trial. A further contrast analysis showed that Chinese participants in MT-mediated groups produced significantly more original ideas than those in English-mediated groups in the second trial (first trial: $F[1,96.4]=.3$, $n.s.$; second trial: $F[1,96.4]=5$, $p<.05$). Thus there is some evidence in support of H1: there was benefit to expressing ideas in one's native language compared to a non-native language.

We also looked at whether MT, without the benefit of native language use (i.e., for English speakers), was detrimental to idea production. A contrast analysis focusing on American participants' productivity showed no difference between American participants generating ideas using MT or using English ($F[1,59.3]=.004$, $n.s.$). The effect of MT on American participants' productivity was uniform across brainstorming trials (first trial: $F[1,96.4]=.5$, $n.s.$; second trial: $F[1,96.4]=.2$, $n.s.$). H3 was thus not supported. Receiving machine-translated messages did not reduce productivity for native language speakers.

Comprehensibility
To test hypotheses H2 and H4, we conducted a mixed model ANOVA using ratings of comprehensibility as the dependent variable. Figure 3 shows perceived comprehensibility by American and Chinese participants in MT- and English-mediated groups.

Again, there was a main effect of linguistic background: Chinese participants in general rated comprehensibility higher than American participants ($F[1,60]=37.1$, $p<.0001$).
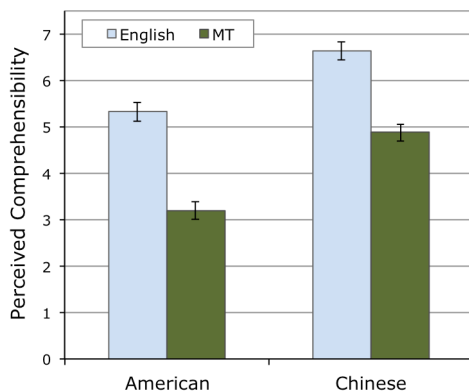

Figure 3. Perceived message comprehensibility by Americans and Chinese in MT- and English-mediated groups.

As messages received by American participants were either English messages produced by second language speakers (Chinese) or translated by MT, one possibility is that there is a large gap between the quality of these messages and Americans' proficiency, leading to lower comprehensibility ratings from Americans. However, this difference may also involve cultural styles of responding to surveys [11] and is not our main focus in this analysis.

What is relevant is the main effect of MT mediation. Participants rated English-mediated messages easier to understand than MT-mediated messages, regardless of their linguistic backgrounds ($F[1,60]=61.9$, $p<.0001$). There was no interaction effect between mediation and linguistic background ($F[1,60]=.5$, $n.s.$), and no main or interaction effects associated with brainstorming trial (all Fs < 1).

To test H2, a contrast analysis focusing on Chinese participants' ratings showed that Chinese participants in MT-mediated groups rated messages as less compre-hensible than Chinese participants in English-mediated groups ($F[1,60]=25.4$, $p<.0001$). The effect of MT was uniform across brainstorming trials. It was more difficult to understand machine-translated messages than English-mediated messages even though translations were in one's native language. MT-enabled native language use reduced perceived comprehensibility, supporting H2.

A contrast analysis focusing on American participants showed that MT also negatively influenced American participants' ratings of message comprehensibility ($F[1,60]=37$, $p<.0001$). The pattern was consistent across brainstorming trials. H4 was thus supported.

Exploratory Analyses of Production Behaviors
In our analyses of productivity, we found that MT-enabled communication was beneficial for participants for whom English was not a native language; at the same time, MT had no negative consequences on the productivity of native English speakers. Thus it appears that there is value to use MT to mediate intercultural idea exchange.

However, the analyses of comprehensibility reveal that messages mediated by MT were less comprehensible than those mediated by English, for both American and Chinese participants (H2 and H4 supported). Whether or not the incoming messages are in one's native language does not appear to be a problem for comprehension, whereas less than perfect translations can have a significant negative impact on people's understanding of messages.

