MEMORY, 2005, 13 (8), 785–795

Psychology Press
Taylor & Francis Group

Study-time effect on free recall within and out of context

Takeo Isarida

Shizuoka University, Hamamatsu, Japan

Three experiments examined whether or not the study-time effect, which was observed when recall took place in the original environmental context, was eliminated or markedly diminished when recall took place in a different environmental context. A total of 456 undergraduates studied a list of words for either a short or long study time before receiving an oral free recall test under conditions where the original environmental context was or was not reinstated. Environmental context was manipulated by the combination of physical features of the room, subsidiary task, and experimenter. Inter-item association was minimised in Experiment 1, and free recall performance was measured independently of inter-item association in Experiments 2 and 3. The results were: (1) a greater study-time effect was found when the original context was reinstated than when it was not reinstated, and (2) the study-time effect disappeared when neither contextual nor inter-item associative cues were available. The results suggest that environmental context is involved in the production of the study-time effect.

An episodic memory trace consists of focal information and peripheral information, referred to as "context". Context can help reinstate the original episode, because it comprises a large part of the memory trace of the episode. Different types of contexts have different rates of change, and hence different generalities of association. As a result, different types of contexts can help reinstate different sizes of episode. In the case of a list-learning episode, semantic context (e.g., Light & Carter-Sobell, 1970), which consists of semantic features from the set of items being processed, changes relatively quickly, and hence will become associated with perhaps only a single item. Thus, semantic context can help reinstate a limited portion of a list-learning episode. In contrast, environmental context (e.g., Smith, 1988, 1994; Smith & Vela, 2001), which consists of the incidental physical features of the environment in which participants process focal information, can become associated with the total list-learning event, because the environmental context typically remains stable throughout the event, and hence is associated with all the elements of the event. The present study manipulated environmental context for the purpose of reinstating the episode of an experimental session including a list-learning event.

Remembering in everyday life is not limited to a specific environmental context; people can remember an episode out of environmental context as well as within it. However, in most laboratory experiments (e.g., Crowder, 1976; Greene, 1992), memory has been studied within the original environmental context. In most experiments, both the initial study and the later testing of recall have been completed within one experimental session, and hence within one environmental context. Even if participants left the laboratory during a long retention interval, they almost always returned to the same laboratory and received the memory test from the same experimenter. As a result, the original context was reinstated at the time of testing. If episodic memory phenomena have been studied only within the original context, it may be that

Correspondence should be addressed to Takeo Isarida PhD, Faculty of Informatics, Shizuoka University, 3-5-1 Johoku, Hamamatsu, 432-8011 Japan. Email: isarida@inf.shizuoka.ac.jp

I thank Professors M. J. Guest and M. J. Sheftall for their comments on an earlier version of this article. Portions of this research were reported at the 51st, 53rd, and 54th Annual Meetings of the Japanese Psychological Association, Japan.

http://www.tandf.co.uk/journals/pp/09658211.html DOI:10.1080/09658210500139218

researchers have clarified only half the characteristics of episodic-memory phenomena. Thus, researchers should examine episodic memory phenomena out of the environmental context as well as within it.

The characteristics of episodic memory phenomena may be different within and out of context. It has been demonstrated that memory performance is influenced by whether it is tested within or out of the original context (e.g., Smith, 1988; Smith & Vela, 2001). This implies that the production mechanism of recall may utilise the environmental context. As such, context may also affect memory phenomena. Empirically, several studies have found that the reinstatement of the original environmental context changed the characteristics of several episodic memory phenomena (Isarida, 1992; Isarida & Isarida, in press; Isarida & Morii, 1986). For example, when the original environmental context was not reinstated, the spacing effect of repetition (Isarida & Morii, 1986) and the recency effect in free recall (Isarida & Isarida, in press) were not present and the rehearsal effect on free recall was markedly diminished (Isarida, 1992), whereas these effects were present when the contexts were reinstated.

