Non-verbal human communication under varying levels of restrictions:

An empirical and computational investigation of *Password* and *Gasekitomu* games

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(in alphabetical order)

ABSTRACT
In this study we have investigated the effects of similarities in cultural backgrounds on the ability of human beings to communicate in a context-less, syntax-free environment in the presence of varying levels of restrictions. We observe that several idiosyncratic tools, like prosody and facial expressions, often help in conveying information. However, as these tools are commonly culture/language specific, we hypothesize that similarities in cultural background might lead to more successful communication between people when usage of "standard" tools are restricted. We empirically test this hypothesis by observing human subjects play two communication games, one of which was devised by us specifically for the purpose. We find that under severe restrictions, people with similar cultural backgrounds are better able to communicate with each other as compared to those with different cultural backgrounds. We also developed a computational model for analyzing one of the games and compare and contrast the results of the simulations with those of the experiments. Finally, we discuss the various types of clues and strategies that can be used by the subjects under the conditions of one of the games.

1. **INTRODUCTION**

Communication is defined as "a process by which information is exchanged between individuals through a common system of symbols, signs, or behavior" (Merriam-Webster online dictionary). Thus, communication studies focus on communication forms, processes and meanings, including speech, gestures etc. In human beings, language happens to be the primary mode of communication and can be defined as a system of finite arbitrary symbols combined according to rules of grammar for the purpose of communication. The use of language to pass on information across space and time has played a great role in the development and sustenance of human civilization. Individual languages use specific sounds, gestures and other symbols to represent objects, concepts, emotions, ideas, and thoughts. The components of language can be broadly divided into two categories, namely standardized and non-standardized.

Standardized tools, for the purpose of this discussion, refer to all those components of a language that are more or less codified/set down, e.g. phonetics, phonology, morphology, semantics and syntax. These components together form the distinguishing features of a language and are used universally by all speakers of that language. On the other hand, non-standardized tools refer to those components of a language that are non-codified and yet can often play a significant role in conveying/receiving information. Examples of these kinds of tools include prosody, uncommon gestures, body language, word associations, use of shared background information etc. Some of these tools form a part of the so-called paralanguage, which describes the non-verbal elements of communication including gestures, kinesics, facial expressions, pitch, volume and intonation. However, since these tools are variable in nature, their successful usage in sending/receiving correct information depends vitally on whether both parties are equally knowledgeable about their meaning. People who share the same cultural/linguistic background are expected to be more knowledgeable about the exact meanings of such idiosyncratic components in the context of that particular culture, than those who belong to different cultures. However, lack of knowledge of these non-standardized tools hardly present a barrier in communication under normal circumstances, as the standardized tools are versatile enough for unambiguous representation of most communicable information.

But, what happens when there are severe restrictions on the usage of standardized tools and common universal gestures? Such restrictions might arise, *inter alia*, due to medical disorders like aphemia where there is "isolated loss of the ability to articulate words without loss of the ability to write and to comprehend spoken language (Albert *et al*, *Clinical Aspects of Dysphasia*, SpringerVerlag, 1981)". How can one communicate under such scenarios? Naively speaking, one would expect that the non-standardized tools would now play a much more important role in successful communication. If that is the case, then are people with similar cultural backgrounds better able to communicate with each other? What is the relative role of cultural background in determining successful communication in the presence of varying levels of restrictions? We decided to investigate these questions by judging the performance of human subjects in playing two communication games, namely the *Password* game and the *Gasekitomu* game. We also formulated a network-based computational model to simulate such restrictive scenarios and investigated how various parameters of the model affected successful communication.

2. THE GAMES

2.1 Password Game

The *Password* Game we worked with, was a modified version of the 1961-67 Columbia Broadcasting System (CBS) TV show of the same name (see http://www.tv.com/password/show/1133/summary.html&full_summary=1 for a summary of the original show). In our version, each game is played between two players. One member of the pair (sender) is supplied with a word (target) by the experimenter. Only common nouns are used as targets, a fact that is made known to the subjects *a priori* (see Table 1 for list of words used). The sender is expected to communicate the target to his/her partner within 180 seconds by giving out related words as clues. The clues offered by the sender are restricted to nouns (including gerunds and infinitives) with the exception of proper nouns. However, homophones (e.g. *arc* as a clue for *ark*) and compound words containing the target (e.g. *lighthouse* as a clue for *light*) are not allowed. On receiving the clue, the receiver puts forth a guess that is rated by the sender as "close" or "far". The sender then gives the next clue and the game continues till the receiver guesses the target correctly or the stipulated time is up. To exclude extra hints, no speech or gestures are allowed and all communications from both sides are put on paper. Thus this game tests the ability of the players to communicate in the absence of syntax and gestures when meaningful words are given as clues. Each pair plays the game six times with the participants alternating in their roles as sender and receiver.