When combining these two sets of findings, it remains unclear whether and how disrupted translation influences the process of message production. Poor translation did not affect task performance (idea productivity), but how do people handle incoming messages when they are difficult to understand? What is the impact of people's perceptions of incomprehensibility on their production behaviors?
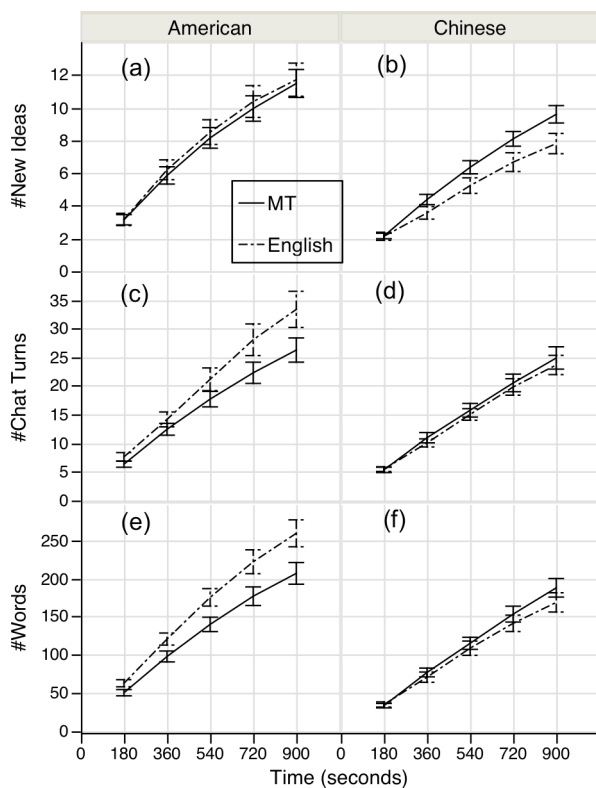
Figure 4. Production behaviors (idea productivity and talkativeness) over time.

To explore this issue, we looked at participants' patterns of production over time during the brainstorming session. Figure 4 shows several production measures over time, including the accumulated numbers of original ideas (Figure 4a and 4b), chat turns (Figure 4c and 4d), and words (Figure 4e and 4f). The time-based graphs allow us to see the consistency of production behaviors and whether people adapt their behaviors at different phases of interaction. Overall, people's production behaviors appear to be consistent over time in all conditions, thus it is safe to focus on behaviors assessed at the end of sessions.

Figure 4a and 4b visually confirm what we learned from the earlier analyses of productivity. MT enhanced idea productivity when it enabled native language use and did not harm productivity for native English speakers.

However, it did affect their talkativeness. In Figure 4c and 4e, American participants in MT-mediated groups appeared to be less talkative, producing fewer chat turns and words, than Americans in English-mediated groups. Mixed model ANOVAs using numbers of words and turns measured at the end of sessions (900 seconds) as dependent variables confirmed this observation. There was a trend that American participants tended to produce fewer turns over MT mediation than with English ($F[1,50.4]=2.6$, $p=.1$). American participants also produced fewer total words total over MT mediation than with English ($F[1,58.9]=3.92$, $p<.05$). Brainstorming trial did not change this pattern.

In contrast to Americans' decreased talkativeness over MT, Chinese participants in MT-mediated and English-mediated groups did not differ in their numbers of chat turns ($F[1,50.4]=.08$, *n.s.*) or words ($F[1,58,9]=.5$, *n.s.*). This can be seen in Figure 4d and Figure 4f.

These patterns provide further information about how disrupted translation subsequently influences one's own production behaviors. When the language used is kept constant, it appears that the influence of MT is more on communication style (talkativeness) rather than on performance (idea productivity). In other words, in MT-mediated communication American participants may have developed ways of communicating differently from what they do in regular English-based conversation. We will discuss this finding and its implications next.

DISCUSSSION

We examined the influence of MT-mediated versus English communication in brainstorming conversations between native English speaking Americans and native Mandarin speaking Chinese. Measures of production behaviors and perceptions of comprehensibility give a clearer picture of the benefits and drawbacks of using MT for idea exchange.

One important message is that MT tends to support cross-lingual groups by enabling people to produce ideas in their native language. Previous studies evaluating MT-mediated communication primarily focused on how translation problems affect certain holistic measures of communication (e.g., the process of grounding) [29]. The current study identifies that the effects of MT on production and comprehension are *asymmetrical*. Although both this study and previous work show that MT lowers comprehensibility of messages, it can boost idea productivity through native language use, as supported by the trend of Chinese participants' increasing ideation performance in this study.

The study also shows that the benefit of MT-enabled native language on productivity is particularly prominent in the second brainstorming trial, which may suggest that prior experience of collaborating over MT (e.g., the first trial) can help people better benefit from MT-enabled native language use for idea production. Learning and the development of coping strategies may be involved in this process. Future work looking into this issue may help further reveal the value and cost of MT-enabled native language use and suggest ways to improve MT technology.

