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Effects of environmental context manipulated by the combination of place and task on free recall

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Three experiments, using a 2 (study context) × 2 (test context) between-subjects design, were conducted to examine the effects of environmental context manipulated by the combination of two contextual elements, place and task, on free recall. Undergraduates individually studied nouns and received a free-recall test, with a 10-minute filled retention interval. The contexts were manipulated by the combination of task and place in Experiment 1, by place alone in Experiment 2, and by task alone in Experiment 3. For the manipulation of place and task, two perceptually distinctive places and two distinctive tasks (a calculation task and a fine-motor task) were used. Tasks were imposed before and after studying target items and before a free-recall test. Significant environmental-context effects were yielded in Experiment 1, but not in the other experiments. The implications of the results are discussed.

Every episodic-memory trace consists of both a focal element and a context (Tulving, 1983). The focal element refers to a salient part of the episode, and the context refers to the rest of the episode. Context is a complex and vague concept; different types of context have different features, rates of change, and generalities of associations. One type is referred to as semantic or verbal context (e.g., Baddeley, 1982; Light & Carter-Sobell, 1970). It represents semantic or verbal features from the set of items being processed, and changes relatively quickly. Thus, it can only associate with a limited number of the focal elements of an episode. The other type of context is referred to as environmental context (e.g., Fernandez & Glenberg, 1985; Godden & Baddeley, 1975; Smith, 1988; Smith & Vela, 2001), which represents environmental features in which an event takes place. This type of context typically remains stable during an event, and hence, can associate with all the elements of the episode.

The present study focuses on environmental context-dependent memory. Environmental context plays important roles in everyday memory. It is useful in distinguishing episodes, because it can associate with all their elements, and hence it can contain many of their defining features. Anecdotally, one usually begins remembering by mentally reinstating the environmental context in which the focal element was encoded, when one must remember a certain focal element, such as the place where one lost one's umbrella, or a funny episode during a trip, without specific cues. A number of other anecdotal experiences have been shown in the literature on human memory (e.g., Bjork & Richardson-Klavehn, 1989; Smith, 1988).

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In experiments on everyday memory, Williams and Hollan (1981) demonstrated that participants begin by specifying a general context, as the environmental context in which the focal element was experienced, by using protocol analysis of recalling the names of participants' classmates. Furthermore, in a series of eyewitness identification studies, the environmental context has played a main role (e.g., Geiselman, 1988; Malpass & Devine, 1981).

For a clarification of the mechanisms of environmental context-dependent memory, it is essential to establish a methodology that reliably detects the environmental context-dependent memory. Unfortunately, there is no standard methodology for manipulating environmental contexts yet. Although the majority of the environmental-context studies in the literature to date have manipulated the physical features of place, a variety of methodologies have been used for manipulating place (cf. Smith, 1988; Smith & Vela, 2001). Furthermore, there have been a variety of other methodologies for environmental-context manipulation, such as perceptual features of computer screens, background music, odour, and so forth (cf. Smith, 1988).

For the establishment of a reliable methodology for environmental-context manipulation, it is necessary to clarify the elements that actually function in the environmental context-dependent processes. Recently, it has been proposed that mental factors other than physical environmental features actually produce environmental context-dependent memory (Eich, 1995; Isarida & Isarida, 1999a), although physical features have been manipulated as environmental context (cf. Smith, 1988; Smith & Vela, 2001). Eich (1995) reported that mood, a mental factor, evoked by environmental (place) manipulation determines memory. Isarida and Isarida (1999a) reported that the environmental context effect is caused by contextual elements other than place. They orthogonally varied place and non-place elements in contextual changes between class and intermission at college. The results showed that recall performance is not determined by place elements but by the non-place elements, suggesting that the environmental-context effect may not be produced by physical features of place but by mental factors of non-place elements.

The authors propose the combined manipulation of multiple elements of environmental context as a reliable methodology. Researchers should not restrict the contextual elements to the physical features of place, if a certain type of mental factor determines memory (Eich, 1995; Isarida & Isarida, 1999a), whether physical features of place determine memory or not. Isarida and his colleagues have manipulated multiple contextual elements (place, experimenter, and task), and they have found reliable context effects (e.g., Isarida, 1992; Isarida & Isarida, 1998; Isarida & Morii, 1986). This combined manipulation of multiple elements can vary the mental factors as well as the environmental physical features. Isarida and Isarida (1998) reported that it varied the participants' perception of the characteristics of the experiment between study and test, and the perception correlated with free-recall performance. However, the roles of the respective elements, individually and in combination, are not yet clear.