2.2 Gasekitomu Game

We devised this game during this workshop for the purpose of investigating the ability of human beings to communicate non-syntactically in the absence of meaningful words as clues. In this game, the sender is expected to communicate a common noun to the receiver within a stipulated time of 15 minutes. However, here the sender can only use a set of five pre-agreed nonsense syllables (namely, *Ga, Se, Ki, To* and *Mu*) for constructing the clues. There is no restriction on the order or the number of times a particular syllable can be used in a given clue by the sender. All clues are communicated orally and modulations of voice and tone (prosody) are permitted. Facial expressions are allowed in this game but hand gestures are not. On hearing the signal, the receiver makes a guess, which is judged by the sender as "close" or "far" as per his/her own discretion. The sender then gives another clue and the game continues till the receiver guesses the target or the end of the stipulated time, whichever is earlier. The participants alternate in their roles as sender and receiver and there are a total of four trials per pair.

3. METHODS

3.1 Experiments

This study was conducted on twenty-four subjects from the pool of Complex Systems Summer School 2005 (Beijing) participants. All participants were well educated and belonged to the age group of 20-40. Participation to the study was voluntary and no remuneration of any kind was paid to the participants.

Since the main question to be tested was whether people who have the same culture/language do better at restrictive non-syntactic communication, we needed detailed information on cultural/linguistic backgrounds of the participants. For this, all participants were required to fill in a questionnaire concerned with their cultural backgrounds and linguistic abilities. We then formed pairs based on the first language of the participants. The teams were always announced at a short notice and the participants were requested not to discuss with their partners before the game. All experiments took place in big, well-lit and well-ventilated rooms in the presence of an experimenter. Before the game began, the experimenter read out the rules to the participants and clarified all doubts/queries. Then the experimenter allotted words randomly to the subjects for both games. The words used were drawn from a set of 100 common nouns (Table 1) prepared by us. These nouns were in turn taken from a list of 1000 most commonly used English words, available at http://esl.about.com/library/vocabulary/bl1000_list_noun1.htm. The words were divided into four sets of twenty-five words each and every pair got one word from each group in *Gasekitomu*. In *Password*, each pair got at least one word from each group. The experimenter was present throughout a game and made sure that all rules were being rigorously followed.

The teams formed in this study can be broadly categorized into two types: 1) when both subjects of a pair had the same first language (henceforth *like*), and 2) when the subjects of a pair had different first languages (henceforth *unlike*). Since the subjects available for the study were from very diverse linguistic backgrounds and the number of participants and time available was limited, it was not possible to create a uniform and balanced experimental design. We ended up with eight *like* groups consisting of teams that had different first languages (four Chinese, two English, one Italian, and one Marathi). Similarly, it was not possible to maintain uniformity in the allotment of the *unlike* groups and there were one Japanese-English and three Chinese-English groups. The *like* played the games in their first language, while the *unlike* played the game in English. We ensured that all non- native English speaking subjects in the *unlike* pairs nevertheless had a good working knowledge of English. Each group was requested to first play the six trials of *Password* followed by the four trials of *Gasekitomu*. While all groups were able to finish the required *Password* trials, constraints on time meant some of them could not finish all the *Gasekitomu* trials. Thus we had a total of 72 (48 *like* + 24 *unlike*) trials of *Password* and 39 (28 *like* + 11 *unlike*) trials of *Gasekitomu* for the statistical analyses.

3.2 Statistical Analyses of the experiments

In *Password*, the performance of a pair was judged by the number of correct guesses (out of six trials) and the mean rate of convergence to the correct solution in each trial. The latter statistic referred to the number of guesses needed to arrive at the target and a relatively lower score indicated better performance in the game. When the pair failed to guess the target, they were assigned an arbitrary score of 10 (the maximum number of guesses that a team made was 8). In *Gasekitomu*, the performance was measured in terms of 1) number of correct guesses out of four trials and 2) the ratio of "close" guesses to the total number of guesses when the pair could not reach the target. When a pair actually reaches the target in a trial, it was given a score of 100. We also computed the ratio of "close" to total guesses only for those cases where both like and unlike were unable to guess the correct word. Separate one-way ANOVAs were done on the various scores from the two games, using pair means as the unit of replication and considering type of pairing as fixed factor with two levels (*like/unlike*). All analyses were executed on a Pentium III machine using the statistical software STATISTICA ® (Release 5.0, Statsoft Inc.).

