It was predicted that the use of a foreign language should cause a *temporary* decline of thinking ability because the heavier processing load imposed by a foreign language than by a native language should produce stronger interference with thinking to be performed concurrently. A divided-attention experiment with Japanese-English and English-Japanese bilinguals confirmed this prediction: performance in a thinking task (i.e., calculation) declined when a concurrent linguistic task (i.e., question-answering) had to be performed in their respective foreign languages. This decline is distinguished from foreign language processing difficulty per se because the thinking task involved no foreign language use. The decline was also observed in another divided-attention experiment employing a different type of thinking task, that is, spatial reasoning problems adopted from intelligence tests.

A TEMPORARY DECLINE OF THINKING ABILITY DURING FOREIGN LANGUAGE PROCESSING

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The present paper proposes and verifies a hypothesis that the use of an unskilled foreign language should be accompanied by a temporary decline of thinking ability. This hypothesis is derived both from analyses of ordinary verbal activities and from two empirical findings established by experimental studies of attention.

Ordinary verbal activities (e.g., conversation and negotiation) can be considered to consist of two kinds of cognitive tasks: linguistic processing and thinking. On the one hand, *linguistic processing* refers to those types of cognitive processes that are directly related to comprehension and production of sentences: phonetic analysis, graphemic analysis, parsing, generation and transformation of sentences, articulation, writing, and the like. On the other hand, *thinking* refers to those types of cognitive processes that do not directly

AUTHORS' NOTE: Portions of the reported study were presented by the first author at the 50th annual convention of the Japanese Psychological Association, October 1986, Nagoya. The authors are grateful to Dr. Ulric Neisser and two anonymous reviewers for their thoughtful comments on earlier drafts, to Dr. Thomas A. Stoffregen and Dr. Brenda Bankart for their assistance in preparing English verbal materials, and to Dr. Ryoji Osaka and the Tanaka Institute of Education for their permission to use their test materials. Requests for reprints should be sent to Yohtaro Takano, Department of Psychology, Faculty of Letters, University of Tokyo, Bunkyo-ku, Tokyo 113, Japan.

JOURNAL OF CROSS-CULTURAL PSYCHOLOGY, Vol. 24 No. 4, December 1993 445-462

deal with the input and output of sentences. They are responsible for further information processing that is needed mainly to make an appropriate response.[1]

It should be noted that, in most ordinary verbal activities, thinking has to be conducted in parallel with linguistic processing, that is, while either listening to the partner's ongoing speech or talking about related but secondary matters. Otherwise, what has to be reasoned may be forgotten, or a response may fail to be emitted in a timely manner. It is usually difficult to secure frequent silent periods for thinking during ordinary verbal activities.

In past experimental studies of attention, it has been established that two demanding cognitive tasks interfere with each other when performed concurrently (e.g., Broadbent, 1958; Norman & Bobrow, 1975; Treisman, 1969). If it is attempted to perform either one of those concurrent tasks efficiently, performance of the other task has to be sacrificed. Accordingly, linguistic processing and thinking performed concurrently in ordinary verbal activities are expected to interfere with each other, resulting in lowered performance of one or the other. Typically, it is thinking that has to be sacrificed because completion of linguistic processing is a prerequisite for any appropriate response.

It has also been established that intensive practice makes it possible to perform both concurrent tasks efficiently with little or no mutual interference (Hirst, Spelke, Reaves, Caharack, & Neisser, 1980; LaBerge, 1981; Schneider, Dumais, & Shiffrin, 1984; Spelke, Hirst, & Neisser, 1976; Underwood, 1974). The proficiency difference between a native language and a foreign language comes into play at this point. The interference by a native language is expected to be relatively small in magnitude because it has been practiced intensively since early infancy, which is often claimed to be a critical period for language acquisition (Johnson & Newport, 1989); by contrast, the interference by an unskilled foreign language is expected to be relatively large in magnitude because it has been practiced much less intensively, typically after early infancy. The decline of thinking ability during the use of a foreign language is thus predicted.