The present study utilised the study-time effect as one of the most basic episodic memory phenomena. The study-time effect refers to the increase in memory performance that accompanies an increase in the duration of time spent studying, and has been observed in multiple studies for more than a century (Ebbinghaus, 1885; Crowder, 1976; Greene, 1992). This research has virtually all been conducted using the same context for study and test. However, it may be the case that the size of the study-time effect is related to the environmental context. It is not only the processing time of individual items, but also the length of time that the environmental context is contiguous with the items, that increases as a function of study time. Increasing the amount of time that items are contiguous with the context may increase the associative strength between the items and the context. If so, the items recalled within the original environmental context will increase as a function of study time. When the original contextual cues are not available, the gain in memory performance with study time should decrease.

The present study manipulated three contextual elements that were stable throughout the study session in order to reinstate the study context. The elements were: (a) the physical environment of the experimental session; (b) the distractor task performed with the encoding task; and (c) the experimenter. The combined manipulation of place and experimenter has been found to produce more reliable context effects than simple place manipulation alone (Smith & Vela, 2001). Although a distractor task has seldom been used as an environmental context element, it can characterise, and therefore might reinstate the context of the study session if participants engaged in it throughout a study session. Empirically, distractor tasks have been found to produce a context effect on recall (Falkenberg, 1972). The combined manipulation of place and subsidiary task has been found to produce a significant context effect, even when place alone did not produce the effect (Isarida & Isarida, 2004). Other elements than these three could also aid or influence reinstatement of context for recall, but were not included in the present manipulation. For example, elements not included were mood or internal states (e.g., Blaney, 1986; Eich, 1980), posture (e.g., Rand & Wapner, 1967), voice (e.g., Geiselman & Bjork, 1980), or various visual features of a computer screen for item presentation (e.g., Murnane & Phelps, 1993, 1994, 1995).

The present study used the following methods for measuring the effects of environmental context on recall separately from the effects of any other explicit or implicit retrieval cues. First, an uncued free recall paradigm was used. Explicit cues in cued recall or recognition can outshine or at least make unclear the effects of environmental context cues, because the explicit cues usually have greater cue strength than the environmental context (e.g., Smith, 1988, 1994). Second, inter-item associative cues—not explicitly provided but generated by participants—were controlled. In memory paradigms measuring more than one response as free recall, inter-item associations as well as environmental context could cue each response. Furthermore, inter-item association is strengthened as a function of study time as a context–item association (e.g., Tulving, 1962). These inter-item associative cues may confound the effects of environmental context. Logically, inter-item associative cues have greater cue strength than the environmental context because they associate with fewer items than does the context. Empirically, Smith and Vela (2001) have reported that inter-item associative processing reduces environmental context effects. Consequently, inter-item associative cues were minimised in Experiment 1, and the recall responses cued only by environmental context were measured separately from the total responses in Experiments 2 and 3.

EXPERIMENT 1

Experiment 1 examined whether the environmental context influences the study-time effect in free recall when inter-item associative processing was minimised by imposing a subsidiary task before and after every item presentation. This method and its variations have frequently been used as a continuous distractor paradigm to investigate the long-term recency effect. The recency effects obtained by this method can be generalised to those obtained by the list-learning method (e.g., Bjork, 2001; Bjork & Whitten, 1974). Additionally, the effects of the retention interval were also investigated.

Method

Design. A 3 × 3 between-subjects design was employed. The first factor was the study time per item (3, 6, or 9 seconds) and the second factor was the test condition (same context, different context, or immediate recall).

Test conditions. In the same context condition participants received a free recall test in the same environmental context as that of the study, whereas in the different context condition participants received the recall test in a different environmental context from that of the study. In both the same context and different context conditions, a 24-hour retention interval was imposed in order to measure the environmental context effect more clearly. According to Smith and Vela's (2001) meta-analysis, the effect size of environmental context for 1 day or longer retention intervals is markedly greater than that for shorter retention intervals.