3.3 The Computational Model

The computational model sought to mimic the *Gasekitomu* game. Concepts (represented by words) in a person's brain were modeled as nodes on a network with perceived connections forming the edges between the nodes. Obviously in real world, every person will have a semantic network of his own. This fact was mimicked by introducing some amount of differences in the way the nodes are connected in the sender's and the receiver's network (keeping the number of nodes and edges constant). Of course, we do not have any *a priori* idea of the topology of such networks. Hence we considered four different kinds of topologies, namely random, regular, scale free and small world and studied their relative performance under a *Gasekitomu-like* scenario. For this, a node (target) is selected randomly on the sender's network. In *Gasekitomu*, owing to the rules of the game, the sender is only able to send a clue that is vaguely related to the target. This step was simulated with the help of a random walk on the sender's network, beginning at the target. The node reached at the end of the random walk becomes the clue and the number of steps in the random walk then determines the ability of the sender to give a clue that is closely related to the target.

Once the receiver receives the clue, he allots a score to the particular node and progressively lower scores to nodes that are farther from the received clue. Thus, as an arbitrary example, if the node that is received as a clue gets a score of x, then all nodes that are at a path length of 1 (that is directly connected) from the clue get a score of x/2, all nodes that are at a path length of 2 are given a score of x/4) and so on. The receiver then picks the node that has the highest score and transmits it to the sender as the *guess*. In case there are multiple nodes with the same score, then one of them is picked at random as the *guess*. If the *guess* lies within a fixed distance of the target, then the sender gives the feedback that the *guess* is *close*, else it is labeled as *far*. If a *guess* is labeled as *close*, then the scores of all nodes that are in its vicinity are increased, while a feedback of *far* leads to a reduction in the score of the neighboring nodes. The sender then sends another clue and the cycle is repeated till the target is reached or a pre-determined maximum number of trials (20 in our simulations) are over. Some rudimentary learning is introduced by stipulating that that nodes once guessed and found to be incorrect shall not be guessed again, irrespective of their score.

We used the number of guesses to reach the correct solution (henceforth, rate of convergence) as the index of performance of the "sender-receiver" pair. Therefore, the lower this score, the better is the performance of the network pair under those conditions. The different scenarios/variables that were studied for all four kinds of networks (i.e. random, regular, scale free, small world) were as follows:

1. Degree of difference between the sender's and receiver's network: We studied 11 levels of differences between the sender's network and the receiver's network, between 0% and 100% at intervals of 10%.

2. Different kinds of search strategies for the receiver: Three different kinds if search strategies were studied. These were:

a. The *efficient* strategy in which the receiver uses both information and feedback from the sender.
b. The *partial* strategy in which the receiver only uses feedback from the sender.
c. The *random* strategy in which the receiver proceeds with random guess without any aid from the sender.

3. Different numbers of nodes in the network: We know that the number of words in a language varies greatly and this might conceivably have an effect on the performance in *Gasekitomu*. Hence, the effect of size of networks on the rate of convergence was studied using networks with different number (100, 200 and 300) of nodes.

4. Different degree distribution of the networks: This effect was studied using networks with different average degree distributions (2,4 and 6).

4. RESULTS

4.1 Experimental Results

In *Password*, the *like* (mean success rate/pair ~0.77) did marginally better than the *unlike* (mean success rate/pair = 0.75, Fig 1a). However, this difference was statistically insignificant ($F_{1,10}$ = .032, p = 0.86). The mean rate of convergence to the correct target for a pair was marginally lower in the *like* (3.13) than the *unlike* (3.79), although this was again found to be statistically insignificant ($F_{1,10}$ = .031, p = 0.59, Fig 1b). Thus, no differences were found in the performance of the *like* and the *unlike* in *Password*.

However, in *Gasekitomu* the *like* (12 success out of 28 trials ~ 43%) were more successful in guessing the right word than the *unlike* (3 success out of 13 trials ~ 23%). In terms of the ratio of "close" to total number of guesses, the *like* (59.10) had a better mean score than the *unlike* (41.91) although this difference was not statistically significant ($F_{1,9}$ = 1.00, p = 0.34). However, closer scrutiny of the data reveals that there was one pair in the *unlike* which put up an unexpectedly brilliant show. This pair was successful in guessing the correct target in all the trials, while none of the other *unlike* pairs could guess even a single target correctly. When we remove the data from this exceptional pair and recalculate the scores, the mean score of the *unlike* drop to 20.85 and the difference turns out to be statistically significant ($F_{1,8}$ = 9.92, p = 0.01; Fig. 2a). However, it is possible that this estimate was biased in favor of the *like* as the *unlike* had fewer success in guessing the correct word. Therefore we also considered the ratio of "close" to total number of guesses in only those trials in which both the *like* and the *unlike* pairs had failed to reach the target. We find that the *like* (28.43) still performed better than the *unlike* (20.85), although this difference was statistically insignificant ($F_{1,8}$= 0.78, p= 0.40; Fig. 2b). Thus, this data suggests that similarities in cultural/linguistic background can have some impact on better communication under severely restricted conditions of the type imposed in *Gasekitomu*.