Several remarks have to be added to avoid often made misunderstandings with regard to this prediction. First, the predicted phenomenon is not the well-known difficulty in understanding or speaking a foreign language but its concomitant difficulty in concurrent thinking. Second, it is not permanent damage of thinking ability but only a temporary deterioration while a foreign language is in use. Third, it does not inevitably accompany every foreign language use: it is expected to disappear when the proficiency level of a foreign language reaches that of a native language. Fourth, the predicted phenomenon is not necessarily confined to the use of foreign languages: it may be observed, for example, when an unfamiliar dialect is being used. Fifth, the proposed hypothesis does not depend on any particular theory of attention. It has been derived directly from the above two established findings about attention. Any valid theory of attention has to be able to explain these established findings. Therefore, the present hypothesis should be compatible with any valid theory of attention.

The sixth remark concerns the presupposed dichotomy, linguistic processing and thinking. For the present hypothesis to be valid, it is unnecessary to assume that thinking is exclusively nonlinguistic. What has to be assumed is simply that thinking consists at least partly of such information processing that is different from linguistic processing defined earlier. This assumption is justifiable because what is usually called thinking is not equal to mere analysis of input language or production of output language. It is indeed possible that thinking may sometimes be accompanied by internal speech, which could be the object of linguistic processing. However, this does not mean that thinking and linguistic processing are synonymous. No reliable empirical evidence has been provided for the strongest version of the linguistic relativity hypothesis that advocates this theoretical position (Takano, 1989a). On the contrary, a number of cognitive processes can be realized only by assuming nonlinguistic information processing (e.g., Anderson, 1976; Gardner, 1974; Holland, Holyoak, Nisbett, & Thagard, 1986; Newell & Simon, 1972), a good instance of which is operation of mental imagery (e.g., Kosslyn, 1980; Shepard & Cooper, 1982). In short, what is needed by the proposed hypothesis is simply that interference is expected between linguistic processing of external language on the one hand, and thinking on the other, which involves both linguistic processing of internal language and nonlinguistic information processing.

However, some experimental studies of task interference suggest alternative possibilities that the present hypothesis may not hold valid. Two of them are worth mentioning: distinctness effect and similarity effect. First, little or no interference is observed when two concurrent tasks are distinct enough from each other (e.g., Allport, 1979; Navon & Gopher, 1979; Treisman & Davies, 1973). The possibility that linguistic processing and thinking are distinct enough cannot be excluded on a priori grounds, and thus the predicted phenomenon may not be observed in reality. The second possibility makes a prediction exactly opposite to the one made by the present hypothesis: Thinking may sometimes be accompanied by internal language, which will be provided mostly in a native language because it is easier to process. Generally, interference tends to be stronger between similar processings than between dissimilar ones (e.g., Brooks, 1968; Hatano, Miyake, & Binks, 1977; Stroop, 1935; Treisman, 1964). Then it is predicted that interference will be stronger when a native language is used overtly because the processing of external language and internal language are similar to each other due to the use of the identical language. In fact, McNellis and Neisser (1982) found that the processing of native language input presented to one modality (either aural or visual) was disturbed more strongly by native language input than by foreign language input presented to the other modality. Given these alternative possibilities, it is obvious that empirical evidence is indispensable in judging whether or not the predicted phenomenon is actually manifested.

EXPERIMENT 1

To differentiate the predicted phenomenon from difficulty in foreign language processing per se in an empirical test, an imposed task has to be a dual task, in which a thinking task with no overt use of language is required to be performed simultaneously with a linguistic task that principally consists of processing of either a native language or a foreign language. In the present experiment, the linguistic task was question-answering whereas the thinking task was calculation. Both Japanese-English and English-Japanese bilinguals were asked to perform these two tasks simultaneously.

METHOD

Design. Two independent variables were manipulated within subjects: the presence or absence of the linguistic task, and the type of language, a native language or a foreign language with which the linguistic task was to be performed. A combination of these two variables resulted in three conditions: (a) a single-task trial without the linguistic task, (b) a dual-task trial with the native language linguistic task, and (c) a dual-task trial with the foreign language linguistic task. The order of the single-task trial and the dual-task trials and the order of the native language dual-task trial and the foreign language dual-task trial were counterbalanced orthogonally to each other between subjects within each linguistic group.