The present study, therefore, was designed to clarify the combined and respective effects of contextual elements on memory. In the present study, environmental context was manipulated as a unique combination of two elements of the context: place and task. Place has been mainly used for the manipulation of environmental context (cf. Smith, 1988; Smith & Vela, 2001), and task seems to be the most influential element concerning perception of the characteristics of the experiment. Specifically, subsidiary tasks, performed concurrently with encoding tasks, were used as the task element. The present study also examined the combined and respective effects of the contextual elements on mental factors. For this purpose, participants rated scales about mental factors following a free-recall test. The rating scales can provide new information about environmental context-dependency, because there have been few studies measuring such mental factors. It should be noted, of course, that the rating was not conducted independently of the recall test. Thus, the results of the rating scales should be carefully analysed.

In the present study, three experiments were conducted. Experiment 1 was designed to examine the effect of the combined manipulation of place and task on free recall and on mental factors measured by rating scales, and to clarify the relation between free-recall performance and ratings of the mental factors. Experiment 2 was designed to examine the effects of the sole factor of place, so the task element was eliminated from the contextual manipulation. Experiment 3 was designed to examine the effects of the sole factor of task when study and test places differ, so that the study place would not provide retrieval cues during test.

EXPERIMENT 1

Method

Design. A 2 × 2 between-subjects design was employed. The first factor was study context (A, B) and the second factor was test context (A, B).

Participants. The participants were 60 undergraduates enrolled in a Liberal Arts Psychology course at Shizuoka University, Shizuoka, Japan. They received extra course credit for their participation. They were randomly assigned to one of the 2 × 2 groups.

Context. A combination of two contextual elements (place and task) was systematically varied. Specifically, Context A consisted of Place A and Task A, and Context B consisted of Place B and Task B.

Two places (Place A and B) were selected to be as perceptually distinct as possible, each differing from the other in size, illumination, locations, and objects and apparatus set in each place. Place A was a dimly lit 200 cm × 200 cm corner of a room, surrounded by one beige wall and three light grey screens. In Place A, there were a 17-inch computer screen (SONY 17sf9), a keyboard, a small table, and a chair. An experimenter instructed the participant from behind the participant's back, and then concealed herself behind the screen during an experimental session. Place B was a brightly lit 550 cm × 520 cm playroom for children. In Place B, the experimenter and the participant sat facing each other across a 180 cm × 90 cm table throughout the session. In front of the participant, there was a big window overlooking buildings and trees. A lot of toys were scattered about the space. Place A and B were on the same floor of the same building, and were within a 1-minute walk of each other.

Two types of tasks (Task A and B) were used. Task A was a calculation task. Participants received three-term addition problems one by one on the computer screen connected to a computer system (Akia Microbook 56), and then they were required to press the numeric key corresponding to the first digit of the sum as quickly and correctly as they could. A tone "beep" was fed back for each correct response, and a buzzer was fed back for each incorrect response. Each response set off the presentation of the next problem, whether it was correct or not. Task B was a fine-motor task; participants were required to carry beans with chopsticks one by one from one cup to a second cup as quickly as they could. Time limits of Tasks A and B were both 30 seconds.

Materials. A list was constructed, consisting of 20 unrelated Japanese two-kanji-character words whose imagery values and concreteness values were both more than 5.00 (Ogawa & Inamura, 1974). The 20 words were randomly assigned to one of five blocks of four items.

Procedure. All the participants individually participated in a 40-minute experiment, consisting of a study session, a retention-interval session, and a test session. The experimenter was a graduate student who was not acquainted with any of the participants.