4.2 Simulation Results

We present below a very brief description of the major findings of our simulation studies, omitting in particular, all statistical analyses. We hope to present a much-detailed account of this part, in a future publication.

1. Topology: In all simulations, we found the rate of convergence to be highest in the scalefree networks and lowest in the regular networks (see fig 3a for one typical example). The corresponding values for the random and the small world networks lay somewhere in between.

2. Degree of difference: As expected, the rate of convergence, increased with the degree of difference between the sender's and the receiver's networks (Fig 3b). However, while the magnitude of increase was high in the random and small world networks the corresponding changes in the scale free and regular networks were negligible (fig 3c).

3. Different kinds of search strategies for the receiver: The average rate of convergence, averaged over all the four topologies, was lowest for the *efficient* strategy, followed by the partial and random strategies respectively (Fig 4a).

4. Different numbers of nodes in the network: Contrary to the expectations, increasing the number of nodes in the networks did not increase the rate of convergence significantly (Fig 4b). However, we only studied 3 different number of nodes (100, 200 and 300), and it is possible that increasing the number of nodes further would lead to an increase in the rate of convergence.

5. Different degree distribution of the networks: Increasing the average degree distribution of the networks from 2 to 4 almost doubles the rate of convergence, while a further increase to 6 only manifests as a negligible increase in the statistic (Fig 4c).

5. DISCUSSION

5.1 General Conclusions

Based on the results of *Password* it seems that differences in cultural backgrounds have no effect on non-syntactic communication, as long as the members of a pair share a common language. This is a slightly counter-intuitive result, as naively speaking one would expect that people with similar cultural/linguistic background would be better at deciphering each other's clues. But both, the frequency of success in guessing the correct word, and the rate of convergence to the target were found to be similar between the *like* and the *unlike.* Therefore*,* it can probably be said that when clues are given as meaningful words, human beings are well able to surpass the barrier of differential past experiences. The fact that the *like* and the *unlike* had similar performance in *Password* also demonstrates that there was no accidental bias in allotment of the pairs to the two treatments and players in both treatments were equally able/willing to communicate with each other. However in *Gasekitomu*, the *like* players were found to be better at deciphering the clues and strategies of their partners, leading to their superior performance in the game. This in turn can probably be attributed to the similarities in concept association patterns, which is a direct product of the cultural/linguistic background of a person. In other words, as the tools of communication become more and more restricted, degrees of similarities in experience play more and more prominent role in the abilities of people to communicate with each other.

The simulation results, at least qualitatively, seemed to be corroborating the experimental findings. Increase in degree of difference led to an increase in the rate of convergence in all four networks, which is analogous to the poorer performance of the *unlike* in *Gasekitomu*. In the computational experiments, the *efficient* strategy, in which the receiver uses information from the clues as well as the feedback of the sender, had the lowest scores (i.e. better performance), while random search produced the highest ones (poorer performance). This result ties in well with the observations on the actual strategies that were used by the participants during the experiments (see section 5.5 for more details). Owing to the small number of participants in the experiments, it was not possible to formally test whether speakers of certain languages, due to a larger vocabulary, had an advantage during hyper-restrictive communication. However based on the data available to us, we did not observe any marked difference in the performance of pairs speaking different languages (*personal observation*). The number of nodes was also not found to make any difference in the performance in the computational experiment. Although these observations support each other, it is not possible to link them conclusively, owing to the limitations of the experiment. Increase in average degree distribution of the networks seemed to lower the performance of the sender-receiver pair in the simulations. This is probably because a higher degree distribution leads to more number of nodes within given topological radius. Since, the search strategy is based on assigning similar scores to nodes that fall within a certain radius, more number of nodes would make zeroing on the correct one that much more difficult. An analogous situation to this can be thought in terms of synonyms. Suppose language A has 2-3 synonyms for the word "lotus" while language B has 10-15. Now if the sender has been able to communicate "big, pink, aquatic flower" then players of both languages would know that the word has to be lotus or a synonym of it. From this point onwards, the sender's clues and feedback become useless, as the receiver needs to conduct a random search over the entire synonym-space. Thus, higher connectivity can also lead to problems under a *Gasekitomu* like scenario!