Subjects. The Japanese group, consisting of 24 undergraduates, graduates, and visiting scholars, were tested at Cornell University in the United States. There were 20 males and 4 females with a mean age of 28.3 years (*SD* 3.9). All of them were born in Japan; their native language was Japanese. They learned English as a second language for 6 to 8 years at high schools and colleges from the age of about 12. Typically, stress is laid upon reading and writing, not upon listening and speaking, in the English programs provided by those regular educational institutions in Japan. All of these subjects had some additional instruction in oral English in programs specializing in the instruction of English as a foreign language, before and/or after moving to the United States. The average length of stay in English-speaking countries (the United States in most cases) was 2.8 years (*SD* 2.7), ranging from 0.4 to 11.5 years. The English-speaking group, 16 native English speakers from the United States, Britain, and Canada, were tested at Waseda University in Japan. Seven of them were undergraduates, 3 were graduates at Waseda University, 2 were students at a private school that specialized in the Japanese language, and the remaining 4 were businessmen. Nine of them were male and the remaining 7 were female, with the mean age of 23.4 years (*SD* 3.6). They learned Japanese as a third or fourth language for 4.8 years on the average (*SD* 3.6) at colleges and language schools. The average length of stay in Japan was 1.9 years (*SD* 1.7) ranging from 0.8 to 5.8 years.

Materials. For the thinking task, a stopwatch and seven calculation sheets were prepared. On each of these sheets, random numbers between 10 and 40 were printed in the form of a 13 × 13 matrix. Three of them were randomly chosen to be assigned to the above three trials; the remaining sheets were used in the practice trials and when the subject performed more than 13 × 13 calculations.

For the linguistic task, two lists of commonsense questions were prepared in both languages. Each list contained 20 questions; 13 of them required yes/no answers (e.g., "Is a lion an animal that lives in water?"), whereas the remaining 7 questions required well-known proper names or common nouns as their answers (e.g., "What is the name of a person who is the president of the United States?"). In the English lists, every question was asked with a complex sentence containing two clauses combined by a relative pronoun so that the linguistic processing would be demanding enough. In the Japanese lists, every question was asked with the type of sentence that would grammatically correspond to an English complex sentence. The English lists, together with directions, were tape-recorded by a male American graduate student who spoke midwestern English; the Japanese lists were tape-recorded by a male Japanese graduate student who spoke Tokyo-standard Japanese. The questions were read out at a rate of 1 question every 10 seconds. The total net time spent presenting all of the 20 questions was about 62 seconds in one list and 63 seconds in the other—the total net time was made equal between the two languages in either list. A list of six similar questions was also tape-recorded in both languages to be used in the practice trials.

Procedures. Each subject was tested individually in an experimental session consisting of an instruction, the above three trials, introspection reports, and demographic questions.

A dual-task trial consisted of a practice trial of 70 seconds and a test trial of 210 seconds, whereas a single-task trial consisted only of a test trial of 210 seconds. A dual-task test trial proceeded as follows: A tape-recorded direction, "Ready?" alerted the subject. Upon hearing the next direction, "Start," the subject initiated the calculation. Ten seconds later, the first question was presented. After a response was emitted, the subject could concentrate on the calculation until the next question was presented. The subject terminated the calculation with a tape-recorded direction, "Stop." In the single-task trial, those three directions alone were given by the experimenter with the stopwatch in the same temporal organization. The contents of the dual-task practice trial were identical to those of the dual-task test trial except for the number of questions presented.

In the thinking task, the subject was asked to add every adjacent pair of numbers in a row of the matrix, and to write down the answer underneath the pair with a pencil as in Kraepelin's (1895) test. Both accuracy and speed were equally stressed. In the linguistic task, the subject was asked to answer each question orally in either of the two languages that first came to mind, irrespective of the language in which the question was asked. The subject was asked to respond by saying, "I don't know," in either of the two languages, whenever the subject did not know the answer or failed to understand the question.[2] In the dual-task trial, the subject was instructed to continue the calculation while listening to and answering the questions. Both tasks were equally emphasized.

RESULTS

According to the proposed hypothesis, the number of correct calculations should be smaller when the foreign language was used than when the native language was used in the question-answering task. This prediction was confirmed in both groups of subjects. The mean numbers of correct calculations and errors for the Japanese group are shown in Table 1. The use of foreign language in the linguistic task caused a performance decline of about 13 correct calculations in the thinking task. This difference between the native and foreign language conditions was highly significant, $t(23) = 5.263$, $p < .001$. The same pattern of results was obtained for the English group as well (see Table 1). The use of foreign language caused a performance decline of about 14 correct calculations. This difference was also highly significant, $t(15) = 6.947, p < .001$.