The study session was held in either Place A or B. Each participant was visually presented with five blocks of items one by one in 30 seconds, either in a 2 × 2 matrix on the computer screen (Context A), or in a column on a 29.5 cm × 21 cm card by the experimenter (Context B). The participant was required to mentally generate a sentence using all the currently presented items within 20 seconds, and then to report the sentence orally within 10 seconds. In Context A, the signal "Report your sentence" was visually presented under the block of items with a accompanying tone. In Context B, the experimenter orally instructed "Report your sentence" without accompanying tone. In both contextual conditions, the participant's report was interrupted if she/he could not finish her/his report within 10 seconds. Before and after each presentation of the block of items, a 30-second Task A or B was imposed.

Following the study session, the participants were led to Place N, where they were required to solve word-fragment completion problems. The word-fragment completion problems were adopted from Fujita (1997). Place N was a 410 cm × 520 cm reception room with a table, two sofas, and two bookshelves. Place N was on the same floor as Place A and B, within a 1-minute walk of each other. While the participants were solving the problems, the experimenter left Place N. The time for solving the problems was about 8 minutes, so that the retention interval would be just 10 minutes.

Following the problem solving, the participants were led to Place A or B, and they received a 60-second oral free-recall test. Preceding the test, the participants completed a 30-second Task A in Place A, or Task B in Place B. Following the test, the participants rated (a) expected similarity of the type of experimental session about to start when they entered Place A or B at the test session (expectation), (b) perceived similarity of the characteristics between study and test (characteristic), (c) perceived similarity of the mood between at study and at test (mood). Each rating was on a 5-point scale ranging from similar (1) to dissimilar (5).

Results

Table 1 shows the proportions of items recalled as a function of study and test contexts. A 2 × 2 (study context × test context) ANOVA using mean numbers of items recalled as a dependent measure was computed. Neither the main effect of study context, $F(1,56) = 1.79$, $MSE = 1.22$, $p < .001$, nor test context, $F < 1$, was significant, but the interaction was significant, $F(1,56) = 10.94$, $MSE = 1.22$, $p < .01$. The weighted effect size (Hedges & Olkin, 1985; Smith & Vela, 2001) between matched study–test contexts (AA and BB) and mismatched study–test contexts (AB and BA) was .80 (95% CI+ = 1.17, CI− = 0.42).

Table 1 also shows the results of the rating scales (expectation, characteristic, and mood). 2 × 2 ANOVAs using the respective scales as dependent measures were also computed. For the expectation scale, neither the main effect of study context, $F(1,56) = 1.49$, $MSE = 1.91$, nor test context, $F(1,56) = 2.03$, $MSE = 1.91$, was significant, but the interaction was significant, $F(1,56) = 39.86$, $MSE = 1.91$, $p < .001$. For the characteristic scale, neither the main effect of study context, $F < 1$, nor test context, $F(1,56) = 2.17$, $MSE = 1.51$, was significant, but the interaction was significant, $F(1,56) = 14.37$, $MSE = 1.51$, $p < .001$. For the mood scale, neither the main effect of study context, $F(1,56) = 2.62$, $MSE = 2.13$, nor test context, $F < 1$, was significant, but the interaction was significant, $F(1,56) = 4.14$, $MSE = 2.13$, $p < .05$.

Correlations between the number of recalls and each of the three ratings were computed. The correlations between recall and expectation ($r = -.59$, $p < .01$) and between recall and characteristic ($r = -.30$, $p < .05$) were significant, but that between recall and mood ($r = -.17$) was not significant.

TABLE 1
Mean number of items recalled and mental ratings (expectation, characteristic, and mood) in Experiment 1

		Study context			
		A		*B*	
		Test context		*Test context*	
		A	*B*	*A*	*B*
Recall	M	10.5	8.8	7.8	11.7
	SD	2.4	2.8	3.2	4.0
Expectation	M	2.4	4.8	4.8	3.1
	SD	1.6	0.4	0.4	1.8
Characteristic	M	2.5	3.3	3.6	1.9
	SD	1.2	1.3	1.3	0.7
Mood	M	3.2	3.5	3.3	2.2
	SD	1.5	1.4	1.3	1.4

EXPERIMENT 2

Method

Design. A 2 × 2 between-subjects design was employed. The first factor was study context (A, B) and the second factor was test context (A, B).

Participants. The participants were 60 undergraduates enrolled in a Liberal Arts Psychology course at Shizuoka University, Shizuoka, Japan. They received extra course credit for their participation. They were randomly assigned to one of the four groups.