5.2 Clues and Search Strategies used in Gasekitomu

The success in communication in *Gasekitomu* also depends vitally on the types of clues given by the senders and the efficiency of the search strategies used by the receiver. However, since we did not allow any discussion between the players prior to or during the games, they were forced to create the clues in the process of playing the games in a way that their partners could understand them. The task was further complicated by the fact that the nouns used were from very different categories (a fact that was *not* known *a priori* to the subjects) and it was unlikely that the same types of clues/strategy would work every time. In fact, the pairs that performed well in *Gasekitomu* ended up in adopting a mixture of two or three types of clues/strategies, some times within a single trial. *Phonetic clues*, which had some phonetic resemblance to the target word, were mostly seen to be ineffective, as the receiver often could not perceive their true nature. *Mathematical clues*, in which the sender tried to establish some numerical pattern using the given syllables (e.g., the clue Ga, Ga,……Ga, Ga…. Ga, Ga, Ga, Ga to convey the concept of calculation, trying to lead up to the word computer), were found to be effective and well understood by the receivers. *Tunes of well known songs* that contain the target word were also used as clues and were seen to be particularly effective in reaching the target. *Prosodic clues* were often used to convey feelings or emotions and were generally found to be helpful in reaching the target.
In terms of receiver's search strategies, the ones that tried to make use of the sender's clues and the past history of the game, were found to be most efficient in reaching the target. However, sometimes the receiver was completely unable to decipher the sender's clues and proceeded on a hierarchical "twenty questions" type search. These searches typically started with very general words like "animal" or "emotion" and progressively went on to take more and more specific instances. Although theoretically speaking, such a strategy is supposed to be successful most of the times, in practice, this strategy performed poorly compared to the one that used information from the sender's clues. In some instances, inability to decipher the clues given by the sender led the receiver to do a random search on the lexical space. Obviously, success using this strategy was simply a matter of luck.

5.3 Future Directions

The major limitation of this study lies in the small number of replication units (pairs) studied in the experiments. Moreover, due to the inherent heterogeneity of the pool of subjects, all languages were not represented equally in the pairings. For example, there was an overwhelming majority of native Chinese speakers while many other languages were represented by just one pair each. Therefore, it might be worthwhile for future studies to include more subjects in such a way that there are approximately equal numbers of speakers of each language. Such a study will enable us to ask whether people from certain cultural/linguistic backgrounds are better at communicating under *Gasekitomu-like* restrictions. This would also enable us to compare the data meaningfully to the simulation results. The subjects for this study comprised exclusively of people with good academic backgrounds and probably donot represent the variation that is generally found in any population in terms of mental abilities of people. Thus, future experiments should include subjects from more diverse socio-economic backgrounds. The simulation results presented in this study only touch upon the broad trends and are devoid of statistical analysis. We plan to present a more detailed account of this portion of our work in a future publication.

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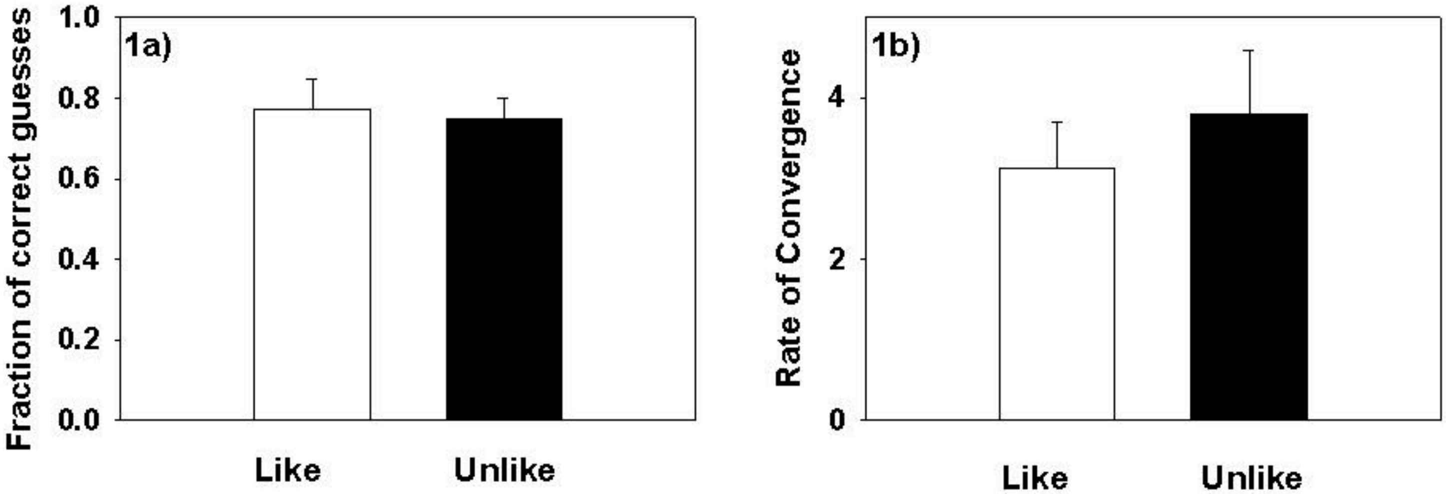

Figure 1. The performance of the *like* (white bar) versus the *unlike* (black bar), in the *Password* game. a) Average fraction of correct guesses per pair in six trials. b) Rate of convergence to the target word. See text for more details. None of the differences were statistically significant, showing that the *like* and *unlike* did identically in *Password*. The error bars represent standard errors around the mean.