For the immediate recall condition, a free recall test was administered immediately after the list presentation. The purpose of the immediate recall condition was twofold. One was to compare the present experiment with the previous experiments on the study-time effects, because most of the studies used only one session without participants leaving the laboratory (e.g., Crowder, 1976; Greene, 1992), whereas both the same and different context conditions needed two experimental sessions across 2 days with participants leaving the laboratory. The other purpose was to test the effect of retention intervals on the study-time effect. In summary, the contexts were varied between the same and different context conditions, and retention intervals were varied between the immediate recall and same context conditions.

Environmental context. A combination of three contextual elements (place, experimenter, and task) was systematically varied. Same context participants attended the test session at the same place as the study session, and received instructions from the same experimenter. Furthermore, before testing, same context participants engaged in the same calculation task that they had performed before and after studying. Different context participants attended a different place for the test session than the study session, the experimenter who instructed participants was different between the study and test sessions, and no task was imposed before testing.

For the place element, two places (Place A and B) were selected to be as perceptually distinct as possible, each differing from the other in size, illumination, location, and objects and apparatus set in each place. Place A was 375 cm × 570 cm. A large bookshelf covered one wall, three large cabinets stood along another wall, and a large window opening to the outside was on the third wall. Place B was 175 cm × 150 cm, with two beige walls and two light blue partitioning curtains. Place B had an aroma of lime. In both Place A and B, a computer system was set up for presenting both the items and the interpolated calculation tasks. Place A and B were on the same floor of the same building. Half of the same context participants were run in Place A for both study and test sessions, and the others were run in Place B. Half of the different context participants studied in Place A and were tested in Place B, and vice versa for the other half.

For the task element, participants engaged in a 20-second calculation task before and after studying each item. Participants were presented with a three-term addition problem on a computer screen, and were required to press the numeric key corresponding to the first digit of the sum as quickly and accurately as they could. Feedback was a "peep" tone for each correct response, and a buzzer for each incorrect response. After the feedback, the next problem was immediately presented.

The experimenter was either the male teacher who lectured in a course that the participants attended (Experimenter A) or a female undergraduate who was not acquainted with the participants (Experimenter B). Half of the immediate recall and same context participants were instructed by Experimenter A and the others were instructed by Experimenter B at both the study and test sessions. In the alternate condition, half of the different context participants were instructed by Experimenter A at the study session and by Experimenter B at the test session, and vice versa.

Participants. Participants were 223 undergraduates enrolled in an introductory psychology course at Shizuoka University, Japan. They received extra points of course credit for their participation. They were randomly assigned to one of the nine (3 × 3) groups. Seven of the participants were excluded from the analysis because four verbally reported that they did some inter-item associative processing and three reported that they anticipated the testing at the second session. These participants were replaced by others, and consequently each condition consisted of 24 participants.

Materials. A to-be-remembered list consisted of 12 unrelated nouns, each formed from three symbols of the Japanese Kana syllabary. The familiarity values of the nouns were from 3.00 to 3.99 (Koyanagi, Ishikawa, Okubo, & Ishii, 1960).

Procedure. All of the participants were individually tested. Immediate recall participants participated in one 20-minute session, whereas both same and different context participants participated in two 20-minute sessions separated by a 24-hour retention interval. The procedure of studying items was identical for all the conditions, except for the place and the experimenter. Every participant came individually to the teacher's room, and was then escorted by Experimenter A or B to Place A or B. The participant received the following instructions:

> The purpose of the present experiment is to investigate cognitive relationships between arithmetic and memory skills. More specifically, the experiment is designed to measure the changes in arithmetic performance with an increase in the number of items in mind. The participant must calculate as fast and correctly as possible, and also must study as many of the words as possible.

The instructions were designed to keep the participant from anticipating the following day's test, so that she or he would not rehearse the items during the retention interval.