Materials. The materials used in Experiment 2 were identical to those used in Experiment 1.

Context and procedure. In the test session, participants performed no task preceding the test, so that the task would not provide retrieval cues. Other contextual manipulations and procedures were identical to those of Experiment 1.

Results

Table 2 shows the proportions of items recalled as a function of study and test contexts. A 2 × 2 (study context × test context) ANOVA using mean numbers of items recalled as a dependent

TABLE 2
Mean number of items recalled and mental ratings (expectation, characteristic, and mood) in Experiment 2

		Study context			
		A		*B*	
		Test context		*Test context*	
		A	*B*	*A*	*B*
Recall	M	10.5	7.5	9.2	11.5
	SD	2.6	2.3	2.7	4.1
Expectation	M	2.1	4.0	3.8	3.1
	SD	1.2	1.0	1.0	0.8
Characteristic	M	3.8	3.6	3.5	2.7
	SD	1.0	1.0	1.0	0.7
Mood	M	4.2	3.7	3.6	3.0
	SD	1.1	1.0	0.9	1.6

measure was computed. The main effect of study context was marginally significant, $F(1,56) = 3.41$, $MSE = 10.77$, $p < .10$, but neither the main effect of test context, $F < 1$, nor the interaction was significant, $F(1,56) = 1.89$, $MSE = 10.77$. The weighted effect size between matched study–test contexts (AA and BB) and misatched study–test contexts (AB and BA) was .35 (95% CI+ = 0.61, CI− = −0.09).

Table 2 also shows the results of the rating scales (expectation, characteristic, and mood). 2 × 2 ANOVAs using the respective scales as dependent measures were also computed. For the expectation scale, the main effect of study context was not significant, $F(1,56) = 2.17$, $MSE = 1.73$, but the main effect of test context, $F(1,56) = 6.03$, $MSE = 1.73$, $p < .05$, and the interaction were significant, $F(1,56) = 11.82$, $MSE = 1.73$, $p < .01$. For the characteristic scale, the main effect of study context was significant, $F(1,56) = 5.60$, $MSE = 0.96$, $p < .05$, but neither the main effect of test context, $F(1,56) = 2.48$, $MSE = 0.96$, nor the interaction was significant, $F < 1$. For the mood scale, the main effect of study context was significant, $F(1,56) = 5.62$, $MSE = 1.43$, $p < .05$, but neither the main effect of test context, $F(1,56) = 1.67$, $MSE = 1.43$, nor the interaction was significant, $F < 1$.

Correlations between the number of recalls and each of the three ratings were computed. Neither the correlation between recall and expectation ($r = -.16$), nor between recall and characteristic ($r = .03$) was significant, nor was that between recall and mood ($r = .12$).

EXPERIMENT 3

Method

Design. A 2 × 2 between-subjects design was employed. The first factor was study context (A, B) and the second factor was test context (A, B).

Participants. The participants were 56 undergraduates enrolled in a Liberal Arts Psychology course at Shizuoka University, Shizuoka, Japan. They received extra course credit for their participation. They were randomly assigned to one of the 2 × 2 groups.

Materials. The materials used in Experiment 3 were identical to those used in Experiments 1 and 2.

Context and procedure. Task was the only element varied. Specifically, participants performed Task A concurrently with the main task in Context A, whereas they performed Task B in Context B. In each condition, half of the participants studied items in Place A, and received the test in Place B, whereas the others studied items in Place B, and received the test in Place A. When the participants engaged in Task B in Place A, each signal for the task was visually presented on a computer screen with an accompanying tone. After completion of each Task B trial in Place A, participants put each cup on its designated place by themselves. In Place B, the experimenter and the participant sat facing each other across a table throughout the study or test session. To control Task A in Place B, a notebook computer (Fujitsu FMV-5166NA5/X) was used. Other contextual manipulations and procedures were identical to Experiment 1.

Results

Table 3 shows the proportions of items recalled as a function of study and test contexts. A 2 × 2 (study context × test context) ANOVA using mean numbers of items recalled as a dependent measure was computed. Neither the main effect of study context, $F < 1$, nor test context, $F(1,52) = 2.03$, $MSE = 10.13$, was significant, nor was interaction significant, $F < 1$. The weighted effect size between matched study–test contexts (AA and BB) and mismatched study–test contexts (AB and BA) was .02 (95% CI+ = 0.41, CI− = −0.36).

