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Introduction to This Issue

It is a great pleasure to devote a special issue of the Newsletter, to the work of several esteemed Japanese colleagues.

The impetus for this collection of essays was provided by a series of visits by members of the Center for Human Information Processing to Japan in 1980 and 1981. In the summer of 1980, I went to Japan to lecture under the auspices of the Japanese Psychological Association. My host, Kunio Wakai of the University of Kobe, School of Education, cleverly arranged my schedule to permit me to give a *series* of lectures which virtually all of the contributors to this issue of the Newsletter attended. After two weeks of lectures and seminars, a group of American cognitive scientists, headed by Donald Norman, arrived for a meeting that included these same people.

As a consequence of this unusual confluence of scholars, a truly remarkable mixture of viewpoints was brought to bear on the question of the nature of basic cognitive mechanisms: how are they to be represented theoretically; what role does the environment play in shaping them?

During this series of communicative encounters I experienced a growing sense of the depth in the viewpoints of my Japanese hosts. Prior to my arrival in Japan, I was extremely unclear about what, precisely, I should be talking about. I knew that I was expected to discuss cross-cultural research. But why? Was I "cultural enrichment" or did my Japanese colleagues have some deeper interest in the cross-cultural enterprise? How did my work fit with their theories and styles of research?

To the limited extent permitted by the etiquette of such situations (I was, after all, supposed to do most of the talking) I contrived to have my hosts answer questions about their possible interest in my work: what set of questions organizes *their* work? Which American psychologists do they use most in their thinking? How do they apply American ideas to their observations and experiments?

The answers surprised and delighted me. I received an impromptu lecture on the affinities between Skinner and von Uexküll. I learned about several pervasive concerns: how can we organize the lives young children to make them intellectually effective in a modern economy?; what distortions does an IQ-based meritocracy introduce into Japanese culture?; how can the children of the tens of thousands of Japanese who live abroad for awhile be helped over the difficulties of readjusting to Japan? Overriding these concerns and perhaps organizing them in some sense, was a deep interest in what it means to be Japanese.

I began attempting to frame my lectures so that they might be relevant to the concerns that I was hearing, if only dimly understanding. At my lectures, I awaited questions with anticipation, struggling to understand my interlocutors just as they had been struggling to understand me. I learned a great deal from these interchanges by assuming that every question made sense to its conceivers; it was my job to figure out the system of ideas that would make each question make sense to me.

By the time I was ready to leave Japan, I had come to believe that Japanese psychologists have a great deal to contribute to the world's knowledge of human nature and the social mechanisms for its change. Their unique historical experience has given them a special vantage point on problems of common interest to all social scientists. However, I also felt that their publications in English (I could not judge those in Japanese) were written on grounds far narrower than those that I had encountered in their conversations around the seminar table.

This discrepancy (which certainly also exists in our own printed, scientific communications!) may be larger in the case of Japanese psychologists because the norms of scientific communications to which they adhere, including the basic technology and theoretical frameworks, are modelled on Western, primarily American, academic psychology. Underlying the carefully bracketed work of formal scientific publication is the assumption that nothing outside the brackets is relevant to real scientific discourse. But when that form of discourse severely fails to meet the concerns of the participants, new forms will be sought. It was my belief that many Japanese psychologists, including the contributors to this Newsletter, are seeking a new, *Japanese* form of psychology.

At present this effort is carried out largely within traditional institutional and scientific frameworks. Even within these constraints there are interesting cultural differences marking the intellectual style and institutional lives of Japanese psychologists. As a result, we often find their work difficult to categorize. During our series of meetings, the same individual was often an educational psychologist, sometimes a developmental psychologist, sometimes a cognitive scientist. They worked in schools of engineering as well as departments of psychology and education, and primate research

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centers. Despite their diversity, there was relatively little evidence that one or another person could not enter equally into the conversation because they were "not expert enough."

The rich intellectual resources of this group are well illustrated in their contributions to this issue of the Newsletter. Hiroshi Azuma's article is an unusually informative description of the national, institutional, and cultural factors that influence the course of collaborative cross-cultural research. His longterm working relationship with Kazuo Miyake, Robert Hess and their colleagues has given him unusual opportunities to address the special contributions that Japanese psychologists can make to our understanding of cultural influences on development. This research went beyond the fulfillment of cross-cultural psychology's historical role of demonstrating the culture-boundedness of our psychological theories. In doing so it has raised fundamental questions about the nature of our psychological theories and the data upon which they are based.

Azuma and his colleagues found that the relationship between interactional styles and intellectual achievement, (as measured by the standard behavior coding scheme derived from prior research in America) is different not only in Japan and America, but differs also according to the nature of the activity which is used to obtain the interactional indices. In some cases, the "same" interactional index predicts differently depending on whether the adult involved in the interaction is the mother or the father. These perturbations in what is otherwise an orderly picture of broad cultural styles and pervasive parental influences challenge our specifications of the behaviors involved. Azuma and his colleagues wish to address that challenge, but, like the rest of us, they are uncertain of how to proceed.

The papers by Inagaki and Kashiwagi explore contexts of socialization in two different ways. Kashiwagi seeks broad patterns of differential socialization through questionnaires; Inagaki through observations of innovative curricular/classroom design. Kashiwagi, like Azuma, bases her inferences on patterns of correlation that differ in suggestive ways between cultures and between sexes both within and between cultures. Like Azuma, she must face the task of "penetrating" various correlations to discover the stuff of which they are made.

Inagaki is working at the level of individual contributions to joint cognitive activity in classroom settings. She makes the extremely important point that systems of control within the classroom do more than control exposure of children to curricular content, they shape the cognitive processing that will go on, thus influencing the kind of conceptual changes that occur. Many developmental psychologists are currently using the notion that cognitive development involves the acquisition of concepts which are higher order in two senses; they are "higher" vertically in the adult system of concepts and they are "higher" horizontally in that they include more and more exemplars as well as more and more contexts of use. It is also becoming fashionable to return to Piaget's early and largely unexplored notion that social interaction is as important an arena of cognitive development as are interactions with objects in the world. A big problem with this line of thinking has been finding ways to make relevant observations. By choosing the experimental physics curriculum, Inagaki is able to take advantage of an ongoing system of activities, the construction of which provides her crucial data. This strategy, too, is becoming more widespread, as seasoned readers of this Newsletter will recognize.

Just as differences in culturally organized patterns of interaction between people (parent and child, teacher and child, child and child) are a rich source of interesting data, so too are differences in the kinds of technology that cultures have evolved to organize their interactions with the world. The articles by Hatano and his colleagues and by Saito investigate the important problem of the way that language is represented in the writing system. Many Americans have been interested in the low incidence of reading disabilities among Japanese children, looking for properties of the writing system to explain the children's early and comprehensive mastery of reading. The Japanese have a different substantive concern. Although written Japanese may be acquired, at least to some functional level, with relative ease, the orthographies of written Japanese are difficult to code for modern computers and highspeed printing systems. Moreover, the *Kanji* system is mastered only to a moderate degree by most Japanese, rendering some people incapable of reading certain kinds of texts without the help of a complex dictionary. On this and other grounds, it has been argued within Japan that the country should abandon its mixed syllabic-ideographic system, and adopt an alphabetic system.

While the decision on such matters is certainly in large measure political, psychologists can be of some use if they can better specify the advantages, as well as the disadvantages of different writing systems. Hatano et al. and Saito make clear that the current Japanese writing systems each have some definite advantages with respect to certain cognitive tasks. The entire issue of "kinds of literacy" associated with different technologies, different language systems and different social systems is a topic that needs far greater attention in a world that believes there are important social and mental differences associated with different kinds of literacy. It also helps to counteract oversimplified theories that place the alphabet at the apex of a developmental pyramid of written language power.

The final article, by Sayeki, neatly creates a link between the kind of interaction that we have with objects in the world and the kind of representation that we form of those objects. In effect, his work on "cognitive empathy" suggests that our basic representations of objects as they act in the world and as we act with them always code a "point of view" in which the "thinker" is a part of the scene being thought about. It also suggests that a great deal of the work that goes into "abstract" thinking involves finding a concrete familiar instantiation of the object being thought about. Both of these ideas have important implications for cognitive science and education.

No single issue of this Newsletter could represent properly the richness of contemporary Japanese psychological thinking. Limitations on space, on common cultural and academic background, and the ever present problem of having to represent complex ideas through the medium of commonly accepted (but imperfectly understood) research conventions all conspire to make this an *introduction* to a set of interesting ideas. It will take further work to produce a working colleagueship.

A Note on Cross-Cultural Study

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If one has studied, worked and raised children in a culture substantially different from that in which he or she was raised, any person becomes something of a cross-cultural psychologist. To that extent, and perhaps a little more so because my training was in psychology, I have been a cross-cultural psychologist for thirty years. My actual experience conducting cross-cultural research is much shorter however. Apart from the co-authorship of a few articles in which my role was that of a native informant, I have just recently written the final report of our first study. The study is a United States-Japan comparison of the influence of mothers' attitudes and communication styles on the cognitive development of their children. My Japanese colleagues and I have collaborated with Robert D. Hess of Stanford University and his associates since 1972.*

One very salient feature of our project was that each national research group was funded by its own national source. I have come to believe that this is the best, if not the only, way to conduct a fair cross-cultural study. It is obvious that both cultures should be represented in the cross-cultural research group that designs the study, selects and develops the tools, collects data, analyzes the data, and writes the work up. At present this desirable situation is difficult to achieve unless the two cultural groups are financially independent. If one group depends financially on the other, the party that finances the study and therefore is accountable to the funding agency will have a much stronger influence upon decision making at various stages. This assymetry is not a matter of personality, or the scientific imperialism of the members of the research group. It is the way the system works. If one group is paying for the work, the study will turn out to be practically mono-cultural in all phases except that the data are collected from two-cultures, unless the concerned people are extremely sensitive and careful.

When two independent cultural groups cooperate as we did, coordination also requires a lot of work, and there is a need for a great deal of communication between the two groups. In our case there was a great expenditure of money and effort. Letters I received alone fill a large box in my office. There were numerous telephone calls across the Pacific. There were seven formal conferences, four times in the U.S., and three times in Japan, plus several minor informal conferences which took place whenever one of the Japanese members visited the U.S. on other business. Although there was no occasion for the American members to visit Japan on other business, one of the American members spent one full academic year in Tokyo working with the Japanese group. We were able to remain in the closest conceivable contact; we liked, respected and enjoyed each other. In spite of such closeness, we discovered that cross-cultural cooperation is different from intra-cultural cooperation; the experience gave us new experiences, better insights, much excitement and a few passing frustrations. I would like to describe some of my experiences as the co-director of the project with the hope that they will help those who plan to undertake similar studies in the future, and that they may motivate some to undertake a similar cross-cultural cooperation.