The results demonstrate the practical value of using MT to mediate cross-lingual idea exchange, in that machine-translated messages at least did not negatively influence American participants' ideation performance. Although previous work found that MT can hamper group work that requires the establishment of common ground [29], one practical implication derived from the current study is that current MT may be more useful for tasks that focus more on productive expression of ideas than on the alignment of perspectives among group members.

Re-Coupling Production and Comprehension

Although brainstorming tasks permit us to analytically decouple production and comprehension of ideas for the purposes of testing our hypotheses, group brainstorming is still a group activity that requires members to communicate their ideas to one another. Theoretical models and studies show that interaction in groups can influence one's own thinking and behaviors [17][23]. Therefore, it is reasonable to think that errors in machine-translated messages may still impact aspects of production behaviors, even if idea productivity stays at the same level.

The exploratory analysis shown in Figure 4 suggests that translation quality influences communication style rather than performance. Americans' decreased talkativeness over MT may be a result of a different conversational process or strategy for handling translation errors. The following excerpt shows a scenario in which machine-translated messages triggered the American to seek clarification.

Chinese: But I do not think a better force.
                   *(*original: 但是我觉得不会更好用力.
                   manual translation: *But I think it won't be easier to exert force.)*

American: huh?

Chinese: But I think even more advantages.
                   *(*original: 但是我觉得好处更多.
                   manual translation: *But I think there are a lot of advantages too.)*

American: than disadvantages?

The need to ask questions to repair understanding may change the priority of various types of conversational moves that people may take in brainstorming such as elaboration of ideas and socialization (see [27] for a coding scheme). This in turn may influence other social outcomes in groups, such as attribution and trust. Future research is needed to look at how the use of MT affects communication styles and shapes social outcomes in group work.

It will also be interesting to take a deeper look at the difference between comprehending messages in a second language versus translated by MT. Either second language mediation or MT mediation can hinder comprehension and production, but possibly through very different mechanisms. Studies with more careful controls of message content and level of comprehension of the content can help us understand the difference. Deliberately degrading the comprehensibility of messages to varying degrees can be another possible approach to explicitly study how comprehension affects production.

Transforming MT-Mediated Idea Exchange

Although receiving machine-translated messages did not reduce overall task performance, it appears that people might not be able to engage in efficient idea exchange over MT and perform brainstorming in a synergistic sense. As

the conversational episode just shows, translation problems can distract people from effective idea exchange.

One possible way to increase the value of MT for idea exchange is the theoretical perspective of "word-based priming". From this perspective, poorly translated messages may still be cognitively stimulating and helpful because they contain keywords useful for triggering concepts and facilitating memory retrieval [1][20]. This "word-as-prime" or "word-as-retrieval-cue" theoretical approach also underlies certain theories of conversation [22] and group brainstorming [23], positing that unconscious cognitive processing is important for language use and idea generation.

To increase the benefits of MT, it might also be possible to change the presentation of translated messages, such as highlighting key words while de-emphasizing function words and syntactical errors, in order to promote the unconscious aspects of cognitive processing.

Asymmetry for Cross-Lingual Communication Design

The study also has implications for the design of cross-lingual communication tools that go beyond idea exchange. The fact that MT-enabled native language use releases one language constraint (production) but not another (comprehension) suggests a divide-and-conquer strategy, dealing with needs of production and comprehension separately by leveraging different technical or social mechanisms.

For example, we might redesign our setting, preserving the MT-enabled native language use component while reducing the translation part. For Chinese participants capable of using English as a second language, requiring them to both type and read ideas in Chinese over MT is not the only option. People might express ideas in their native language, with the system only translating bilingual Chinese speakers' ideas to English, leaving native English speakers' ideas untranslated. This design may better match the language skills of different cultures, allowing people to receive the benefit of producing ideas in their own native languages while avoiding comprehension problems introduced by MT.

Limitations of the Current Study

One consideration for future study is that Chinese participants' English proficiency may interact with type of mediation—MT may be more helpful to both non-native speakers and their partners when English fluency is low. In this study, Chinese participants identified themselves as fluent or nearly fluent English speakers, and were randomly assigned to groups. Thus, individual difference in English proficiency is unlikely to influence our results. However, to further understand the role of second language skills in cross-lingual communication, explicit measurement and control of linguistic proficiency is needed.

The current study also only looks at Chinese-American dyads where English is the designated common language. To generalize the results, it will be beneficial to look at

Chinese-American dyads where Chinese becomes the common language, and other types of cross-lingual dyads that involve other languages.

For simplicity and generalizability, the current work does not control for individual differences. Future studies may benefit from controlling certain variables, such as language proficiency and familiarity with MT, to obtain clearer patterns of the effects of MT.