TABLE 3
Mean number of items recalled and mental ratings (expectation, characteristic, and mood) in Experiment 3

		Study context *A*		*B*	
		Test context		*Test context*	
		A	*B*	*A*	*B*
Recall	M	10.8	9.5	10.9	9.7
	SD	3.5	3.1	3.3	2.3
Expectation	M	4.0	4.1	4.1	4.1
	SD	1.2	1.1	1.2	0.8
Characteristic	M	2.2	3.5	3.6	2.3
	SD	1.1	1.2	1.2	1.1
Mood	M	3.7	4.0	3.6	3.1
	SD	1.0	1.2	1.4	1.3

Table 3 also shows the results of the rating scales (expectation, characteristic, and mood). 2 × 2 ANOVAs using the respective scales as dependent measures were also computed. For the expectation scale, neither the main effect of study context nor test context was significant, $Fs < 1$, nor was interaction significant, $F < 1$. For the characteristic scale, neither the main effect of study context nor test context was significant, $Fs < 1$, but the interaction was significant, $F(1,52) = 17.67$, $MSE = 1.38$, $p < .001$. For the mood scale, neither the main effect of study context, $F(1,52) = 2.45$, $MSE = 1.64$, nor of test context, $F < 1$, was significant, nor was the interaction, $F(1,52) = 1.31$, $MSE = 1.64$.

Correlations between recall number and each of the three ratings were computed. Neither the correlation between recall and expectation ($r = -.01$), nor between recall and characteristic ($r = -.08$) was significant, nor was that between recall and mood ($r = -.07$).

DISCUSSION

The present results demonstrate the effectiveness of combined manipulation of multiple environmental contextual elements. Combined manipulation of place and task determined mental factors as well as free recall, and that free-recall performance correlated with mental-factor ratings. The interaction between study and test contexts was significant in free recall. Significant interactions of study and test contexts were also observed in all ratings, and two of three correlations between recall performance and each of the three ratings were significant. In contrast, the respective manipulations of single elements could not determine free-recall performance. The effects of respective manipulations on mental ratings were quite different from each other. Place determined the expectation of the forthcoming experimental session but not characteristics of the session or mood, whereas task determined the characteristics but not the expectation or mood. Mood may be determined only by the combined manipulation. Furthermore, in respective manipulations of a single element, correlations between recall performance and any ratings were not significant.

These findings may favour the notion that mental factors mediated environmental context-dependent memory processes as proposed by Eich (1995) and Isarida and Isarida (1999a). The results of Experiment 1 may imply that combined contextual manipulation determines mental factors, and that mental factors determine free recall. It should be noted, of course, that the relations between free-recall performance and ratings are not causal relations but only correlations, and further, that mental-factor ratings might have been influenced by the free-recall test preceding them.

Before discussing what the combined manipulation produces, the effects of respective manipulations of a single element must be discussed. The present results suggest that place alone does not reliably determine free recall. Experiment 2 found no significant interaction between study and test contexts in free recall. Although the effect size on memory revealed a considerable value, it was not significant. This absence of context effect in free recall may confirm the unreliability of context effect on memory manipulated by physical features of place or environment, as has been demonstrated by several researchers (e.g., Bjork & Richardson-Klavehn, 1989; Fernandez & Glenberg, 1985). Another possibility is that associative processing at study and a short retention interval may have eliminated the effect of place in Experiment 2. The sentence-completion task used for studying clearly includes associative processing. According to Smith and Vela's (2001) meta-analysis, associative processing during study reduces and often eliminates environmental context effects. Additionally, the 10-minute retention interval may have been too short to yield clear effect of place according to the meta-analysis (Smith & Vela, 2001). However, the combined manipulation in Experiment 1 did yield a significant effect by using a sentence-completion task and a 10-minute retention interval, even if associative processing and the short retention interval reduced the effect. Furthermore, significant effects on memory have been found by using combined manipulation of place, task, and experimenter (Isarida, 1992; Isarida & Isarida, 1998; Isarida & Morii, 1986). At least, combined manipulation can produce the contextual effect more powerfully than place manipulation.