The first thing we had to learn was that the research groups themselves are the products of their respective cultures. Each side had to learn the thinking, working and communicating style of the other party, and adapt to it. There were wide individual differences within each group in the readiness and speed with which they made this adaptation. During the beginning stage of the study the individual differences of this kind sometimes caused subtle intra-group disagreements about how to proceed, confounded by a touch of ethno-centric emotion.

The cultural difference in basic ideas about the research problem was confounded by differences in the organizational structures of science in our two countries, and this in turn affected important characteristics distinguishing the two research teams. In Japan, research funds usually do not provide for the employment of personnel. A research team typically consists of people employed on a permanent, full-time basis by various research institutions, who have pledged to contribute some of their time which they can spare from their full-time obligation to the project without monetary compensation.

This form of organization perhaps reflects the old Japanese tradition that the employee should be loyal to a single employer and the employer should, in return, look after the employee until his retirement age or beyond. Even now, the salary system itself curbs employment mobility. It is rare and difficult to employ a researcher full-time or part-time for a research project, for even a limited time. Only temporary student helpers are employed by the project on an hourly basis.

In the U.S., on the other hand, a research team typically consists of one or two senior researchers who are paid from the project fund on a part-time basis; one or two junior researchers who receive a full-time stipend for the duration of funding; and several graduate students who are employed as part-time assistants. When the period of funding is over, associates and assistants leave the project and are employed elsewhere. This is in line with the American style of employment where people often move from employer to employer, and from job to job.

Such differences lead to a difference in team structures and a difference in work styles. In Japan, the structure of the team is much looser and the control of the director has to be weaker because the team members are not employees. Instead they are people who devote their spare hours to the project because of their own research interest, without economic compensation. They accommodate their interests to the common goal of the project, but at the same time the project must accomodate to their more or less diverse

*The major financial support for this work came from the Japan Society for the Promotion of Science for the Japanese group, and from the Spencer Foundation for the American group. The project is still continuing on a smaller scale, as we are conducting follow-up studies with our subjects.

interests in order to keep them associated. The team proceeds slowly and somewhat awkwardly at first, seeking to establish consensus within the team. This is often a very hard and painstaking process because good researchers tend to be independent and uncompromising. Once started, however, they are persistent. The end of the funding does not mean the end of the project. Members will continue working if there is work still to be done.

If I may exaggerate things a little in order to emphasize the contrast, the American group structure resembles that of an efficient combat team. The director is "the boss." He may consult with his members and may even yield to them, but nevertheless, *he* is the decision maker. Other members are bound by contract to work for his project. The plan can, therefore, be much better structured and focused from the beginning, and can be executed without lengthy negotiations. However, as a consequence of its funding and social organization the American project has to be over at the end of the funding period. The team is dissolved and the members set forth for new duties.

As a rule, at least in soft sciences, a research project ends with more unknowns than it had at the beginning. The formal end of the project often comes at the climax of the actual quest. The project director may continue, but without the majority of the original members the project has to take on a quite different shape. Schematically, the above difference can be represented as in Figure 1 in which the two lines are intended to cover the same amount of area (work completed).

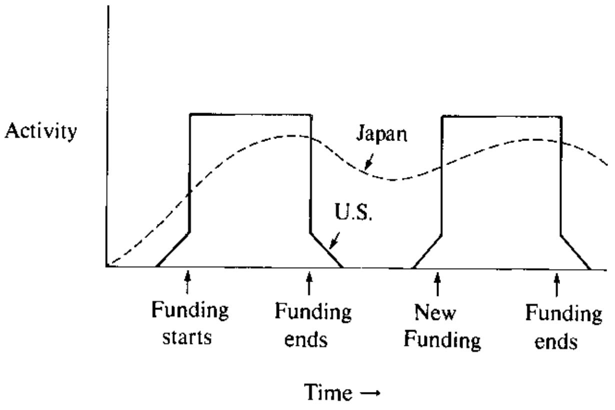

Figure 1. Schematic representation of work styles.

To start a project in Japan, the project director must be sure that there is a certain number of researchers sufficiently interested in the project to pledge their time and wisdom without financial compensation. Activity must start prior to funding. Once funded, however, the American activity quickly shifts into high gear and continues to be more intensive than that of Japanese research until it suddenly ceases at the end of the period of funding.

Each style has its own advantages and disadvantages, and I think it was truly fortunate that two groups with different styles were able to cooperate in good harmony. If both groups had been working in the American style, we might not have had that period in which we were able to reflect on our data, looking at them from various angles and gradually attaining a deeper grasp of what happened. If both groups worked in the Japanese way, we would not have been able to collect as much data in a structured fashion within a limited time period.

But, much as I appreciate the merits of such collaborations, it is easy to see that cooperation of two groups with such different work styles requires special patience, as well as an active effort to understand the constraints under which the partner group is operating.

It is even possible that the two groups originally conceived of the research topic differently. Research in Chicago, by Robert Hess et al., gave impetus to our present project, seemed to agree well with Bernstein's socio-linguistic ideas based on the contrast between the elaborated and restricted codes. The American group appeared to use a framework similar to what was found in the Chicago study as a frame of reference in thinking about the present study. The Japanese group, on the other hand, acted on the supposition that we would need to add another framework. The elaborated-restricted context seemed to represent a kind of "discriminant function" which clearly differentiates between middle and lower class people in Euro-American society. The elaborated code as a concept, (for example), pools together personal considerateness, individuality, exactitude, etc. It represents the language style of the sophisticated class in Europe and the U.S. In the western tradition they have been highly valued characteristics.

According to Japanese value orientations, however, the same component characteristics do not necessarily go together. Of course, the personal considerateness is again an important characteristic of a sophisticated communication. However, in Japan personal considerateness will often mean less explicit, less detailed and vaguer ways of communicating which give more freedom of mind to the addressee. To wrap one's individuality almost completely under the routine of ritualistic expression is often appreciated as a sign of high self-control among the Japanese well-educated class. The one contrast which differentiated European and American classes may need to be split in two if Japanese classes were to be differentiated within a single system with American.

Most cross-cultural studies conducted thus far have not encountered the problem described above because the funding source was single and mono-culturally western. In our case, each group was funded from its own national source, and I will argue that it was a very important feature of our cooperative project.

When there is only one source of funding, it is the researcher of the country of the funding agency who is held accountable for the project. Naturally, the weight of their opinion in decision making must match their responsibility.

Even the mind of a cross-cultural researcher, however, has many cultural blocks. If one culture plays a dominant role in making decisions about the research methods, tools to be used, data processing, and interpretation, the blocks and biases typically found in one's culture tend to influence these decisions.

When two cooperating groups are independently funded, each group can be more confidently self-assertive. Being self-assertive at the planning stage is particularly important in correcting and counter-balancing the cultural blocks and biases by which each group is almost unavoidably affected.

Even at the planning stage, researchers are culture bound. Their judgment as to the relevance, appropriateness, or importance of a method or a tool is heavily loaded by the value orientation, life style, and language style of their culture. Furthermore, the dominant culture of the scientific world is occidental. Even researchers who are oriental ethnically tend to be occidentally acculturated, more so than their non-academic compatriots. This may bias the research methods and tools used in cross-cultural studies.

At the time when our subject children were 3 years and 8 months old, we administered the Concept Familiarity Index developed by F. H. Palmer. In constructing this test, Palmer selected concepts which should be encountered and verbalized everyday in the common physical environment of a child. They are concepts related to color, shape, number, quantity, size, position, direction etc. This test, therefore, was presumed to be culture-fair and we decided to use it for that reason. Unexpectedly, however, we found that the performance level of American and Japanese children differ in some areas. Particularly, Japanese children scored poorly on items related to position and direction; such as *behind, around, over, through,* etc. While about 80 to 90% of American children passed these items, the percentage of Japanese children passing was around 50%.

There is no such difference in other items. The difference seems to be domain specific. Our conjecture about the reason for finding this is that the Japanese language is less articulated than English with regard to directional concepts. Although we have words representing directions, the meanings are often equivocal unless appropriate context is provided.

Another example of culture--research tool interaction is found in how we chose to structure the settings for observing mother-child interaction. As it turned out, we observed how mothers teach their children and communicate with them under three interactive situations. One of them was what we called the "block sort." The mother was taught how to sort a set of wooden blocks, and was then asked to teach it to the child. All utterances and teaching strategies were recorded, coded and analyzed. Another interactive situation was called "free play." While sitting in the waiting room, the mother and child were left unattended with two sets of constructive play materials. Spontaneous conversations and interactions were video-taped and coded.

The block sort was used in the past by our American partner, R. D. Hess, in his Chicago study, and had proved itself to be highly useful. The Japanese group members, however, doubted that it was appropriate for Japanese subjects. We were not able to give an explicit reason, but the task was somehow incongruent with our image of mother-child interaction in Japan. We preferred less structured free play which seemed to us to be more 'natural.' After an intensive debate, neither side of the two national groups yielded and our compromise was to administer both tests to both groups.

The data very clearly showed that the block sort variables were more relevant in the U.S. while the free play variables were more relevant in Japan,[1] and that each national group, unknowingly, favored the research tool which had higher relevance in its own culture.

A post hoc interpretation is that the block sort requires an analytical and structured approach on the part of the mother. As other results show, the Japanese mothers tend to be less analytical, more impressionistic and more feeling oriented in their communication with children. They want to avoid direct teaching when possible, and tend to model behavior rather than structure behavior through verbal instruction. Therefore, for Japanese mothers, the block sort situation was awkward; they tended to be more tense as compared to American mothers. The free play was not a teaching situation, and thus more personal approach styles were observable, although well-specified coding of the variables had to be sacrificed to some extent.

It is significant that we vaguely felt this about free play vs. block sort, but we did not have clear grasp of it at the planning stage. We were not ready to be logically persuasive. If we had not been working together on equal grounds and did not have mutual respect of each other's intuitions as mature researchers, perhaps we would have ended up discarding free play since its coding had to be less objective. In so doing we would have lost a set of predictor variables which turn out to be very suggestive in cross-cultural comparison.