For the question-answering task, Table 1 presents the mean numbers of correct answers, errors (i.e., wrong answers), and failures (i.e., "I don't know" responses), for the Japanese and English groups, respectively. Not surpris-

TABLE 1
The Results of Experiment 1: The Mean Numbers of Correct Calculations and Errors in the Thinking Task (i.e., Calculation) and the Mean Numbers of Correct Answers, Errors, and Failures (i.e., "I Don't Know" Responses) in the Linguistic Task (i.e., Question Answering)

		Calculation		*Question-Answering*		
Group	*Linguistic Task*	*Correct*	*Error*	*Correct*	*Error*	*Failure*
Japanese	None	116.7	4.6	—	—	—
(*N*=20)		(24.1)	(4.1)			
	Native	93.9	2.9	19.1	.3	.6
	(Japanese)	(23.8)	(2.6)	(1.2)	(.5)	(1.0)
	Foreign	80.6	2.8	16.6	1.2	2.2
	(English)	(19.1)	(2.9)	(2.3)	(1.2)	(1.7)
English	None	77.6	3.1	—	—	—
(*N*=16)		(17.9)	(3.7)			
	Native	62.6	2.0	18.4	.5	1.1
	(English)	(16.0)	(2.5)	(1.8)	(.7)	(6.8)
	Foreign	49.0	2.1	8.9	1.2	9.9
	(Japanese)	(16.8)	(1.7)	(3.6)	(1.2)	(3.4)

NOTE: Standard deviations are shown in parentheses. The total number of questions asked in the linguistic task was 20.

ingly, a larger number of correct answers and smaller numbers of errors and failures were made in the native language condition. The numbers of correct answers were converted into proportions and then submitted to arcsine transformation. A statistical test conducted on these transformed data showed that the difference between the two language conditions was highly significant: $t(23) = 5.717$, $p < .001$ for the Japanese group, and $t(15) = 15.439$, $p < .0001$ for the English group. Although these results merely confirmed the well-known difficulty of foreign language processing, the fact that both concurrent tasks showed performance reduction in the foreign language condition makes it implausible to interpret the performance reduction for the calculation task in terms of a trade-off between these two tasks.

DISCUSSION

Validity of the findings. The prediction was confirmed by the results in the thinking task (i.e., calculation). It should not be confused with the well-known difficulty of foreign language processing; no foreign language was used in the thinking task where the predicted interference effect was observed. It is implausible that the observed phenomenon was an artifact due to some properties peculiar to a particular language or a particular linguistic group because exactly parallel results were obtained for both Japanese-English and English-Japanese bilinguals. Furthermore, the observed effect should not have been produced by peripheral interference but by central interference as predicted, for the thinking task was visuomanual whereas the linguistic task was aural-oral.

Alternative possibilities. It was formerly suggested that the prediction might not be true if the distinctness effect or the similarity effect is taken into account. First, the present results demonstrated that thinking and linguistic processing are not distinct enough from each other to avoid mutual interference. Second, according to the introspection reports, all the subjects who reported internal speech accompanying the calculation claimed that the internal speech was generated in their native language because it was easier to handle. Accordingly, if the similarity effect observed by McNellis and Neisser (1982) had been manifested, the results contrary to the predicted phenomenon should have been observed. However, the results obtained in the present experiment favored the prediction previously proposed. Why has such a discrepancy between these two studies emerged? It can be explained by focusing on the difference in the characteristics of the respective dual-tasks. In the experiments conducted by McNellis and Neisser (1982), both concurrent tasks were heavily linguistic: Two descriptive paragraphs were presented visually and aurally to be understood simultaneously. When the two paragraphs were presented in the same language, therefore, they had to compete for exactly the same parsers and other linguistic analyzers for that language. The resulting interference could have been potent enough to override the predicted phenomenon. In the case of the present experiment, however, the thinking task did not involve external language at all, and the linguistic analyses of accompanying internal speech, if any, may not have been indispensable to carry out that task. To put it another way, it is highly probable that the linguistic task and the thinking task did not substantially compete for the same parsers and other linguistic analyzers in the native language condition or in the foreign language condition. Consequently, the predicted phenomenon was manifested in the final outcome without being overridden by the similarity effect. It is important to note that ordinary verbal activities (e.g., conversation and negotiation) are more like the present experiment in that thinking is not given from the outside in the form of an external native language. Therefore, it is expected that the predicted phenomenon rather than the similarity effect will be predominant in the case of ordinary verbal activities.