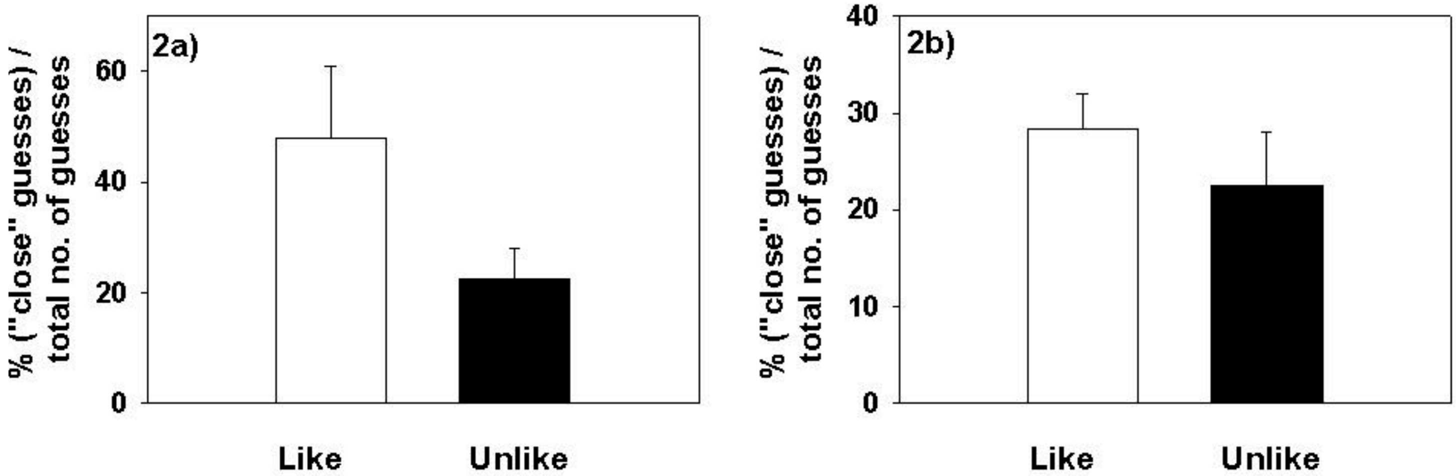

Figure 2. The performance of the *like* (white bar) versus the *unlike* (black bar), in the *Gasekitomu* game. a) Average percentage of "close" guesses to the total number of guesses per pair. In this case, we have omitted the score of one outlier pair in the *unlike* group. The difference between the *like* and the *unlike* was found to be statistically significant. b) Average percentage of "close" guesses to the total number of guesses per pair after omitting the trials in which the target word was guessed correctly. See text for more details. The differences between the means were statistically insignificant, although the *like* still do better than the *unlike*. The error bars represent standard errors around the mean.