The last point that I would like to make is about an intra-cultural problem. In Japan, at least, the sub-culture of researchers is at the most westernized extreme of the spectrum of Japanese sub-cultures. According to our data, the level of education of the mother, as represented by years of schooling, closely correlates with the similarity of her attitudes to the American modal pattern. In modern Japan, after the Meiji Reform of one hundred years ago, being well-educated meant some mastery of western civilization. Researchers usually have been schooled substantially longer than the average of the population. In our project we had to set aside the data from remote rural areas because apparently some of the research tools we have developed were inappropriate and unfair to their culture. For example, in many rural homes, it was not the mother, who had to work in the field, but the grandmother who was the primary caretaker. Thus, to be left alone in a room with her child was a very strange situation for the mother, and perhaps for the child as well. This was a bitter lesson which taught us that we have to study our sub-cultures with the modesty of foreigners. Being a Japan born Japanese does not guarantee a fair knowledge of our culture, and being a well-trained researcher can mean a well-westernized mind. This will be true with researchers from other non-western cultures too.

[1]The asymmetry of free play variables was not quite as pronounced as that of block sort.

Facilitation of Knowledge Integration through Classroom Discussion

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Significance of Peer Interaction in Cognition

It is well known that social interaction plays an important role in the development of all higher mental functions. There are two kinds of distinguishable social interactions. One is vertical or asymmetrical, such as adult-child interaction, and the other is horizontal or symmetrical, such as peer interaction. Vygotsky, and other researchers inspired by him, have emphasized the importance of vertical social interaction. Piaget, on the other hand, assigned an important role to peer, horizontal, interaction in the construction of knowledge.

Vertical interaction is an efficient vehicle of knowledge integration; the strengthening of the network linking components, each giving reasonable justifications to some others. I expect, however, that peer interaction contributes more than adult-child interaction to knowledge integration. At least two reasons can be proposed for this. First, assuming that knowledge integration is facilitated by an attempt to defend or to justify one's own judgement or opinion, the child's motivation to disclose his/her knowledge to others is both more natural and stronger in peer interaction than in adult-child interaction. Suppose that a child is asked for an explanation by an adult. The child may be puzzled. He may wonder why the adult asks for an explanation which is already known to the adult. However, when a child is asked for an explanation by peers, or when a child must defend his/her opinion against an opponent's argument, he/she is likely to be motivated to seek coherent explanations by activating prior knowledge and attempting to integrate it. The fact that younger children are willing to give explanations to a puppet, but not to an adult, supports this line of reasoning.

Peer interaction also contributes more to knowledge integration in that it produces a continued, non-reinforced situation, whereas vertical interaction is likely to give children immediate external reinforcement. Children are likely to accept information from adult authorities without examining it critically, while they are not ready to do so if information is given by peers. As suggested by Piaget's theory on equilibration, continued non-reinforcement may activate search processes for internal information. Therefore, peer interaction, especially group discussion, may facilitate knowledge integration in classroom learning.

A Japanese science-education method called "Hypothesis-Experiment- Instruction" (Itakura, 1962) is a program in which children acquire integrated knowledge through classroom discussion. The procedure is as follows: First, pupils are presented with a question with three or four answer alternatives and asked to choose one by themselves. Then, pupils' responses are tabulated on the blackboard and they are encouraged to explain and discuss their choices with one another. Finally, pupils are allowed to test their predictions by observing an experiment. Let me give an example, from the first lesson on 'buoyancy,' given to 5th graders in "Hypothesis-Experiment-Instruction" (Shoji, 1975). The lesson began with the following question.

> Suppose that you have a clay ball on the end of a spring. You hold the other end of the spring and put half of the clay ball into the water. Will the spring become (a) longer; (b) shorter; or (c) retain its length?

The pupils were asked for an immediate response. Some of them were then asked to give reasons for their choices. Some responses were: (letter in parentheses represents alternative chosen).

Odagiri (b): The clay ball consists of tiny particles (atoms). When we put the clay ball into the water, the water will be absorbed into the space among tiny particles. This makes the spring longer.

Itohisa (b): When there is no air in objects, I suppose they will sink.

Ide (b): The spring will be longer because the clay ball will sink.

Fukuda (b): Because the water will be absorbed into tiny particles which the clay ball consists of.

Kurokawa (a): The iron sinks into the water, but I think the clay ball won't. The water has a power to make things float, so the spring will become shorter.

Sano (a): The clay ball won't float, but in general all the things become lighter in water, so the clay ball will also be lighter in water than in air.

Imai (a): I feel lighter in water. I have this experience when I take a bath.

Shimazaki (a): The water has a power to make things float. Therefore, I think the water will make the clay ball float to some extent.

Kimura (c): The nature of the clay will not change when we put it into the water.

Chiyo (c): The weight of the clay will remain the same when we put it into the water.

Ehara (c): The clay ball is as heavy in water as in air.

Kurosaka (c): The water has a power to make completely immersed things float, but that power will not operate if it is only half immersed.

The teacher then encouraged them to give counter arguments against other opinions.

Kurokawa (a → c): Your opinion is strange to me. You said, "The weight of the clay ball won't change because it is only half immersed in water." But you know, when the person's head is above the water, his weight is lighter in water.

Uehara (a → b): The clay ball will absorb the water if it is put into the water for a long time, but, if for a short time as in this case, it won't absorb the water, thus the clay ball won't be heavier.

Ide (b → c): The clay ball will be heavier because we are making the clay ball sink half in the water.

Enjo (a → b): The water has a power to make things float, so the clay ball will become lighter.

Sano (a → b): I don't agree with supporters of (b) alternative. You said, "The clay ball sinks half in the water." But the clay ball is being pushed down as well when it is hanging by the spring in the air.

Nouchi (a → c): I don't agree with the idea that the clay ball is as heavy in water as in air. I suppose the water has a power to make things float.

Kurosaka (c → a): Even if the water has a power to make things float, the clay ball will not float, I suppose.

Shiga (a → c): If the clay is a very small lump, I suppose, the water can make it float.

Momozaki (a → c): A thing will float when its weight is lighter than the weight of the water with the same volume. I wonder if the weight of the clay ball is lighter than that of water. . . .

Odagiri (b → a): I have heard that we feel lighter when we dive into the pool. This means that our weight is lighter than the weight of the water. I guess, the weight of the clay ball is heavier than that of the water.

Shimazaki (a → b): You said a few minutes ago, "A person's weight is lighter than that of water." However, a person won't float in the air. This means that a person weighs less in water by the power to make things float which the water possesses. This power also operates on clay balls. So the clay ball will become lighter to some degree in water. Thus, I think, the spring will be a little shorter.

Sano (a → c): Let's imagine the scene that we pick up a pebble in a pool. When we throw the pebble into the water, it goes down slowly into the water. This means that the pebble weighs less to some degree in water, I think.

After the discussion, the teacher retabulated the pupils' responses by asking whether there were any pupils who had changed their choices. (See Table 1).

Finally, the problem under discussion was submitted to an experimental test, and its result supported the pupils who had chosen alternative (a).

In this program, all that the teacher does is to take the chair in the group discussion. She does not, as a rule, comment on pupils' ideas. In addition, she neither verbalizes the results of the experiment nor gives any reasons for them. In other words, pupils are left to judge for themselves the appropriateness/inappropriateness of reasons offered by other pupils in the discussion. It is expected that pupils will be motivated to seek or "construct" the knowledge to justify their responses. As shown in the protocol described above, they seem to be motivated to use various pieces of knowledge already acquired through previous experiences in order to justify their responses.

Table 1

Tabulation of response frequencies

Response	*Before discussion*	*After discussion*
(a) Become shorter	12	21
(b) Become longer	8	5
(c) Retain its length	14	8

Effects of Classroom Discussion

We examined the effects of discussion on the acquisition of generalizable and stable knowledge. In our earlier study (Inagaki & Hatano, 1968) the "Hypothesis-Experiment-Instruction" procedure was performed for fourth graders in the experimental condition. A question with multiple choice answer alternatives was presented, Pupils' response frequencies were then tabulated, followed by discussion, and observation of an experiment. The subjects in the control condition simply observed the experiment one day after they were given the question with a multiple-answer choice. The question concerned the conservation of weight in the dissolution of sugar in water. The pupils were asked, "When lumps of sugar are put into water and completely dissolved, is the combined weight of the sugar and water heavier, lighter, or does it remain the same as the individual weights?" In the experimental condition, the procedures described above were performed group by group. Each group consisted of about 20 pupils, two-thirds of whom were non-conservers. In the discussion phase, non-conservers insisted that: "The weight of sugar is lost when it dissolves and disappears. The tray on which the sugar and water are placed becomes lighter to the extent that the sugar 'dimishes' into the water." Another proposed explanation was: "The water becomes heavier when sugar is dissolved in it." Conversely, conservers explained that, "The sugar is still present in the water," and "sugar does not vanish, but merely becomes tiny particles, so it must retain its weight."

There were about 40 pupils each for experimental and control conditions. Pupils in both conditions were given a post-test immediately after the observation of the weighing of the sugar and water solution on a balance scale. Almost all of the children in both conditions (with two exceptions in the experimental condition) showed conservation responses after the observation. However, the children in the experimental condition could state more adequate explanations for the conservation of weight of dissolved sugar and water than the children in the control condition. For example, 11 experimental subjects gave atomistic or quasi-atomistic explanations, whereas none of the control subjects gave such reasons. Eighteen control subjects gave mechanical generalization or phenomenalistic explanations such as "The weight remained constant even after the sugar was dissolved," or "Because the sugar is put into the water" etc. On the other hand, only 9 experimental subjects gave such reasons. In addition, experimental subjects showed greater progress in generalizing the principle of conservation to a variety of situations. Furthermore, experimental subjects tended to resist extinction more often than control subjects when they were shown an apparently non-conserving event. That is, after the post-test, all the subjects were shown an experiment on the weight of combined baking soda and vinegar and asked why the combined weight did not retain the individual weights after the baking soda was "dissolved." More than 1/3 of the experimental subjects who had predicted no change in weight on the post-test switched their explanations by referring to the loss of some gas and retained the principle acquired through the observation of the experiment on dissolved sugar. On the other hand, only 1/6 of the control subjects showed such responses. Instead, most of them tended to give phenomenalistic reasons, such as "The baking soda was completely dissolved into the vinegar," or "Bubbles produced by combining have disappeared," or "Bubbles are light in weight," etc. In short, knowledge acquired through the group discussion followed by observation of experiment tended to be more generalizable and more stable in nature than the knowledge acquired through mere observation.

These findings were replicated in our later study (Inagaki & Hatano, 1977), in which we used a simulated discussion. Discussion was replaced by the presentation of a table of fictitious response frequencies with reasons for each alternative, allegedly given by the fourth-graders of another school. Though these reasons were fictitious in this context, all had actually been cited by the subjects of previous experiments. We used the same question on conservation of weight of sugar and water. The results showed that this procedure also led pupils to make greater progress in generalizing the principle of weight conservation to a variety of situations than mere observation.