Effect size. The size of the performance reduction produced by the foreign language processing, 13 correct calculations for the Japanese group or 14 for the English group, may look unimpressive or even negligible when compared with the total number of correct calculations, from about 50 to over 100 (see Figure 1). However, the total number of correct calculations is not an appropriate baseline to evaluate the size of the performance reduction because the 210-second period of testing was not entirely filled with linguistic processing and thus with interference. Once a question had been answered, the subject was able to concentrate only on the calculation until the next question started. An appropriate baseline is estimated to be 46 for the Japanese group and 31 for the English group.[3] It is these baseline numbers that suffered from interference due to the concurrent linguistic task and/or foreign language processing. The numbers of correct calculations thus estimated to have been conducted in 83 seconds are presented in Figure 1 for respective conditions and respective groups. The estimated size of the predicted phenomenon is a decline of nearly 30% of the baseline performance for the Japanese group, and a decline of about 45% for the English group. Such interference effects are by no means negligible.

It is known that no interference is expected when concurrent tasks are not demanding enough (Norman & Bobrow, 1975; Wickens, 1984). In the present experiment, the thinking task depended on overlearned cognitive skills (i.e., addition of 2-digit numbers), which must have been very easy for the current sample of subjects. Furthermore, the linguistic task was also easy in the present experiment: An identical grammatical structure was repeated during a whole trial and no substantial foreign language production was involved. The predicted phenomenon may well be more pronounced than the above estimates in the case of ordinary verbal activities where more complicated linguistic processing and thinking are typically required.

Although the present results were in perfect agreement with the prediction, it seems desirable to answer the following two questions before drawing a final conclusion. First, it may be suspected that addition of 2-digit numbers may not be appropriate to represent thinking in general. Second, it is possible that the observed performance reduction in the thinking task was produced solely by linguistic interference; for example, switching between an external foreign language and an internal native language (for language switch, see Kolers, 1966; Macnamara & Kushnir, 1971). Although such linguistic interference may well be part of the predicted phenomenon, it is preferred to examine whether interference could be observed between linguistic processing and nonlinguistic information processing because this interference constitutes an essential part of the proposed hypothesis. To answer these questions, the thinking task has to satisfy the following two conditions. First, it

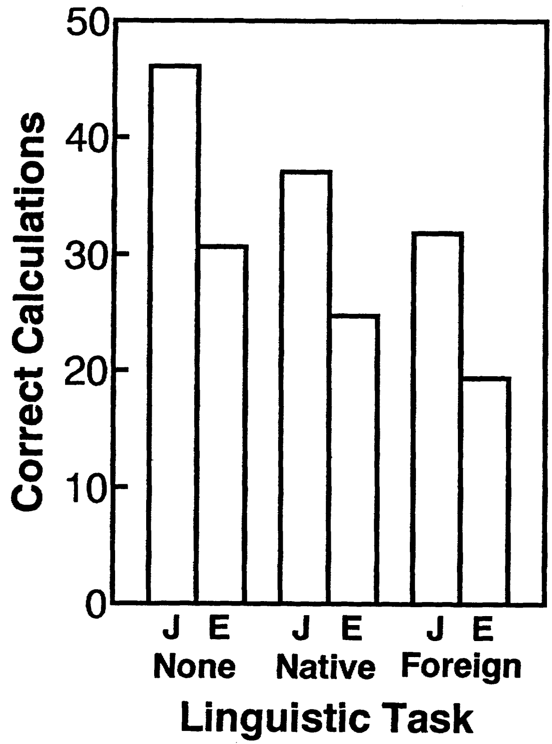

Figure 1: The Estimated Number of Correct Calculations Performed in 83 Seconds That Were Supposed to Have Been Actually Spent for the Concurrent Performance in the Case of the Dual-Task Trials in Experiment 1

NOTE: None = the single-task trial where the linguistic task was not imposed; Native = the dual-task trial where the linguistic task was imposed in the respective native languages; Foreign = the dual-task trial where the linguistic task was imposed in their respective foreign languages; J = the Japanese group; E = the English group. The size of the predicted phenomenon is defined by the difference between the native language condition and the foreign language condition for each group of subjects.

must be consistent with the general notion of thinking. Second, it must be purely nonlinguistic. In principle, however, it is impossible to assure empirically that no internal language has been used in a certain task because it cannot be observed objectively. The best practical way to cope with this problem is to adopt a thinking task that has been proved by past psychological studies to involve minimal linguistic processing. The following experiment employed a thinking task that seemed to satisfy these requirements.