Following the instructions, each participant viewed a list of 12 items one at a time on a computer screen, and was requested to study only the currently presented item without making any inter-item associations. The presentation order of the items was randomised across participants. Every item presentation was preceded and followed by a 20-second calculation task. The participant engaged in the calculation task 13 times. At the end of the last calculation task, if triple question marks (???) were presented, then the participant received a 60-second oral free recall test (immediate recall condition), and if an end mark (END) was presented, then the first-day session was finished without testing (same and different context conditions). Twenty-four hours after the first session, same and different context participants received a 60-second oral free recall test according to the corresponding procedures. After the recall test, participants were asked verbally to report whether they did some inter-item associative processing and whether they anticipated the testing at the second session. Both the oral responses in recall and the verbal report were tape-recorded. At the end of the experimental session, participants were debriefed about the experiment.

Results

Table 1 shows the proportions of items recalled as a function of study time and test condition. A 3 × 3 (study time × test condition) ANOVA for the number of items recalled was computed. The main effects of test condition, $F(2, 207) = 84.51$, $MSE = 2.42$, $p < .001$, and study time, $F(2, 207) = 23.23$, $MSE = 2.42$, $p < .001$, were both significant, and the interaction was also significant, $F(4, 207) = 4.77$, $MSE = 2.42$, $p < .01$.

Because the interaction between study time and test condition was significant, several additional analyses were conducted. A 3 × 2 (study time × immediate recall vs same context) ANOVA showed both significant main effects of test condition, $F(1, 207) = 59.54$, $MSE = 2.42$, $p < .001$, and study time, $F(2, 207) = 27.02$, $MSE = 2.42$, $p < .001$, but their interaction was not significant, $F(2, 207) = 1.68$, $MSE = 2.42$. A 3 × 2 (study time × same context vs different context)

TABLE 1
Proportion of items recalled as a function of study time and test condition

	Study time (seconds)		
Test condition	*3*	*6*	*9*
Immediate recall			
M	.434	.510	.653
SD	.054	.094	.071
Same context			
M	.267	.382	.443
SD	.105	.095	.133
Different context			
M	.250	.267	.275
SD	.075	.082	.081

ANOVA showed both significant main effects of test condition, $F(1,207) = 27.57$, $MSE = 2.42$, $p < .001$, and study time, $F(2,207) = 7.77$, $MSE = 2.42$, $p < .001$, and the interaction was also significant, $F(2,207) = 3.74$, $MSE = 2.42$, $p < .05$. In addition, the simple effects of study time were analysed. The study-time effects were significant in both the immediate recall condition, $F(2,207) = 17.61$, $MSE = 2.42$, $p < .001$, and the same context condition, $F(2,207) = 14.31$, $MSE = 2.42$, $p < .001$, but there was no effect in the different context condition, $F < 1$.

Finally, 95% confidence intervals and skewness values for the number of items recalled in the different context condition were computed to examine the possibility of a floor effect. The confidence intervals for the 3-second, 6-second, and 9-second conditions were 2.33–3.26, 2.64–3.69, and 2.01–3.54, respectively. The skewness values for the 3-second, 6-second, and 9-second conditions were –.01 (CR = –.03), –.36 (CR = –.76), and .61 (CR = 1.28), respectively. None of the skewness values showed a significant deviation from the normal distribution.

Discussion

The results of Experiment 1 show that a study-time effect appeared when the study context was reinstated for recall, but disappeared when the study environmental context was not reinstated. The results show a significant interaction between context and study time. Furthermore, subsequent analyses show a significant study-time effect in the same context condition, but no effect in the different context condition. The present results imply that environmental context information is used to produce the study-time effect in free recall.

The absence of a study-time effect in the condition without the same environmental context cues is not the result of measurement artefacts. The range of study times was long enough to produce a study-time effect, because the effect was clearly found in both the immediate recall and same context conditions. Although the recall level in the different context condition may be too low to rule out a floor effect, the possibility that the study-time effect in the different context condition was masked by a floor effect should be rejected for two reasons. First, the 95% confidence intervals for the number of items recalled were much greater than zero for all the study-time conditions. Second, the distribution of the number of items recalled in the different context conditions for any study-time condition was not positively skewed. Experiment 2 further examines whether the disappearance would be replicated.