There may be an argument to the effect that manipulated size of change in place was not enough to produce the context effect on memory. Possibly, a greater change in place might have produced significant context effects. In general, it is difficult to assess whether manipulated size of change in place is sufficient in experiments on environmental context-dependent memory. At least, it is clear that the present difference in place is enough to produce significant context effect, if place is manipulated in combination with task.

Place can determine participants' expectation of the characteristics of the forthcoming experimental session but neither the actual perception of the characteristics of the experiment or mood. Experiment 1, in which place and task were manipulated, also found context dependency in the expectation scale. Thus, place should be the main cause of expectation. However, the expectation alone cannot determine free recall. The correlation between the expectation rating and free-recall performance was not significant.

On the other hand, task alone can determine the perception of experimental characteristics. The interaction between study and test contexts was significant in the characteristic scale, but not in the expectation scale or in the mood scale. The expectation may depend on changes in place, and mood may depend on the combined manipulation. However, task manipulation did not determine free-recall performance. Recall performance did not show a significant interaction between study and test contexts, or correlations between recall performance and any of the three ratings.

These findings suggest that task alone does not have enough effect to change free-recall performance, and further, that the perception of event characteristics cannot solely determine memory. However, task cannot always produce context effects on memory. Falkenberg (1972) found significant context effect of calculation tasks in the Brown-Peterson paradigm. Possibly, task may produce context effects on memory of a single item but not of a number of items, similar to the context effect of background colour (e.g., Dulsky, 1935; Isarida & Isarida, 2001; Pointer & Band, 1998; Weiss & Margolius, 1954).

There should be an argument that tasks for encoding could themselves have produced significant contextual effect on memory, because they must affect the perception of the experiment more than subsidiary tasks. However, the use of the encoding tasks for the contextual manipulation has the following methodological problems: if the encoding tasks are used for contextual manipulation, participants will receive the task as a contextual cue at test; more specifically, they must engage in the same encoding task when the study context is reinstated at test. It should be noted that new items other than the items presented at study must be used for the encoding task at test. Thus, both items presented at study and at test should associate with the context when the context is reinstated at test, whereas only the items presented at study should associate with context when the context is not reinstated. As a result, the contextual cue load is greater, and hence the cue strength is weaker (Watkins & Watkins, 1975) when the context is reinstated at test than when it is not reinstated. This inference was empirically supported by Isarida and Isarida (1999b).

What does the combination of task and place produce? One possible answer is that place and task function independently. If so, the effect of combined elements will be the addition of place and task effects. However, this should not be plausible. First of all, the effect size of combined manipulation (.80) was far greater than the addition of place (.35) and task (.02). Furthermore, the respective effects of place and task on mental factors were quite different and complementary. Place did not substantially determine the perception of event characteristics in which the focal element was processed, although it affected the expectation of the forthcoming event. In contrast, task clearly determined the perception of event characteristics. Furthermore, mood may be determined by the combination of place and task. Consequently, place and task may function interactively rather than independently.

The authors propose that environmental context determines episodic memory not because context incidentally associates with focal elements by contiguity, but because context has many distinguishing features of episodic memory. It is plausible that the more distinguishing features of episodic memory are manipulated, the more reliably a context effect on episodic memory is produced. Combined manipulation of multiple contextual elements can change more distinguishing features of episodic memory than can the manipulation of a single element such as place. Place has, of course, a considerable importance in episodic-memory processes, because episodic memory is spatiotemporally encoded and represented. Thus, place alone can produce context effects according to a meta-analysis (cf. Smith & Vela, 2001). However, place lacks information about the characteristics of the event—the experiment—which is also an important distinguishing feature of the episode. This lack may sometimes cause the unreliability of place-dependent memory (Bjork & Richardson-Klavehn, 1989; Fernandez & Glenberg, 1985). From the participants' viewpoint, where the experiment took place is less important than what was conducted in the experiment. Task can compensate this lack, because it can influence the characteristics of the event, including its focal elements.

In conclusion, the present results provide evidence that environmental context manipulated by a combination of multiple elements determines memory more reliably than context manipulated by a single element. The multiple elements may function interactively rather than independently. Furthermore, environmental context may determine episodic memory not because the context incidentally associates with the focal element, but because context has many distinguishing features of episodic memory.

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