EXPERIMENT 2

The new thinking task consisted of four types of subtests, all of which were adopted from intelligence tests. These subtests had been proved to assess nonverbal spatial factors of intelligence by factor-analytic studies. A first type of subtest was a card rotations test (Ekstrom, French, Harman, & Dermen, 1976). What was required of the subject was to choose a different figure among four alternatives, all of which had been rotated to various degrees, respectively, in a picture plane. The different figure was always an enantiomorph (i.e., a mirror-image) of the others. This subtest is essentially identical to a mental rotation task (Shepard & Metzler, 1971), which is considered to be performed by manipulating a spatial mental image (Shepard & Cooper, 1982). Although the nature of mental imagery has been a focus of dispute (Takano, 1981), there is agreement that rotational transformation of a mental image is not conducted by means of language (Funt, 1983; Kosslyn, 1980; Pylyshyn, 1979, 1984; Shepard & Cooper, 1982), and that it is closely related to form perception (Takano, 1987, 1989b).

A second type of subtest was a maze-tracing speed test (Ekstrom et al., 1976). The subject was required to show a way to go through a printed maze by tracing it with a pencil. In factor-analytic studies of intelligence, this subtest is known to have a substantial loading on a nonverbal spatial factor (Cohen, 1959; Ekstrom et al., 1976; Eysenck, 1979).

In a third subtest, a surface development test (Ekstrom et al., 1976), the subject was shown a pattern of six connected squares such as result when the faces of a cube are unfolded onto a flat surface. The required response was to draw an arrow that would meet another arrow marked on this pattern if the squares were to be folded back up into a cube. This subtest had also been shown to be nonverbal (Ekstrom et al., 1976), requiring transformation of a mental image (Shepard & Feng, 1972).

The last type of subtest was an origami-punch test, which was similar to a paper-folding test (Ekstrom et al., 1976). The subject was shown a picture of a square sheet of paper that had been folded in four, through which several punches of various shapes had been made. The required response was to choose among five alternatives a picture of an unfolded sheet that was identical to the folded sample. This subtest was adopted from the Kyoto University SX15-Intelligence Test (Osaka, Umemoto, Okuno, Sumida, & Fujimoto, 1972). In factor-analytic studies, it had been shown that the origami-punch test had a substantial loading on a nonverbal spatial factor (Okuno, 1969a; Osaka & Okuno, 1956), but not on a verbal factor (Okuno, 1969b).

METHOD

Design. The experimental design was identical to that of Experiment 1 except that all of the possible six orders of the three trials (i.e., the single-task trial, the dual-task trial with Japanese, and the dual-task trial with English) were used. Four subjects were randomly assigned to each order.

Subjects. Twenty-four Japanese undergraduates, 12 males and 12 females, at Waseda University participated as volunteers. All of them were born in Japan; their native language was Japanese. Their mean age was 20.67 years (*SD* 0.69). Their average experience in English as a second language was 9.92 years (*SD* 1.85). Most of this period had been spent in English programs at regular educational institutions. All of the subjects had received additional training in oral English in various forms (e.g., taking English conversation courses offered by the Institute of Language Teaching at Waseda University).

Materials. The linguistic task was changed to a sentence-verification task. Two lists of sentences were prepared; each list consisted of 36 complex sentences. Every sentence stated that its grammatical subject belonged to a category that was modified by a relative clause (e.g., "A horse is a creature that lives in water"). The task was to indicate whether the statement was true or false by saying yes or no. The sentences were presented every 8 seconds (cf., every 10 seconds in Experiment 1). In other respects, the organization of each list was identical to that of Experiment 1. The lists were tape-recorded in Japanese by a female Japanese graduate student; in English by a female American professor. The interval between the directions "Start" and "Stop" was 296 seconds. In one list, the total net time spent in presenting the 36 sentences was about 124 seconds for the Japanese version and about 126 seconds for the English version; in the other list, about 123 seconds for the Japanese version and about 124 seconds for the English version. Two similar lists consisting of six sentences, respectively, were prepared in both Japanese and English to be used in practice trials.