In contrast to the results showing the influence of environmental context, the retention interval did not influence the study-time effect but did influence the total amount of recall. For the 24-hour retention interval, the slope of the study-time effect did not change, although the amount of recall markedly decreased. This result implies that the factors arising during the retention interval—such as retroactive interference—do not influence the production mechanism of the study-time effect. Thus, the retention-interval factor was omitted in Experiments 2 and 3.

EXPERIMENT 2

The purpose of Experiment 2 was to examine whether the results of Experiment 1 would be replicated when inter-item associative cues were available. Participants usually associate items into several clusters to lighten their memory load when the number of items exceeds their memory span in standard free recall experiments. Items clustered in memory should also be clustered in recall (Bousfield, 1953). When the items associated into several clusters are recalled, the first response of each cluster in recall cannot be cued by inter-item association but only by the environmental context. On the other hand, the responses following the first can be cued by inter-item associations as well as the environmental context. Thus, the first response within each cluster can be used to evaluate the simple effect of environmental context.

To identify the first response, researchers must know the members constituting each cluster. For this purpose, Experiment 2 employed the following procedure. Participants were required to encode several sets of items. Each set of items was presented simultaneously. At the time of the encoding, participants were required to generate a sentence with all the currently presented items, enabling them to associate the items within each set into a cluster. The experimenter gave participants no instructions to memorise the items. Before and after encoding each set of items, subsidiary tasks were imposed to make the sets of items separate from each other in memory. As a result of this procedure, the participants' representation in memory was predicted to consist of several clusters of items having the following structure: (a) the items within each set would be associated into one cluster; (b) the sets would be separated from each other; and (c) all the sets would be associated with a common environmental context. The results were analysed for the proportion of the first responses within each set of items as well as the proportion of total items recalled.

Method

Design. A 2 × 2 between-subjects design was employed. The first factor was the study time for each set of items (10 or 30 seconds). The second factor was the context condition (same context or different context).

Environmental context. The contextual manipulation was identical to that used in Experiment 1, except that the duration of each calculation task was 30 seconds instead of 20 seconds.

Participants. Participants were 120 undergraduates from an introductory psychology course at Shizuoka University, Japan, who received extra credit for their participation. They were randomly assigned to one of the 2 × 2 conditions. Consequently, each condition consisted of 30 participants.

Materials. A list consisted of 16 unrelated Japanese two-kanji-character words whose imagery values were more than 5.00 (Ogawa & Inamura, 1974). The 16 words were randomly assigned to one of four sets of four items.

Procedure. Participants were required to generate a sentence using the four words within the set, which were simultaneously presented in a 2 × 2 matrix on the computer screen for 10 or 30 seconds. After the presentation of each set, the participants were required to speak their sentence within 10 seconds. A buzzer was the start signal for the oral report of the sentence. During the oral report, none of the items was presented. Before and after each presentation of the set of items, a 30-second calculation task was imposed. The task was the same as that used in Experiment 1. Otherwise, the procedure was identical to that used in the same and different context conditions of Experiment 1, with participants performing the encoding task on day 1 and recalling on day 2.

Results

The results of Experiment 2 are summarised in Table 2. A 2 × 2 (study time × context) ANOVA for the total number of items recalled was computed. The main effects of study time, $F(1, 116) = 56.96$, $MSE = 4.28$, $p < .001$, and of context, $F(1, 116) = 32.41$, $MSE = 4.28$, $p < .001$ were significant. The interaction between study time and context was significant, $F(1, 116) = 4.67$, $MSE = 4.28$, $p < .05$. In addition, simple study-time effects and simple context effects were analysed, because the interaction between study time and context was significant. The study-time effect was significant for both same context, $F(1, 116) = 47.14$, $MSE = 4.28$, $p < .001$, and different context, $F(1, 116) = 14.49$, $MSE = 4.28$, $p < .001$. The context effect was significant for both the 10-second, $F(1, 116) = 6.23$, $MSE = 4.28$, $p < .05$, and the 30-second $F(1, 116) = 30.86$, $MSE = 4.28$, $p < .001$, conditions.