It should be pointed out, however, that discussion does not always facilitate knowledge integration. Pupils must be strongly motivated to know the truth or to justify their own responses in order to acquire integrated knowledge through discussion. The existence of a limited number of plausible opinions, which conflict with one another, tends to arouse epistemic curiosity. This line of reasoning suggests that, when the subjects belong to the majority group in the discussion and are not attacked by others' plausible arguments against them, their motivation to justify their responses will not be heightened. In fact, in one of our earlier studies (Inagaki & Hatano, 1968), discussion group children, more than 4/5 of whom were conservers, did not show greater progress on transfer tasks than control group children. In that study we presented third-graders with the question on conservation of weight of the clay ball. Both experimental (i.e. discussion) and control children may not have been interested in defending their own choices. In other words, cognitive motivation was not strongly induced in that situation; thus knowledge integration may not have occurred either.

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Notes on the Sex Differences in Socialization Processes in Japan

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The development of psychological differences associated with sex differences, or sex-typing, is one of the ubiquitous phenomena of socialization in every culture. In this article, I present data collected in my studies of the development of sex differences in Japan from childhood to adolescence.

Initially, I will consider sex-differentiated discipline by mothers in Japan. To examine sex-differentiated training, a questionnaire was given to mothers with sons or daughters aged 10, 12 or 14 years. The mothers were queried about their child training methods and ways in which these methods might differ according to the sexes of their children. The mothers were then classified into four child-training types based on their responses: (a) mothers who train their children differently according to their sexes; (b) mothers who report specific sex-differentiated training for sons only; (c) mothers who report specific sex-differentiated training for daughters only; and (d) mothers who report that they train children equally regardless of sex. Some examples of the sex differentiated practices reported are included below:

Boys:

--encouraged to play outside
--made anxious about academic achievement, especially in
mathematics and natural science
--not asked to help with housework
--physically punished for bad behavior
--provided with more freedom in exploring environments
(play, academic, etc.)
--scolded for cowardly behavior
--instilled with higher academic aspirations

Girls:

--asked to help with housework
--made anxious about their manners
--instructed in the use of elegant and polite language
--encouraged to take lessons in artistic subjects
(piano, ballet, tea-ceremony, etc.)
--taught to be modest and restrained
--taught to obey elders

I found that sex-differentiated training is quite common among Japanese mothers; only 20% of the mothers studied train their sons and daughters equally without any discrimination. In general, girls receive more specific sex-differentiated training than do boys, and this kind of training appears to increase with age for daughters, while it decreases with age for sons.

To investigate these age-related changes, male and female university students were questioned about their personal experiences with parental sex-differentiated training and discipline from childhood through adolescence. Females reported much more experience with sex-differentiated training compared to their male siblings than did males compared to their sisters at all age levels. The results also showed that sex-differentiated discipline for boys decreases rapidly around the university age level, while it remains constant for girls.

In an attempt to assess the discrepancy between male and female experiences, male and female high school and university students' attitudes toward parental sex differentiated training were examined (Kashiwagi 1975a). Male adolescents tended to evaluate parental training more positively than did females. Within the female sample, negative and rejecting attitudes toward parental training of this sort were expressed, with the negative attitudes becoming increasingly pronounced at the university level.

An earlier study on the concept of sex-role in adolescence (Kashiwagi 1974), also indicates the presence of a dissimilarity between male and female attitudes toward sex-differentiation. In this study male and female university students were given a list of twenty-one sex-typed behavioral traits. The students were asked to rate the desirability of each trait for males and females according to two criteria:

1. What do *you* think about male and female roles?
2. What expectations about male and female roles are found in *society?*

The results showed a much larger discrepancy between personal concept of sex-role and perceived social norm of sex-role in female students than in male students. I believe that this disparity arises from the existence of a more modern concept of sex roles in women than in men. In other words, women do not necessarily discriminate between the two sexes, nor do they perceive the two sexes as having extremely opposite characteristics; but at the same time, they tend to perceive the social norm of sex-roles to be quite different from their own conception, and believe that contrasting traits are expected for men and women. This suggests that female adolescents may have some difficulties in accepting social normative sex-roles. Consequently, they may suffer from frustration, social and personal conflicts when they try to realize their own ideal way of life.

The predominance of sex-differentiated training in Japan led me to question its actual effect on the development of sex-typed behavior (Kashiwagi et. al., 1972). I compared the degree of sex-typed behavior of children who experienced severe sex-differentiated training, and of children who were equally trained regardless of sex. A positive relationship between maternal discipline and a child's sex-typing was found for both sexes and at all age levels. Children who were trained differently according to their sex tended to be much more sex-typed than children who were trained equally.

I gathered additional data which also support the relationship between parental sex-differentiated discipline and adolescent sex-role attitudes (Kashiwagi 1975b). Girls who received strong sex-differentiated discipline from their parents tended to accept parental discipline positively, and had a more traditional concept of sex roles in general. On the other hand, girls who experienced less sex-differentiated discipline tended to show less agreeable attitudes toward parental discipline of this type. In boys, equivalent relationships between parental discipline and child's attitudes were found at the high-school level, but not at the university level, where in fact the opposite attitudes were expressed. As previously mentioned, parental discipline for boys diminishes rapidly around the university age-level, a fact which provides a possible explanation for their change in attitudes toward parental discipline.

In a recent cross-national study (Azuma, Kashiwagi & Hess, in press) a number of maternal factors (mothers' attitudes and behavior toward their children) were found to be positively correlated with children's cognitive development in Japan and in the United States. However, when the data were later reanalyzed for each sex separately, the relationships between maternal factors and childrens' cognitive measures were found to be different for boys and girls, especially in Japan.

Tabulation of the number of correlations between these maternal variables and children's cognitive measures showed a similar number of correlations for boys and girls in the U.S. (37 for boys, 36 for girls). In Japan, however, there are significant differences in the number of correlations for each sex, with a higher proportion of correlations for boys than for girls (36 for boys, 22 for girls).

Moreover, the contents of the correlational patterns were not equal between the two sex groups. Although some of the correlations were common to both, others were significant for only one or the other sex. In the U.S., 63% of all correlations were common to both sexes, while the parallel figure was only 49% in Japan. The number of correlations effecting only one or the other sex appeared to be the same in both countries, but opposing correlations (negative correlation in one sex, positive in the other) were recognized much more in Japanese children.

These data suggest that maternal factors play a more important role in sex-typing in Japan than in the U.S. They also show that some kinds of maternal attitudes and behaviors which are related positively to a child's cognitive development are more frequently given to boys than to girls.

The implications of the data are great. Sex-typing is an almost ubiquitous characteristic of the environment in which most Japanese children are raised. However, the fact that a large percentage of female university students disapproved of their mothers' methods of sex-differentiated training suggests that the next generation will effect a change in this cultivated inequality between the sexes.

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"in the working of culture, the life of the individual is controlled by the culture and the individual effects the culture. The causal conditions of culture lie always in the interaction between the individual and society."

Franz Boas

Kanji Help Readers of Japanese Infer the Meaning of Unfamiliar Words.*

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Japanese sentences in newspapers, books, journals and letters are usually written by using "*kanji,*" and "*kana*" (more specifically, "hiragana") in combination. Kanji, is the word for Chinese character(s), about 2000 morphograms which originated in China, while kana are 71 syllables. Since the number of kinds of syllables is limited in the Japanese language because no two consonants appear consecutively, the 71 kana are enough to effectively represent any Japanese word. Therefore, one might ask: isn't the use of kanji unnecessary? It has often been claimed, by scholars as well as laymen, that we could stop using kanji, or at least reduce the number, in order to increase practical efficiency.

As Glushko (1979) aptly pointed out, the desirability of an orthography may be different for writers and readers, and differ according to the extent of their experience. The use of morphograms is apt to be difficult for beginners, and in fact Japanese students spend much time learning how to read and write kanji. For experienced writers, the use of kanji may not be inconvenient (except for typewriting), but it is not necessarily facilitative either. Therefore, it may benefit experienced readers only. Readers are certainly able to comprehend a text with kanji faster than without kanji. But what else? Suzuki (1975, 1977) claimed that kanji help readers resolve homonymic ambiguity and infer meanings of unfamiliar words.

Before reporting experiments examining this claim, let us briefly explain a unique characteristic of kanji in the Japanese language, one not shared by these characters in the Chinese language. Our basic assumptions about kanji's cognitive function are derived from this characteristic. Kanji are unique in that most of them are given two readings (pronunciations), i.e., Chinese and Japanese readings. Each Japanese reading historically originated by attaching a native Japanese word representing the meaning of the character to a Chinese character. Therefore, the Japanese reading is sometimes called the *semantic reading,* while the Chinese reading is regarded as the *phonetic reading.* A rough approximation in English is found in "etc.": "et cetera" could be called the Latin reading, and "and so on" the English reading.

Giving each kanji a Japanese reading has strengthened the association between individual kanji and their meanings. This dual reading system has also served to weaken the association between a kanji and either of its readings, as has the fact that many different kanji share the same Chinese reading. This is not the case for Chinese characters in the Chinese language, where each character is always given one and the same reading, shared by few, if any, other characters.

Does this unique characteristic of the dual readings of kanji affect the information-processing of words in the Japanese language? A majority of the substantive words in Japanese are comprised of several kanji, with or without kana. They are given either the Japanese or the Chinese reading, seldom both. However, because of the increased association of the component kanji with meaning (and the decreased association with pronunciation), we assume that the meanings of words transcribed in kanji can readily be retrieved by experienced readers in a direct manner and need not be mediated by phonetic codes. This notion of alternative information processing routes is schematically shown in our model in Figure 1. It implies the following three specific hypotheses:

Hypothesis 1: Meanings of words written in kanji can be understood even when their phonetic codes are not retrieved from the written transcriptions; meanings of the same words transcribed in kana can be understood only through the mediation of the phonetic codes.

Hypothesis 2: Meanings of words transcribed in kanji are better understood than those in kana when the phonetic codes are insufficient for determining meanings.

Hypothesis 3: In retrieving meanings from unfamiliar words transcribed in kana or their phonetic codes, kanji codes stored in the long-term memory (LTM) may be used as mediators.

Hypothesis 1 has been fairly well supported. The strongest evidence has come from studies on brain injuries. For example, aphasic patients with apraxia of speech showed much greater difficulty in transcription-to-picture matching for tachistoscopically presented kana words than for kanji words (Sasanuma & Fujimura, 1971). Alexia patients' reading ability was better preserved for kanji words than kana words (Yamadori, 1975). But Hypotheses 2 and 3 have not received any direct support, and we have, therefore, tried to investigate these two by experimentation.