Figure 2

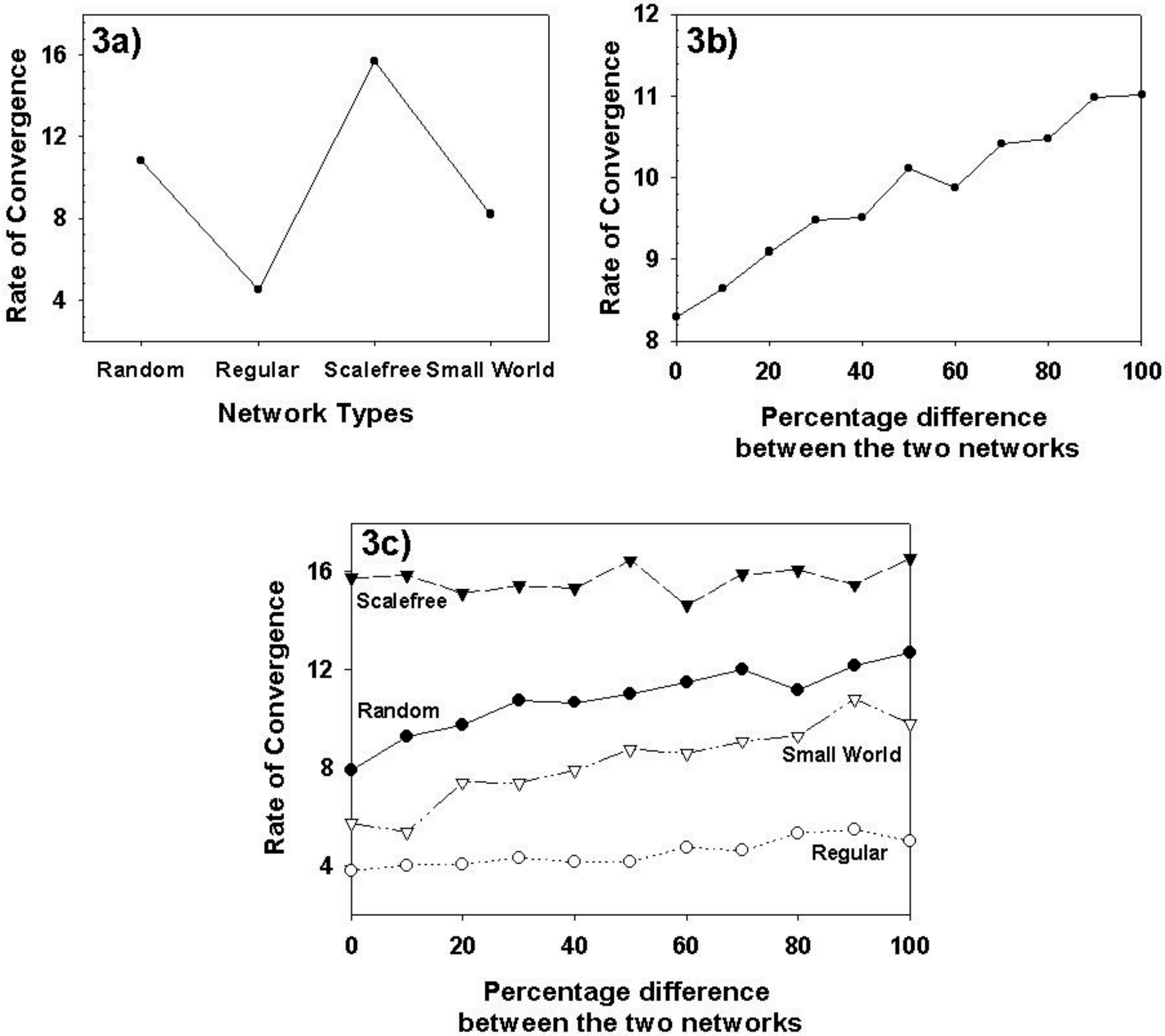

Figure 3. Computer simulation results. The four kinds of networks were simulated for different degrees of difference between the sender's and receiver's networks. For all simulations, there were 100 nodes in each network with an average degree distribution of 4. 3a) Here we see that, averaged across all levels of degrees of difference, the performance of the regular network was the best, while that of the scalefree was the worst. 3b) This shows that averaged across all kinds of topologies, the performance of the pair become poorer, as the degree of difference between the networks increase. 3c) shows that the increased rate of convergence is more in the random and the small world networks than the scalefree and the regular ones.