TABLE 2
Summary of the results in Experiment 2

	Study time (seconds)			
	10		*30*	
	M	*SD*	*M*	*SD*
Total items recalled				
Same context	.382	.126	.610	.161
Different context	.298	.125	.427	.134
First responses within sets of items				
Same context	.692	.176	.855	.157
Different context	.583	.231	.600	.186

A 2 × 2 (study time × context) ANOVA for the number of first responses within sets of items was computed. The main effects of study time, $F(1, 116) = 6.22$, $MSE = 0.59$, $p < .05$, and of context, $F(1, 116) = 26.11$, $MSE = 0.59$, $p < .001$ were significant. The interaction between study time and context was significant, $F(1, 116) = 4.08$, $MSE = 0.59$, $p < .05$. In addition, simple study-time effects and simple context effects were analysed, because the interaction between study time and context was significant. The study-time effect was significant for same context, $F(1, 116) = 10.19$, $MSE = 0.59$, $p < .01$, but not for different context, $F < 1$. The context effect was significant for both the 10-second, $F(1, 116) = 4.77$, $MSE = 0.59$, $p < .05$, and the 30-second $F(1, 116) = 25.42$, $MSE = 0.59$, $p < .001$, conditions.

Discussion

The proportion of total items recalled reflects the effects of both environmental context and inter-item association. The interaction between study time and context was significant, although the study-time effect was significant for both the same and different context conditions. The interaction reflects the fact that the slope of the same context function of the study-time effect is about twice as large as that of the different context function. This pattern of results replicates Isarida's (1992) findings that the correlations between the number of rehearsals and recalled items were significant in both the same and different context conditions, and the same context correlation was about twice as large as the different context correlation. In Isarida's (1992) experiment, as in standard free recall experiments, participants were free to associate items, and their responses in free recall were not classified as the first or the following responses.

The results for the proportion of the first responses replicated the results of Experiment 1. First, the interaction between study time and environmental context was significant. Second, the study-time effect appeared in the same context but not in the different context condition. This pattern of results would be expected only if environmental context cues are available in recall regardless of whether inter-item associations were available or not. Additionally, the absence of a study-time effect in the proportion of the first responses in the different context condition was not caused by a floor or ceiling effect, because the recall level was too high (about 60%) to suspect a floor effect and too low to suspect a ceiling effect.

EXPERIMENT 3

Experiment 3 examined whether the results of Experiment 2, in which participants studied items incidentally, would be replicated when participants studied items intentionally. Most experiments on the study-time effect have used intentional-learning paradigms. Thus, it is important to determine whether the results obtained in an incidental-learning paradigm would be replicated in an intentional-learning paradigm.

Method

Design. The design was identical to that of Experiment 2.

Environmental context. The contextual manipulation was identical to that used in Experiment 2.

Participants. The participants were 120 undergraduates enrolled in an introductory psychology course at Shizuoka University, Japan, who received extra credit for their participation. They were randomly assigned to one of the 2 × 2 conditions. Consequently, each condition consisted of 30 participants.

Materials. The list used in Experiment 3 was identical to that used in Experiment 2.

Procedure. Participants were instructed to intentionally study the currently presented items using any mnemonic strategies for 10 or 30 seconds. There was no 10-second period for reporting the sentences; otherwise, the procedure was identical to that used Experiment 2.

Results and discussion

The results of Experiment 3 are summarised in Table 3. A 2 × 2 (study time × context) ANOVA for the total number of items recalled was computed. The main effects of study time, $F(1, 116) = 35.06$, $MSE = 4.02$, $p < .001$, and of context, $F(1, 116) = 33.99$, $MSE = 4.02$, $p < .001$ were significant. The interaction between study time and context was significant, $F(1, 116) = 4.39$, $MSE = 4.02$, $p < .05$. In addition, simple study-time effects and simple context effects were analysed, because