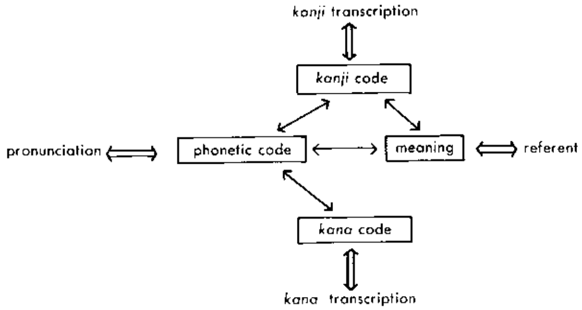

Figure 1. Retrievability relationships among various internal codes of a word (in rectangles) with the corresponding observables.

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Kanji words have high inferability of meaning

Now let us turn to our experiments on the role of kanji when a person must infer the meanings of unfamiliar technical terms. Most technical terms in the Japanese language, which are often translations from one of the European languages, are made up of two or more kanji. The resulting compound is usually given a Chinese reading which is simply the Chinese reading, in order of the component kanji. This is similar to the practice in English in which Greek words or Latin words are combined. In both cases these are compound words consisting of morphemes which are not used in daily conversation and are free from varieties of connotations, but semantically appropriate. Our basic model and Hypothesis 2 imply that, in comparing the inferability of meanings, technical terms transcribed in kanji are superior to the corresponding kana transcriptions (i.e., in the within-language comparison), and better also than Greek or Latin derived compound words in English (i.e., in the between-language comparison). The latter prediction was initially made by Suzuki (1975). He gave two primary reasons: (a) The component kanji are semantically understood far more easily than the component Greek or Latin words, because the former are already imbued with Japanese or semantic readings; (b) The component kanji are, unlike Greek/Latin components, not deformed by the influence of modified pronunciation.

An example will help readers recognize the plausibility of these predictions. Suppose that a person is trying to infer the meaning of the unfamiliar technical term *limnology* written in kanji (three morphograms), kana (six syllables) and English (nine letters). The English speaker can probably infer that the term has something to do with a branch of science from *-logy* but not beyond that, since he or she does not know what *limno* means. Presented with the term in kana, the Japanese speaker will list several possible semantic interpretations, but will not be able to narrow them down. With kanji, however, the reader of Japanese will be able to identify the meaning of each component character and then infer the meaning of the term.

In our experiment, undergraduates were asked to match 30 unfamiliar, technical terms with their definitions (and/or descriptions). We selected 30 Latin or Greek-derived English technical terms and their Japanese translations, which were kanji compound words with 2-5 component characters from the list given by Suzuki (1978). These were mostly from botany, zoology, medical science, psychology and linguistics.

Let us examine two examples of the technical terms and their definitions. They are: *limnology*--the scientific study of physical, chemical, and biological conditions in lakes and ponds; and *piscivorous* - eating fish as a regular diet.

Three groups of Japanese students were asked to match the words with their definitions. The word lists were presented in kanji, kana and English, respectively. A group of American students were tested by using the English definitions and word list.

The results are shown in Figure 2. The inferability in the kanji condition is almost perfect. Why is it so easy to infer meanings from the kanji expressions? The kanji expression for limnology is constructed of three characters, 湖沼学. Though it naturally has a phonetic reading, the three characters have semantic readings roughly corresponding to "lake(s)," "pond(s)" and "study (studies)" respectively, and these semantic readings can easily be understood even by children. (In Japanese we use the same character for singular and plural nouns: e.g., 湖 湖 "represents "lake" and "lakes".) Similarly, the component kanji of the Japanese word corresponding to "piscivorous" are semantically, "fish-eat-nature."

The order of performance of the four conditions was kanji, kana, English (American students) and English (Japanese students). It is not surprising that the Japanese students in the English condition performed very poorly, since English is not their first language. The kanji condition is superior to any other condition. This is consistent with our prediction that the words in kanji have higher inferability than the words in kana and English. Another interpretation is possible, however: Japanese students are already more familiar than Americans with the technical terms. To check this, we asked other groups of Japanese and American students to give the words corresponding to 30 definitions. When the students did not know the words, they were encouraged to invent them. The mean correct responses which included invention, were 7.23 among the Japanese students, and 5.00 among American students. The difference in mean correct responses between the two groups was small, and could not explain the large difference found in the matching performance.

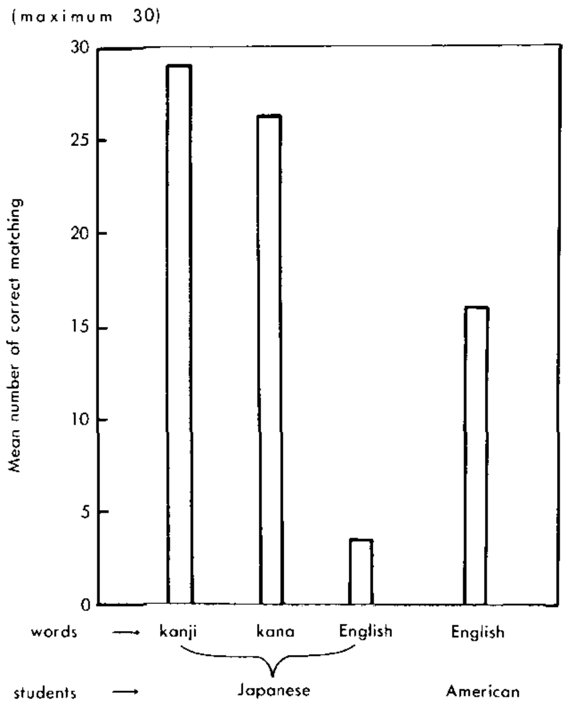

Figure 2. Mean Number of Correct Matchings of Definitions with Words.

The reader may wonder if the meanings of component kanji are really sufficient cues for inferring the meaning of most compound words. It is true that the meaning of a compound word cannot be determined solely by the meanings of its component kanji. However, there are other constraints by which the range of possible meanings for the word can be limited. First, experienced readers have acquired several compounding schemata by which kanji words are constructed. For example, when two nouns are compounded, the new word belongs to a family of the last noun. Thus 乳牛 (milk-cow) means a cow for milking and 牛乳 (cow-milk) means milk of a cow. Secondly, our world knowledge can be used to exclude some possible meanings and also to choose likely ones. This is similar to English speakers' differentiated interpretation of structurally similar phrases, like "horseshoe" and "alligator shoe." Finally, the context of the sentence, passage, or work as a whole can give additional clues to the meaning of the word in question. Therefore, meanings of component kanji only increase the inferability, but this increment is often very helpful.

Kanji's latent cognitive functions

Figure 2 shows that performance in the kana condition is at a fairly high level and only a little lower than that in the kanji condition. Hypothesis 3 suggests that this is because students in the kana condition often succeed in retrieving mentally the appropriate kanji, overcoming the phonetic constraint of the kana, by using the definitions as contextual information.

To test this idea, we examined the kanji representation of the technical terms chosen by the students in the kana condition. After matching the definitions with the words, the students in the kana condition were given a kanji encoding test. In the test they were given the 30 definitions and corresponding kana words correctly combined, then asked to change the kana into kanji. We examined the proportion of correct matchings as a function of correctness in the kanji encoding test. When kanji encodings were correct, the mean proportion of correct matching was 0.89, but when kanji encoding responses were incorrect or missing, the mean proportion was 0.69.

This difference is statistically significant, but the latter proportion is still fairly high. This is due to the fact that only the "critical" character(s) must be correct in order for the correct matching. For example, the Japanese word corresponding to "laryingal" consists of three kanji, but only the last one meaning "sound" is critical in order to match the word with the definition, "a sound articulated between vocal cords when breathing out."

Thus we conducted an auxiliary experiment to examine the correspondence of inferred meanings and the kanji representation of technical terms in a weaker sentential context. Ten technical terms sampled from the main experiment were used. Each of the sentences included one target word written in kana and underlined. As shown in the following examples, the target words were not given strong sentence contexts as had been done with the definitions in the main experiment.

He is a specialist in *koshogaku* (limnology) and has studied everywhere in Japan.

This animal lives by the river bank and is *gyoshokusei* (piscivorous).

A group of Japanese undergraduates were asked to write meanings of kana target words and to change the target words into kanji. Both inferred meanings and kanji encodings were classified into three categories: correct response, incorrect response, and no-answer (including incomplete response). The relationships between the meanings and kanji encodings were examined. Table 1 shows that the correspondence between inferred meanings and kanji encodings is very close. When the students make correct kanji encodings, they infer correct meanings in most cases. When they retrieve incorrect kanji, inferred meanings are also incorrect. Where the students fail to give kanji, they can not infer meanings.

Table 1
Relationships between Meaning and *Kanji* Representation of Target Words

Meaning	*Kanji Responses*		
(lenient criterion)	*Correct*	*Incorrect*	*No answer*
Correct	51.2%	4.2%	0.8%
Incorrect	2.7	16.9	1.5
No answer	6.5	6.2	10.0

Close correspondence is observed also among the incorrect responses. Three different incorrect responses are given for *koshogaku* (limnology) in the kanji encoding test: 古証学 古匠学 古称学 (all pronounced *koshogaku*). The component kanji have the meanings of "old-document-study," "old-artist-study" and "old-naming-study," respectively. As expected, the meanings of the words inferred by the students are highly similar to the integration of the meanings of the three component kanji. For example, students who gave 古匠学 in the kanji encoding test infer that *koshogaku* is a study of great artists in olden days. There were few incorrect responses for *gyoshokusei* (piscivorous). This can be attributed in part to the small number of kanji having the pronunciation of "gyo" or "shoku."

Several psycholinguistic studies (e.g., Rubenstein, et al., 1971) have tried to demonstrate that a written word is transformed into a phonetic code before its meaning is retrieved. This may be true with the Japanese language as long as the word is written in kana and is a familiar one, which can easily be understood by its phonetic code. However, when a phonetic code is insufficient for retrieving its meaning because it is unfamiliar, experienced Japanese readers do quite the opposite: they try to find a combination of kanji satisfying the given phonetic code and seemingly appropriate in the context, and then retrieve the meaning. This is what Hypothesis 3 is about. People rely on the same procedure when a pronounced word is ambiguous because of the presence of homonyms.

If this analysis is correct, as suggested by our experiments, it has an important implication. Readers of Japanese can understand unfamiliar words, spoken or written in kana, by the help of kanji codes stored in LTM. Therefore, it may well be misleading to claim that the use of kanji can be reduced without much sacrifice because readers of Japanese can communicate effectively in a spoken language.