For the thinking task, three sets of problems were prepared to be used in the three trials, respectively. Each set contained 10 problems of each type, 40 problems in total. They were presented in 10 cycles, each consisting of four different types of problems. The order of presenting the four problems in one cycle was determined randomly for each set. The assignment of the three sets to the three trials was determined randomly for each subject with the constraint that the proportion of the assignment to a particular type of trial would become equal among the three sets throughout the experiment. Each set was presented in a booklet, each page of which presented one problem. Three similar sets of problems were prepared to be used in practice trials; each set contained two problems of each kind, eight problems in total. Finally, a different set of the same organization was prepared to be used in the instruction.

Eleven problems of the card rotations test were adopted from the Tanaka-Binet Intelligence Test (Tanaka, 1989c), which is a Japanese version of the Binet test. Twenty-five similar problems were newly prepared, 10 of which were based on the figures used by Shepard and Metzler (1971). Eleven problems of the maze-tracing speed test were adopted from a different version of the Tanaka-Binet Intelligence Test (Tanaka, 1989d). Twenty-five similar problems were newly prepared. Thirty-six problems of the surface development test were prepared, following the instances shown in the Shepard and Feng (1972) study. Finally, eight problems of the origami-punch test were adopted from the Kyoto University SX15-Intelligence Test (Osaka et al., 1972). Twenty-eight similar problems were newly prepared.

Procedures. The same procedures as in Experiment 1 were followed except for the following modifications concerning the thinking task: The experimenter explained how to answer the problems by actually solving the four demonstration problems, then the subject tried to solve the four exercise problems before going into the practice and test trials. In these trials, the subject was instructed to solve the problems in the order of presentation in the booklet without skipping any problem. When a problem appeared extremely difficult, the subject was asked to provide the most plausible answer without consuming too much time on that problem. It was forbidden to rotate the booklet or to write something other than answers on its pages.

RESULTS

For the thinking task, it was predicted that a larger number of correct answers would be provided in the Japanese condition than in the English condition. The mean numbers of correct answers and errors presented in Table 2 are consistent with this prediction. The interference rate (I) was calculated for each condition with the following equation:

$$I = (S - D) / S \times 100(\%), \tag{1}$$

where S denotes the number of correct answers in the single-task trial, and D the number of correct answers in the dual-task trial. This index represents how much interference was produced by the concurrent linguistic task. The mean interference rates for both conditions are shown in Figure 2. As predicted, stronger interference was observed in the English condition. A

TABLE 2
The Results of Experiment 2: The Mean Numbers of Correct Answers and Errors in the Thinking Task (i.e., Spatial Problems), and the Mean Percentages of Correct Answers, Errors, and Failures (i.e., "I Don't Know" Responses) in the Linguistic Task (i.e., Sentence Verification)

	Spatial Problems		*Sentence Verification*		
Linguistic Task	*Correct*	*Error*	*Correct*	*Error*	*Failure*
None	13.88	4.50	—	—	—
	(4.32)	(3.07)			
Native	11.79	4.33	96.18	2.31	1.50
	(4.37)	(3.10)	(6.20)	(3.56)	(3.30)
Foreign	9.13	4.58	68.98	10.88	20.14
	(3.42)	(2.50)	(11.69)	(7.21)	(12.69)

NOTE: Standard deviations are shown in parentheses.

statistical test with arcsine transformation indicated that this difference was reliable, $t(23) = 3.000, p < .01$.

The percentages of correct responses, errors, and failures in the linguistic task are also presented in Table 2. Not surprisingly, it seems to have been harder for the current subjects to understand English sentences than to understand Japanese sentences. According to statistical tests with arcsine transformation, the difference in the percentage of correct responses was significant between the English and Japanese conditions, $t(23) = 13.497, p < .0001$; the difference in the percentage of failures was also significant, $t(23) = 9.507, p < .0001$.