TABLE 3
Summary of the results in Experiment 3

	Study time (seconds)			
	10		*30*	
	M	*SD*	*M*	*SD*
Total items recalled				
Same context	.284	.141	.466	.129
Different context	.197	.104	.288	.097
First responses within sets of items				
Same context	.663	.235	.853	.131
Different context	.488	.196	.550	.183

the interaction between study time and context was significant. The study-time effect was significant for both same context, $F(1,116) = 32.13$, $MSE = 4.02$, $p < .001$, and different context, $F(1,116) = 7.31$, $MSE = 4.02$, $p < .01$. The context effect was significant for both the 10-second, $F(1,116) = 6.97$, $MSE = 4.02$, $p < .01$, and the 30-second $F(1,116) = 31.40$, $MSE = 4.02$, $p < .001$, conditions.

A 2 × 2 (study time × context) ANOVA for the number of first responses within sets of items was computed. The main effects of study time, $F(1,116) = 15.15$, $MSE = 0.46$, $p < .001$, and of context, $F(1,116) = 58.55$, $MSE = 0.46$, $p < .001$ were significant. The interaction between study time and context was significant, $F(1,116) = 4.05$, $MSE = 0.46$, $p < .05$. In addition, simple study-time effects and simple context effects were analysed, because the interaction between study time and context was significant. The study-time effect was significant for same context, $F(1,116) = 17.44$, $MSE = 0.46$, $p < .001$, but not for different context, $F(1,116) = 1.76$, $MSE = 0.46$, $p > .10$. The context effect was significant for both the 10-second, $F(1,116) = 15.89$, $MSE = 0.46$, $p < .001$, and the 30-second $F(1,116) = 46.71$, $MSE = 0.46$, $p < .001$, conditions.

The pattern of results of Experiment 3 is almost identical to that of Experiment 2, which indicates that the pattern of results is reliable. Furthermore, the similarity between the results of Experiments 2 and 3 indicates that the intentional processing of the focal information may be independent of the processing of the context, because an almost identical pattern of results was obtained regardless of whether the learning was intentional or incidental. These results support the view that the environmental context is encoded unintentionally or automatically (e.g., Glenberg, 1979).

GENERAL DISCUSSION

The present three experiments have an almost identical pattern of results, indicating that this pattern is reliable. First, when inter-item associative cues were available at retrieval, both same and different context conditions showed significant study-time effects. The size of the study-time effect in the same context condition is markedly greater than in the different context condition. The interactions between context and study time were significant in all three experiments. Second, when inter-item associative cues were not available at the time of retrieval, the study-time effect was not present in the different context condition, whereas it was present in the same context condition.

The present results show that the size of the environmental context effect increases as a function of study time. This increase in effect size implies that participants' processing of individual items increases not only the item strength but also the strength of the relationship between the environmental context and the items. Even though participants focused exclusively on the individual items, they processed the items not in a vacuum but in an environmental context. Thus, the focused items are associated with their background environmental context, and the strength of the association increases with the time spent processing the items within the environmental context. The interaction can be explained by item–context integration as well as by association. The ICE theory proposes that context and items will be integrated into an *ensemble* if the context information is relatively rich in meaningful content (Murnane, Phelps, & Malmberg, 1999). Thus, if the environmental context, including place features as used in the present study, is rich in meaningful content, then the context and items will be integrated into the *ensemble* through item processing. The present results support this prediction, and add further evidence that the strength of the integration increases as a function of study time. The ICE theory has been demonstrated for recognition by manipulating simple and rich visual contexts on a computer screen (Murnane et al., 1999). The present findings extend these demonstrations to a free recall paradigm and to environmental context including place features.