Multiple mental lexicons

From the above findings and those from other experiments on the cognitive functions of kanji (e.g., Kuhara & Hatano, 1981), we now think that experienced readers of Japanese have, in addition to the usual mental lexicon of words, a mental lexicon of kanji or the corresponding morphemes as building blocks for compound words. The latter lexicon has a complex structure so that the component kanji can be retrieved either phonetically or semantically. Suppose Japanese readers fail to find the word in their word-lexicon that matches a given word-like utterance or string of characters. They will recognize that they do not know the word as a word, but still try to figure out its meaning by using the kanji-lexicon. Compounding schemata, world knowledge and contextual information may also be relied upon.

The readers can continue reading or oral conversation without break if the inferred meaning of the unknown compound word seems correct. Even when the inferred meaning has proven to be incorrect, they can easily learn the word "meaningfully" by using the kanji-lexicon. After the inference or learning, they may add the word to their word-lexicon or store the word only temporarily. For the purpose of the efficient processing of linguistic information, the word-lexicon should not be very large, and must be comprised of frequently used words. The kanji-lexicon can potentially generate a great number of compound words, though it may not give specified precise meanings, and retrieving word meanings from the kanji-lexicon tends to take a longer time. Thus these two lexicons can be used most effectively in combination, producing a flexible, large vocabulary.

Because of this multiple mental lexical system, experienced Japanese readers have, in fact, been able to increase and reorganize their vocabulary quite easily. According to a newspaper article by S. Ono (Mainichishinbun, June 17, 1980), about 15,000 words were invented in the first 20 years of the Meiji period to represent Western ideas, customs and things, and many of them were incorporated into the vocabulary of ordinary Japanese people. Most of the invented words were, as expected, compound kanji words. Thus we may credit kanji with playing an important role in the the rapid modernization of Japanese society.

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Toward Comparative Studies in Reading *Kanji* and *Kana*

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Recently many psychologists and linguists have become increasingly concerned about the Japanese language. In general, however, the tendency of the Japanese psychologist has been to give priority to the outcome of research conducted in America and Europe over original research conducted in Japan. This tendency does not pose any problems when a psychologist is working with rats or doing experiments with animals.

But there may be some barriers when we consider the theories of verbal learning and information processing involved in visual word recognition, since these processes are closely related to many aspects of language. Unfortunately, most theories of reading come from experiments with alphabets or syllabaries; as of now, we do not yet have enough evidence to show whether they can be directly adapted to the Japanese language, especially the ideographic script called Kanji (Chinese characters).

Since the Japanese language does differ from European languages in some fundamental respects, some knowledge of its structure and comparative studies are indispensable to creating a more general theory of visual word recognition, or reading. Therefore, I will briefly introduce the following three topics: (a) A general summary of the two writing systems used in the Japanese language; (b) Differences between Kanji and Kana reading from a standpoint of information processing; and (c) One possibility for cross-cultural studies in reading.

Two writing systems in the Japanese language

Writing systems are divided broadly into two types. The first type, alphabetic or syllabic script, uses a limited number of visual symbols to represent phonetic units. The second type, ideographic script, uses a very large number of visual symbols to represent semantic units. For example, the biggest Chinese character dictionary, compiled in Japan, the "Morohashi-Daikanwa-jiten," contains 49,946 Kanji characters (Osaka, 1976). To readers of an alphabetic system, the load of memorizing thousands of characters seems overwhelming. However, in average daily life in Japan, only 3,000 to 4,000 Kanji are used, of which 1,850 Kanji have been chosen as the "Tôyô-Kanji" (the Kanji for daily use, as designated in 1946), and 1,926 Kanji were chosen as the "Jôyô-Kanji" (the Kanji for common use, as designated in 1979). Newspapers, magazines, official documents and school books are generally written with only Tôyô-Kanji, or Jôyô-Kanji. Furthermore, out of these Tôyô-Kanji, about 900 characters have been chosen for all Japanese to learn during the first 6 years of compulsory education. These Kanji are called "Kyoiku-Kanji" (Educational-Kanji). Even 900 Kanji becomes quite a memory load for beginners, but the combination of Kanji elements, as explained later, makes it easy to master them.

Most languages use only one of the two systems, syllabic or ideographic script, but the Japanese language has both. The first is called "*Kana,*" with each character representing a syllable, (or more precisely, *mora,* see Sakamoto, 1980), and the second is called "*Kanji,*" with each character representing a morpheme, or meaningful unit. Consequently, semantically related words often contain a visually similar unit as a common radical. The Kanji characters were borrowed from China during several epochs, and the Kana characters were originally developed into two parallel syllabaries by simplifying Kanji (Hiragana) or by squaring the cursive style of writing Kanji (Katakana). Figure 1 shows an example of the origin of Kanji and the derivation of Katakana and Hiragana.

Both syllabaries employ only forty-six symbols and only two diacritical marks to represent phonetically the sounds of specific syllables. For that reason, individual characters from the two types of Kana may require no greater learning effort to master than Kanji themselves on the basis of physical memory load. Hiragana is used mainly for grammatical addenda or suffixes.

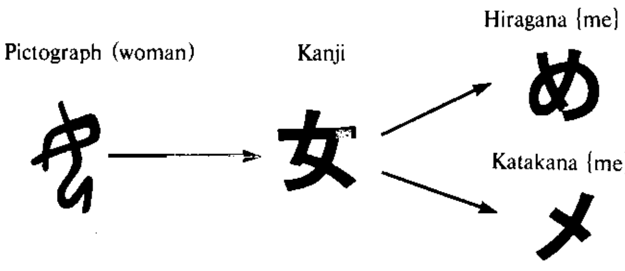

Figure 1. An example of the origin of Kanji and the derivation of Katakana and Hirangana.

Japanese is quite unlike Chinese, being highly inflected, though in a way entirely different from Indo-European languages. Verbs and adjectives can become very long through agglutination, for example, the word *kaku,* "to write," is changed into *kakanakatta,* "did not write" (Reischauer, 1979, p. 388). Katakana is used for loan words taken into Japanese, somewhat in the way italics are used in the alphabetic writing system. For example, it is used with names of foreign places, new words, and scientific terms.

It is possible to write Japanese using only Kana since the function of Kana is to represent sounds with no fixed meaning. Most commonly, in newspapers, magazines, and books, a combination of Kanji and Kana are used together. There seem to be several reasons why the Kanji-Hiragana combination is superior to other writing systems, such as Kana alone. Sakamoto and Makita (1973) argue that the Kanji-Hiragana combination enjoys three advantages over other writing systems:

1. Each Kanji has its own meaning so that nouns, roots of verbs, adjectives, and adverbs can be written in Kanji. In other words, key ideas or key words in each sentence are expressed in ideographs.
2. In an average sentence, from 25 to 35 percent of the total number of characters are written in Kanji. It must be emphasized that visual images of Kanji and Hiragana are quite different: Kanji are more complicated and square in shape than Hiragana. Kanji stand out, therefore, from the main background of Hiragana and can be recognized easily.
3. It takes fewer characters to make up words using Kanji than it does using only Hiragana, as a single Kanji can represent up to four syllables, although the most common is two syllables.

The internal structure of Kanji

In order to understand the nature of Kanji characters and their simplification by the combination of their elements, we must first examine their internal structure.

According to an old Chinese dictionary called "Setsumon Kaiji," Chinese pictographs (Kanji in Japan) are classified into six principal categories. Here I will take up the outline of four of the six categories related to word formation.

1. *Ideographic Characters (Shokei-Moji)*

Ideographic characters were simplified from concrete pictographs. Kanji are well known as pictographs, but pictographs are only a minority in the total vocabulary of Kanji.

2. *Diagrammatic Characters (Shiji-Moji)*

It is possible to illustrate an abstract idea, which is indicated with the help of points and lines above or below a line.

3. *Compound-ideographic Characters (Kaii-Moji)*

A compound-ideographic character is a combination of ideographic and diagrammatic characters.

4. *Phonetic-ideographic Characters (Keisei-Moji)*

A phonetic-ideographic character is the combination of a meaning part called the "radical" and a "phonetic" element. About 80 percent of Kanji belongs to his group (Sato, 1973). In this sense, we Japanese can guess the broad meaning of Kanji by the radical and guess the pronunciation of it by the phonetic element. However Chinese words as used in Japanese produce a problem. Over the centuries the Japanese incorporated into their own vocabulary a huge number of Chinese words, while disregarding the Chinese tonal system. When the Japanese borrowed the Chinese writing system they attempted to apply the logographic system of Chinese pronunciation to spoken Japanese. The result was that Kanji has two ways of being read in Japan, i.e., the "On-reading" and the "Kun-reading." The On-reading is the Chinese-style reading, which was taken from the original Chinese pronunciation, and the Kun-reading is the pronunciation of Japanese origin, which more directly corresponds to the meaning of the ideogram in Japanese. Although each Kanji has its own meaning, most words are made from the combination of two or more Kanji. These words are called *Jukugo* (a compound word) and most of them are assigned an On-reading. The compound word facilitates the inference of the meaning of each written word. It must be emphasized that technical and scholarly words written in compound always reveal clearly their component elements and in a way are self-explanatory. However, since the richer Chinese phonetic system was reduced to a much smaller number of sounds in Japanese, a great many words which sound quite different in Chinese are pronounced alike in Japanese (Reischauer, 1979, p. 390). For this reason, there are many homonyms in Japanese. Further information pertaining to the origin and formation of Kanji is available in Saito, Inoue, and Nomura (1979).

Past psychological research on reading and writing Kana

Imai and Fukuzawa (1980) reviewed the psychological research on reading and writing Kana. Their review included studies of:

(a) word-perception.
(b) mechanisms and processes of reading.
(c) factors affecting the acquisition of reading ability.
(d) teaching methods in reading.
(e) handwriting.
(f) the actual condition of reading and writing ability in kindergarten and preschool: age and sex differences.

Their summary shows that 76 percent of the research studies reported in this field were undertaken between 1970 and 1979. Because the number of studies reported on mechanisms and processes of reading was very small at the time of Imai and Fukuzawa's review, I will concentrate my discussion on this topic.

Differences between Kana and Kanji in extracting sound and meaning

Kanji have meaning even in sub-analytic units, or radicals. Moreover, compound words, *Jukugo,* are composed of two or more Kanji characters, with each character having its own meaning. Kanji generally have a hierarchical structure of meaning in the graphemic dimension. On the other hand, Kana represent a syllable, and are related directly to the sound of the letters or word rather than to its meaning. A word represented by Kanji is relatively more dominant in semantic processing than Kana, but a word represented by Kana is dominant in phonetic processing. Therefore it is possible that Japanese subjects pronounce or name Kana more rapidly than Kanji, but they have more ready access to semantic codes with Kanji than Kana.