DISCUSSION

The nature of cognitive processes invoked to perform intelligence test problems seems to be consistent with the general notion of thinking. Moreover, factor-analytic studies of intelligence have shown that those problems principally require the ability of nonlinguistic spatial reasoning. The cognitive studies have also shown that two of the four types of problems are solved by transformation of mental imagery. Nevertheless, exactly the same pattern of results was replicated in the present experiment. Thus, it now seems to be justified to draw the following conclusions: First, it is probably typical processes of thinking that are interfered with by concurrent processing of a foreign language. Second, it is nonlinguistic processes of thinking that are

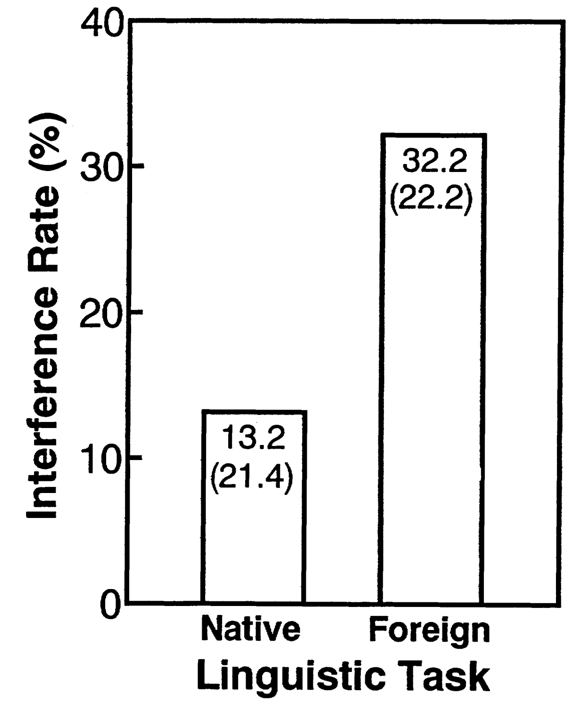

Figure 2: The Mean Interference Rate (With Its *SD* in Parentheses) in the Thinking Task for Each Language Condition in Experiment 2

NOTE: The interference rate is defined as a percentage of the difference between the number of correct answers in the single-task trial and that in the dual-task trial to the number of correct answers in the single-task trial (see Equation [1] in the text). Standard deviations are shown in parentheses.

primarily responsible for this interference. Although linguistic interference (e.g., switching between languages) may also be involved, it is not indispensable to produce the predicted phenomenon.

It is undeniable that the current thinking task may have been accompanied by some amount of internal language. With any empirical procedures, however, it is impossible to assure with perfect confidence that performance of a certain task is not accompanied by any internal language. Because it has been confirmed by the preceding studies that those types of problems that were used in the current thinking task do not require substantial linguistic processing, the above conclusion seems to be fairly convincing as the one that can be drawn from empirical data.

NOTES

1. Suppose, for example, that a conversation partner has just said, "You are wrong." In addition to linguistic analyses of this input sentence, the following questions among others have to be answered internally before responding appropriately: what is meant to be wrong in the former statements on this part, why the partner believes it to be wrong, whether it is really wrong or not, and even whether the partner is angry or not. These analyses require a considerable amount of inferential thinking that can be distinguished from linguistic processing as defined above.

2. This task was chosen as the linguistic task and its questions were made as easy as possible to minimize the portion of nonlinguistic information processing. However, nonlinguistic information processing in the linguistic task, if any, will not make it impossible to interpret the findings in the present experiment, for the following reason: The interference by nonlinguistic information processing in the linguistic task should be identical between the native language condition and the foreign language condition because the same linguistic task is used in both conditions. Therefore, nonlinguistic information processing in the linguistic task should not be responsible for any systematic difference between these two conditions, and thus its effect cannot be confounded with the predicted phenomenon.

3. The time spent in presenting the 20 questions was about 62 seconds in one list and 63 seconds in the other. Although the response time to emit a single word answer (e.g., "Yes") appears to have been shorter than 1 second, suppose that 1 second was the average response time to be conservative. Then the period during which the subjects were actually engaged in the dual-task is roughly estimated as 83 seconds at most. When no linguistic task was imposed (in the single-task trial), the Japanese group made about 117 correct calculations. It follows that they made about 46 calculations correctly in 83 seconds. Similarly, the number of correct calculations performed in 83 seconds by the English group is estimated to be 31.

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