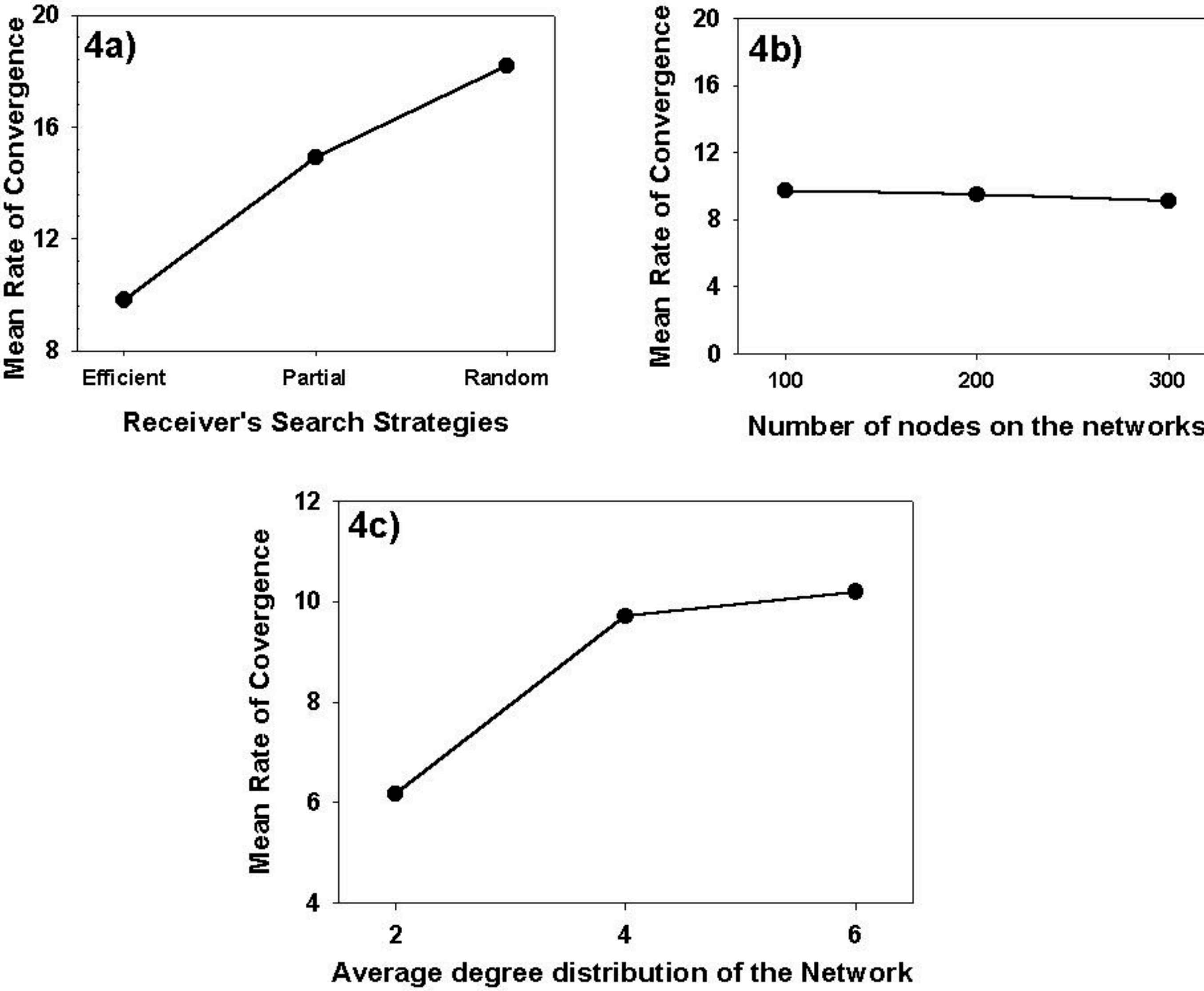

Figure 4. Computational results. 4a) Shows that the *efficient* strategy has the best performance in a *Gasekitomu*-like scenario, while random search has the worst. 4b) Here we see that increasing the number of nodes in the networks have negligible effect on the pair performance. 4c) illustrates that increasing the average degree distribution of the networks lead to a fall in the performance of the pair as shown by the increase in the score. In all panels, the Y-axis represents the mean rate of convergence over all four types of networks, when the degree of difference is 30%. Unless otherwise stated (see text for details), the average degree distribution = 4, number of nodes = 100 and the *efficient* search strategy was used for the receiver's network.

Group	I	II	III	IV
1	AEROPLANE	BLOOD	AMBITION	ANIMAL
2	BABY	BODY	ANGER	ATOM
3	BEAR	BONE	CURIOSITY	BEAUTY
4	BIRD	BOOK	DESIRE	BROTHER
5	BOAT	BOX	DISGUST	CENTURY
6	BOY	CELL	ENVY	COUNTRY
7	CAR	CORN/MAIZE	GREED	DEATH
8	CAT	COTTON	GUILT	DREAM
9	CLOCK	EAR	HAPPINESS	DUTY
10	COMPUTER	FINGER	HATE	ENEMY
11	COW	FLOWER	HOPE	ENERGY
12	DOG	FRUIT	HORROR	FAMILY
13	DUCK	ISLAND	HUMILIATION	FRIEND
14	ENGINE	OFFICE	LOVE	GROUP
15	GAME	ROCK	MADNESS	NAME
16	GIRL	ROOM	PAIN	NEIGHBOUR
17	HEART	ROOT	PITY	NIGHT
18	LANGUAGE	ROPE	PRIDE	NOON
19	OCEAN	SHOP	RAGE	NUMBER
20	RIVER	STATION	REGRET	PLANET
21	SCHOOL	STREET	RELIEF	SHAPE
22	VILLAGE	STUDENT	RESPECT	SPEECH
23	WATER	TABLE	REVENGE	TEMPERATURE
24	WAVE	TENT	SHAME	WAR
25	WIND	VALLEY	SORROW	WINTER

Table 1. List of common nouns used in the *Password* and the *Gasekitomu* game. The hundred nouns were divided into four groups. Group I consisted of objects that can possibly be represented by some kinds of sounds, while group II consisted of objects that did not make any typical sound. Group III included nouns depicting emotions while group IV comprised of abstract concepts. This classification was not very rigorous and some words can equally belong to groups other than the one to which they were assigned.