Opposing this hypothesis, however, are the following considerations: First, if a prerequisite to reading a word aloud is lexical access to the word, it might be supposed that because Kanji have some advantage over Kana in this respect, reading aloud a word written in Kanji should be faster than reading aloud the same word written in Kana. Second, if the more familiar visual pattern is easier to perceive--and in Japan, Kanji provide the more familiar pattern in compound noun words--then it might be expected that Kanji would be read aloud faster than Kana.

To investigate this hypothesis, an oral-word-reading task was constructed, using compound Kanji words and the corresponding Kana words.

In Experiment I[1] there were two variables. One was the script type, each word occurred with equal frequency in four script-combination types: (1) Kana-Kana; (2) mixed Kana-Kanji words; (3) mixed Kanji-Kana words; (4) Kanji-Kanji. The other variable was the effect of varying the number of Kana required to write a word.

Eight native Japanese served as subjects. They were required to read aloud, as quickly as possible, the words written in the four script types, containing up to five *mora* when written in Kana. The stimulus words were presented on slide projectors with tachistoscopic shutters. They were projected onto a black glass rear-projection screen for 0.3 seconds followed by a dark interval of 2.5 seconds. Subjects viewed them from a position 0.7 meters away, directly in front of the screen. Response latencies were measured from stimulus onset to the onset of vocalization. The four script types of five mora forms were each presented eight times in a random order making a total of 160 observations.

The results of Experiment I showed that oral reading time for Kanji was not affected by the number of mora to be pronounced. Kana readings were affected, although Kana were read aloud more rapidly than Kanji. This supports the hypothesis that a word represented by Kana has some advantages in phonetic processing. The same result is reported by Feldman and Turvey (1980). One possible difficulty with this conclusion is that rapid naming does not necessarily indicate thorough semantic processing.

Experiment II[2] was performed to investigate whether the words represented in Kana were read aloud with adequate semantic processing. There were three factors in Experiment II: the first was the script type studied in Experiment I; the second was the reading method: reading aloud (Aural Reading condition), or reading silently (Silent Reading condition); and the third was the order of presentation: either a single word preceded a sentence, or vice versa. In the Word Preceeding condition, Aural Reading subjects were instructed to read aloud as quickly as possible the first stimulus word, presented for 0.3 seconds followed by a dark interval of 0.4 seconds. They were then to judge whether or not the word was semantically congruent with the sentence, which was presented for 3 seconds. Silent Reading subjects were

[1]Experiment I was reported in the 91st Annual Convention of Kansai Psychology, 1979.

[2]Experiment II was reported in the 21st Annual Convention of the Japanese Association of Educational Psychology, 1979.

asked to perform the same task. In the Sentence Preceeding condition, the same instructions were given the subjects, the only difference being that the sentence preceded the target word.

The results showed that with the Aural Readers, there were no differences in the speed of judgement between Kanji and Kana, but with the Silent Readers, Kanji were judged for semantic appropriateness faster than Kana.

These results suggest that Kana are superior in access to the phonemic codes than Kanji, but this does not imply that the meaning is comprehended more rapidly. In contrast, Kanji take longer to read aloud (decode) than Kana, but Kanji make rapid access to semantic codes possible.

This would seem to indicate that Kanji are processed directly from visual (graphemic codes) to meaning (semantic codes) in the silent reading condition, whereas in Kana, the relation of graphemic code to meaning is mediated through the sound system. That is, Kanji have the ability to suggest their meaning without reference to their sound. However, Kanji present some difficulties for reading aloud with the appropriate pronunciation because each Kanji is related to both On and Kun readings while each Kana is related to only one pronunciation.

One possibility for cross-cultural studies in reading

According to Glushko (1979), in the absence of comparative studies of the comprehensibility of different orthographies by fluent readers, it is premature to suggest that the learnability of a script takes precedence over its oral readability.

I agree with his opinion, and so would like to propose one possibility for comparative cross-cultural studies of reading. Many psychological experiments are now controlled by microcomputers which contain many possibilities for use in a wide variety of apparatus. In my case, for example, I have begun to use a microcomputer system which consists of "Apple II Plus" with an "Apple clock," a "mini floppy disk," and a "graphic tablet." The programs used in the system are usually written in Basic Language, and the time control programs are written in Machine Language. They enable us to control the time duration of two stimuli and size ratios, and the order of stimuli are changed easily.

Whereas making identical slides for the standard projector-type tachistoscope was extremely time consuming and unreliable, this kind of microcomputer system provides us with the necessary accuracy and speed for reproducing identical stimulus conditions anywhere, at any time. Therefore, if we could utilize mini floppy diskettes containing individual research programs in the future, we could reproduce the same experiments in any laboratory.

More specifically, Kanji and Kana experiments could quickly be performed by researchers with no knowledge of the Japanese language. This could provide us with fruitful evidence as a comparative cross-cultural experiment, for both Japanese and non-Japanese researchers in reading.

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'Body Analogy' and the Cognition of Rotated Figures

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A few years ago, I bought a new moped for daily transportation to my office. For the first couple of weeks that I rode the bike, I could not overcome a particular difficulty in signaling turns: when I was turning, I always found the turn-signal flashing in the opposite direction I intended. The cause of the difficulty was obvious. The turn-signal switch, which was located near the right grip, was set up so that flipping to the right would flash the signal for a left turn and flipping to the left would flash the signal for a right turn. (See Figure 1).

The first thing I tried in order to overcome this difficulty was to flip the switch twice, first to the direction which I naturally *felt* to be correct, then to the opposite side, which I *knew* to be correct. Although this habit ultimately guaranteed the correct signal, it took too long and angry drivers often honked behind my bike.

Fortunately, I found an easy way to make the trouble disappear, and I have never had any trouble in signaling turns since then. The trick was quite simple: I imagined a steering wheel of an ordinary car over the handle bars of the bike. (See Figure 1). In Japanese cars, a steering wheel usually has a *turn-signal* attached to the right side of the steering column. (The driver's seat is located at the right side in Japanese cars). The right turn-signal flashes if the lever is flipped downward, and the left turn-signal flashes if the lever is flipped upward (See Figure 1). So, when I wanted to signal a turn on the bike, I simply imagined myself manipulating a "turn-signal lever" over the handle, flipping to the direction which was quite natural for turns if I were driving a car.

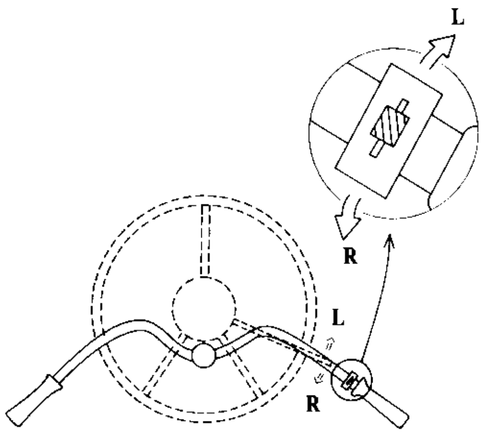


Figure 1. Imaginary steering wheel and turn signal lever over the handlebars of the bike.

Such elaborated imagery of a steering wheel and a turn-signal lever was necessary only at first. The image soon faded away, and after a week or so, it seemed that a faint feeling, or only a small fragment of the "tactile image," of flipping the lever by the thumb was sufficient to elicit a correct response. After a few more weeks of practicing, signaling for turns became completely automatic, and I did not even think of the direction of flipping the switch.

This episode is an example of a very common heuristic, namely, "To see something as if it were something else." This kind of heuristic is well practiced in children's play, poets' metaphors, physicists' models, and equations in mathematicians' theorems. The only thing we know for sure about this heuristic is that it works. Once we discover that object A can be viewed as if it were object B, for the purposes at hand the relevant structural and functional relationships suddenly become apparent.

In viewing A as if it were B, we do not transfer all of the relations or the procedures from B to A. In the above example, when I viewed the turn switch as if it were the turn-signal lever of a car, I did not grasp the switch by the right hand, as I would do for the turn-signal lever. I only pushed a tiny nob in the direction of the "lever" turn with the thumb. Thus in viewing A as if it were B, most of the schema for A may remain the same, with modifications at a crucial point. The image of B seems to prepare the new schema for activation as soon as the old schema has been "detached" from the environmental constraints. In the present example, grasping the grip of the handle belongs to the old schema and is strongly imposed by the environmental constraints: we cannot remove the right hand from the grip, no matter how vividly we imagine the steering wheel or the turning lever of a car. But the direction of moving the thumb is a "detachable" part of the schema, although in the old schema the thumb tends to move in the wrong direction. Thus it is the direction of the movement of the thumb that was replaced by the new schema which had been prepared for activation by imagining the turn-signal lever.

From this analysis, we may understand why seeing A as analogous to B works. It works by opening our eyes to the new *possibilities* which have been well-practiced with B but which have never been thought of for A because of the old schema for A. The introduction of B as an analogy for A replaces those "detachable" parts of the old schema for A by new possibilities suggested by B, while the "undetachable" parts of the old schema for A remain the same, because of strong contextual, environmental constraints.

This interpretation explains the so-called "directionality" of analogy. The analogy of B for A is not the same as the analogy of A for B. Such directionality comes from the simple fact that "detachable" parts of the schema for A are different from "detachable" parts of the schema for B.

The experiments introduced below demonstrate that viewing a configuration of blocks as if it were a *human body* drastically reduced the reaction time to decide whether the presented shape (rotated through a variety of degrees) was the same as the standard shape or different (its mirror image), regardless of the angular disparity. Response time on this task has been known to be proportional to the amount of physical rotation necessary to align the two shapes spatially, (e.g., Shepard and Metzler, 1971). In our experiments, however, once a visual cue hinted at a "body analogy," then even with the "hint" subsequently removed, subjects could immediately attend to the critical part of the "body" which distinguishes most effectively different "postures" in the block configurations.

Experiment I compares three conditions: Non-Instruction in which the subject was not given any specific suggestions about strategy, Turn in which the subject was instructed to rotate the standard figure in his mind to align it with the stimulus figure, and Head-at-Normal-Position in which the subject was given a visual "hint" without any verbal comment - a configuration of blocks was shown with a "head" placed in a position which suggested the shape (posture) of a "human body."

Experiment II simply adds two conditions to the instruction; Arrow-Indicator in which an arrow-line was indicated in place of the "head" in the Head-at-Normal-Position, and Head-at-Abnormal-Position in which the position of the "head" was shifted to a position not conducive to interpreting of the block configuration as a "human body." Reaction time was taken separately for "same" judgements and "different" judgements in Experiment II.