CONCLUSION

This paper presents a laboratory study looking at tradeoffs around MT-enabled native language use for cross-lingual idea exchange. The design of the study allows us to explore the benefits and constraints imposed by MT in group communication. Results show that MT tends to be beneficial rather than detrimental for idea production when it enables people to speak their own native language. However, machine-generated translations hinder comprehension. The work provides a fresh understanding of the roles of MT on cross-lingual idea exchange, with two main contributions. First is the finding that MT-enabled native language use tends to increase productivity in divergence-oriented domains. Second is the observation that MT has effects on production and comprehension asymmetrically. Our findings suggest that the classic view that MT obstructs teamwork is too coarse and that more study of the processes by which MT affects teamwork are needed. We also believe that applying these insights may lead to the design of CSCW tools that leverage these asymmetries to support idea exchange in particular and cross-lingual communication in general.

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REFERENCES

1. Bargh, J. A. & Chartrand, T. L. (1999). The unbearable automaticity of being. *Amer. Psychologist*, *54*, 462–479.

2. Chevrier, S. (2003). Cross-cultural management in multinational project groups. *J. World Business*, *38*.

3. Clark, H. H. (1996). *Using Language*. Cambridge Press.

4. Collins, F. S., Morgan, M., & Patrinos, A. (2003). The human genome project: Lessons from large-scale biology. *Science*, *300*, 286–290.

5. Culhane, J. L., & Worms, J. C. (2001). Improving the effectiveness of international collaboration in space science. *Space Policy*, *17*, 179–186.

6. DiStefano, J. J. & Maznevski, M. L. (2000). Creating value with diverse teams in global management. *Organizational Dynamics*, *29*, 45–61.

7. Dornyei, Z., & Scott, M. L. (1997). Communication strategies in a second language: Definitions and taxonomies. *Language Learning*, *47*, 173–210.

8. Everitt, B. (1996). *Making sense of statistics in psychology: A second-level course*. Oxford Univ. Press.

9. Frederiksson, R., Barnr-Rasmussen, W., & Piekkari, R. (2006). The multinational corporation as a multilingual organization: The notion of a common corporate language. *Corporate Communications, 11*, 406–423.

10. Hall, E. (1976). *Beyond Culture*. New York, NY: Doubleday/Anchor Books.

11. Hamamura, T., Heine, S. J., & Paulhus, D. L. (2008). Cultural differences in response styles: The role of dialectical thinking. *Personality and Individual Differences*, *44*, 932–942.

12. Harzing, A-W., & Feely, A. J. (2008). The language barrier and its implications for HQ-subsidiary relationships. *Cross Cultural Management, 15,* 49–61.

13. Henderson, J. K. (2005). Language diversity in international management teams. *International Studies of Management and Organization*, *35*, 66–82.

14. Jiang, H. & Singley, K. (2009). Exploring bilingual, task-oriented, document-centric text. *Proceedings of Group 2009* (pp. 229–232). NY: ACM Press.

15. 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.

16. Landis, J. R. & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*, 159–174.

17. Levine, J. M., & Moreland, R. L. (1990). Progress in small group research. *Annual Rev. Psych.*, *41*, 585–634.

18. Littell, R., Milliken, G. A., Stroup, W. W., & Wolfinger, R. D. (1996). *SAS system for mixed models*. SAS Inst.

19. Luo, Y. & Shenkar, O. (2006). The multinational corporation as a multilingual community: Language and organization in a global context. *Journal of International Business Studies, 37*, 321–339.

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

21. Osborn, A. (1957). *Applied Imagination*. NY: Scribner.

22. Pickering, M. J., & Garrod, S. (2004). Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences*, *27*.

23. 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.

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

25. Takano, Y. & Noda, A. (1995). Interlanguage dissimilarity enhances the decline of thinking ability during foreign language processing. *Lang. Learn.*, *45*, 657–681.

26. Tange, H. & Lauring, J. (2009). Language management and social interaction within the multilingual workplace. *Journal of Communication Management*, *13*, 218–232.

27. 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.

28. Wang, H-C., Fussell, S. R., & Cosley, D. (2011). From diversity to creativity: Stimulating group brainstorming with cultural differences and conversationally-retrieved pictures. *Proc. CSCW 2011* (pp. 265–274).

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

30. Yamashita, N., Inaba, R., Kuzuoka, H., & Ishida, T. (2009). Difficulties in establishing common ground in multiparty groups using machine translation. In *Proc. CHI 2009* (pp. 679–688). NY: ACM.