Experiment I

Twenty-four male students at Tokyo University of Science participated in the experiment. They were arbitrarily assigned to three groups, Non-Instruction, Turn, Head-at-Normal-Position, each containing eight subjects.

A set of 48 slides were projected on a screen in front of the subject. On each slide, there were two figures displayed horizontally: the figure on the left was always the same, standard figure, a perspective line drawing of a three dimensional configuration of blocks, similar to the figures in Shepard and Metzler (1971). The figure on the right was obtained by rotating on the picture plane either the standard figure or its mirror image. There were twelve different positions of the standard figure, rotated in steps of 30° from 0° to 330°. Twelve positions of the mirror image were similarly obtained. Each of the twenty-four different pairs of figures were presented twice during each experimental run.

The experiment was run for each subject individually. The subjects were informed that there would be 48 trials, with two figures projected on the screen for each trial. The figure on the left was always the same, but the figure on the right was either a rotation of the figure on the left, or a rotation of its mirror image. They were asked to judge whether the two figures were the same, or mirror images, and to respond accordingly as quickly as possible.

The subjects were then shown a slide with a standard figure and a rotated standard figure. The experimenter explained that the two figures were simply different views of the same object. He instructed the subjects to examine the figures and respond when they had confirmed that the figures were the same.

The next slide was of the same standard figure and a rotated mirror image of the standard. The experimenter explained that in these slides the two figures were different views of the mirror images of each other. The subjects were asked to examine the slides and respond when they had confirmed this fact.

After the instruction, subjects under the three conditions were treated differently. The subjects in the Non-Instruction condition were simply shown a slide of the standard figure alone for one minute. The subjects in the Turn condition were shown a slide of the standard figure alone for one minute and instructed to practice mentally rotating it. They were told that rotating the standard figure to align it with the second figure would help them judge identity. In the Head-at-Normal-Position condition, subjects were presented for one minute a slide of the standard figure with a head on it. The head was positioned to suggest correspondence between the block configuration and a specific body posture. This suggested correspondence was not verbally mentioned and no instructions were given concerning strategies for making identity judgements. (See Figure 2).

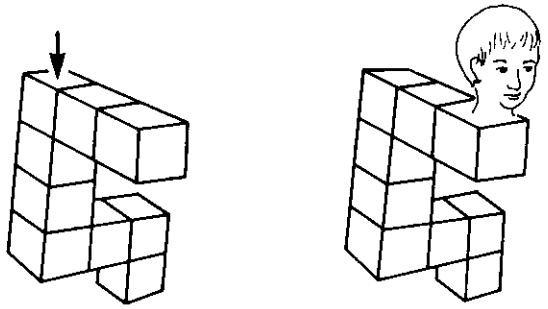
After the above instructions were given, subjects in all of the three conditions were presented with the same set of 48 slides. The reaction time was recorded to the nearest millisecond by a microcomputer from the time of onset of the projected slide, to the subject's button push.

Results

We computed regression lines for reaction time as a linear function of angular disparity between the two figures in the stimulus display. Angular disparities for more than 180 degrees were transformed into the interval of 0 - 180 degrees. For example, data for 270 degrees of clockwise rotation, or 90 degrees of counterclockwise rotation, were both treated as 90 degrees of disparity in the analysis.

The slope of the regression lines for Non-Instruction and Turn were almost identical except for the intercepts (Turn, $y = 0.0140X + 2.37$; Non-Instruction, $y = 0.0147X + 1.81$). In other words, the instruction to "Turn" produced almost the same "speed" of mental rotation (68-70 degrees per second) as "No-instruction," but asking subjects to "Turn" their mental images slowed their overall responses 0.6 seconds more than "No-instruction."

On the other hand, the regression line for Head-at-Normal-Position is almost flat ($y = 0.0010X + 1.50$). This result can hardly be interpreted as the effect of "mental rotation." If we use the Head-at-Normal-Position data to estimate the "speed" of rotation, we would calculate 2.6 revolutions per second! The Head-at-Normal-Position instructions also produced less errors in subjects' judgements: 11.5 percent errors in Non-Instruction, 10.7 percent errors in Turn, and 6.3 percent errors in Head-at-Normal-Position.



a.   b.

Figure 2.

a. **Block configuration in standard position.**
b. **Standard block configuration with head suggesting body position.**

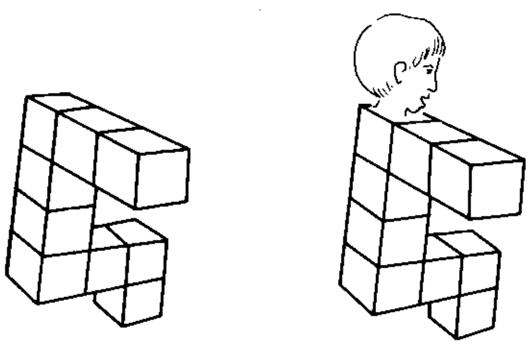
In order to see what individual subjects were doing as they became more practiced, we traced the change of the regression coefficients, slope and intercept, for the subject's responses in *moving intervals* of every six trials; that is, the subject's responses from the first trial to the sixth trial were analyzed, and then his responses from the second to the seventh trials were analyzed, and so on. If the subject was really *rotating* his mental image with a fixed speed, then the slope and the intercept in every moving interval should not change. More precisely, if the subject did not learn about the rotation of mental images, but did learn how to respond, then we would expect that the slope would not change much, while the intercept would go down. On the other hand, if the subject learned about the rotation, without learning about responding, then the slopes would become smaller, without much change in the intercepts, and so on.

When we analyzed individual data for the moving intervals, we were surprised to see that in the Non-Instruction and Turn conditions there were large fluctuations of slopes and intercepts like a random walk from one trial to another. On the other hand, responses under Head-at-Normal-Position were, without exception, very stable. All slopes and intercepts were near zero and fluctuated only slightly.

Although the drastic reduction of reaction time and the small effect of figural rotation were observed in the Head-at-Normal-Position group, perhaps those effects simply resulted from the addition of an external cue to the stimulus figure in the instruction period. In order to eliminate such possibilities, Experiment II introduced two additional conditions; Arrow-Indicator in which an arrow line was put at the position where the "head" had been put in the figure for Head-at-Normal-Position, and Head-at-Abnormal-Position in which the "head" was shown in a position that makes it difficult to imagine the configuration of blocks as a "human body." It was expected that neither condition would reduce reaction time and that some "rotation effects" would be observed as in the previous conditions, Non-Instruction and Turn.

Experiment II

Subjects were forty male student volunteers at Tokyo University of Science. They were randomly assigned to two conditions, Arrow-Indicator and Head-at-Abnormal-Position, with equal numbers of subjects. Subjects under each condition were further divided into "SAME" group and "DIFFERENT" groups. Subjects in SAME responded by pushing a button only when the two figures on the display were different views of the same object, and did not respond (simply saying "Pass") when the two figures were views of different objects. Subjects in DIFFERENT pushed the button only when the two figures on the display were views of different objects, and said, "Pass" otherwise. The experimental procedure was the same as in Head-at-Normal-Position in Experiment II except for the slide presented during the instruction period. The slides shown in Figure 3 were presented in place of the slide shown in the Head-at-Normal-Position condition in the first experiment.



a. b.

Figure 3.

a. Block configuration in standard position.
b. Standard block configuration in Head-at-Abnormal-Position.

Results

Regression lines were computed for Arrow-Indicator-SAME, Arrow-Indicator-DIFFERENT, Head-at-Abnormal-Position-SAME, and Head-at-Abnormal-Position-DIFFERENT. The two SAME judgements produced essentially the same regression line which has a large slope (0.02) with small intercept (about 1 second). This slope implies about 50 degrees of "rotation" per second. The two DIFFERENT judgements produced similar slopes (0.00786 for Arrow-Indicator, and 0.00109 for Head-at-Abnormal-Position), approximately 100 - 125 degrees of rotation per second, but with about 1.5 seconds' difference in the intercepts. This analysis clearly indicates that subjects were paying attention to many different points in the stimulus figures before they decided whether the two figures were the same or different, and that no one point was considered "critical." What they seemed to be doing was to search for any point which proves "difference," but they did not know *where* to look. If they could not find a point which proved difference after searching for some period of time, they decided that the two figures were the same. They would allow themselves more time to decide if the two figures had a large angular disparity.

Individual response data were analysed for moving intervals of every six trials. As in the previous analysis of the Non-Instruction and Turn conditions, the slopes and intercepts fluctuated up and down from one trial to the next.

Conclusions

The results of the two experiments suggest the following points.

During the ordinary "mental rotation" task, similar to that of Shepard and Metzler (1971), subjects actually attempted a number of different strategies to find distinct cues and the ways to match the two figures. This resulted in great fluctuations of both slopes and intercepts of successive regression lines.

The unstable search for cues seems to be rather unconscious. Even if the subjects were instructed to "rotate" their mental images (and they actually reported that they had done so), the fluctuations of the response data appeared to be even larger than in the no-instruction case.

On the other hand, the suggestion of a "body analogy" for the figures seems to be very easy for the subjects to use. Without exception, all subjects showed extremely stable responses from the first trial, with almost zero slopes and extremely small intercepts. The suggestion for the "body analogy" was not explicitly stated; subjects were shown only a single slide of a block with a human head placed at a proper position.

Neither placing the human head at an improper position nor putting an arrow line at the normal "head" position made much difference from the no-instruction condition, although putting the "head" at the improper position helped slightly for matching the figures with small angular disparities.

It should be noted that there was a large difference between the SAME and DIFFERENT conditions; with much faster reaction in the SAME condition. This fact may support our conjecture that the so-called "mental rotation" task may not be like a physical process of rotation/matching of a template, but more like a search process of *disproving* the proposition that the two figures were DIFFERENT. The reaction time seemed to be spent for finding what kinds of cues can disprove the proposition most effectively. The reason that the "body analogy" worked may be that it is easy to find cues which trigger entirely different actions (imaginary extensions of the right or left arm), which clearly prove or disprove the proposition that the two figures are the SAME or DIFFERENT. The distinctiveness of these cues comes from the mental schema which directs the activation of different body movements. The "body analogy" seems to be a rich storehouse of such schemata consisting of a variety of levels and hierarchies of cues triggering different body movements. Moreover, all of the schemata in the body movements have been well practiced, ready to be called upon whenever proper goals and constraints are imposed. Therefore, the schemata are ready to be activated even to a fragment of external stimulus, as long as it is possible to "view the object as if it were (a part of) my own body."

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