It should be noted that the present context manipulation is associated with context novelty or familiarity as well as study–test context matching. The present experiments manipulated context between subjects to ensure comparability with context-reinstatement experiments, because most of them have employed this between-subjects design or AA–AB (and BB–BA) paradigm (cf. Smith, 1988; Smith & Vela, 2001). In this paradigm, the memory test in the different context condition (AB, BA) is conducted in a novel context, whereas that in the same context condition (AA, BB) is done in a familiar context. This context novelty or familiarity may influence memory performance regardless of study–test context matching. Context novelty might arouse certain moods such as anxiety, curiosity, or suspicion, any of which might produce a performance decrement. At the same time, all study contexts are inevitably novel. If the study context novelty arouses a mood similar to that in the test context, the AB and BA conditions may lead to study–test mood congruency, which can produce a performance increment (e.g., Eich & Metcalfe, 1989). The possibility that the mood induced by context novelty exclusively produces the difference between the same and different context conditions is unclear—it was rejected by Smith (1979) but not by Bjork and Richardson-Klavehn (1989). Thus it is possible that the simple difference in memory performance between the same and different context conditions reflects context novelty or familiarity as well as study–test context matching.

It is possible that context familiarity produced the present interactions between context and study time. Context familiarity may be one of the factors producing context effects rather than a confounding factor. Murnane and his colleagues developed a global matching theory which posits that recognition judgement is based not on context matching but on context familiarity when the context is truly incidental or is not integrated into an ensemble with the items as a simple visual context (Murnane & Phelps, 1993, 1994, 1995; Murnane et al., 1999). Additionally, context familiarity increases with exposure time to the context regardless of what participants are doing in the context. In the present experiments, the study session took more time with the longer study times for individual items, because the study time was manipulated between subjects. Consequently, the context familiarity could have increased with study time, and this increase might have produced the interaction between context and study time.

However, there is evidence against this possibility. Isarida and Isarida (2001) examined whether the background colour context interacted with study time in free recall. They manipulated study time between subjects, so that the longer study times for individual items brought about longer total exposure times for the background colour contexts. They found no interaction between study time and context; the context effect size did not increase with study time. In contrast, previous experiments on study time and simple visual context manipulated the context within subjects, so that only the presentation time for each item–context pair was varied and the exposure time for each context was constant (Dougal & Rotello, 1999; Murnane & Phelps, 1995). Two further studies consisting of six recognition experiments (Isarida, Isarida, & Okamoto, 2005; Isarida & Ozeki, 2005) have reported no increase in the effect of context as a function of between-subjects study time. This finding implies that context familiarity does not increase the context effect size associated with study time, regardless of whether familiarity increases with exposure time or not. Thus, it seems more likely that context familiarity was not involved in the present interactions between context and study time. The interactions may have simply reflected the strength of item–context associations or integration with study time for individual items. In any case, further research is needed that manipulates study time within subjects.

The finding that study time, manipulated between subjects, interacted with the place context but not with the background colour context (Isarida & Isarida, 2001; Isarida et al., 2005; Isarida & Ozeki, 2005) raises another interesting question about whether place context and background colour or simple visual context have different characteristics. That is, place context may be more than merely independent context, whereas background colour and simple visual contexts could be truly independent contexts. However, this question is beyond the scope of this article, and further research is needed to address this issue.

Inter-item association, as well as environmental context, is strengthened as a function of study time and enhances free recall performance (e.g., Glenberg, 1979; Tulving, 1962). The present results imply that inter-item association works both independently and cooperatively with the environmental context in producing the study-time effect. First, a study-time effect in free recall is produced when either inter-item associations or environmental context cues are available. Second, a greater study-time effect is produced when both cues are available than when only either one of them is available. Third, the study-time effect disappeared when neither the environmental context nor the inter-item association cues were available. Thus, environmental context and inter-item association cues may additively produce a greater study-time effect.

The disappearance of the study-time effect when context was changed at recall suggests that item strength may not always influence free recall performance, although a variety of theories of memory have assumed that it does (e.g., Clark & Gronlund, 1996; Glenberg, 1979; Murnane et al., 1999). Item strength might be a necessary factor in recognition memory, in which item-based judgements are assumed to play a key role. However, this finding does not deny the possibility that shorter and/or longer study times, out of the range manipulated by the present experiments, might change memory performance even in the different context condition. Possibly, very short study times of less than 1 minute may be involved in the integration of the presented letters into one word, and long study times might bring about the decontextualisation of items (e.g., Smith, 1988, 1994). In any case, further empirical studies are needed to examine this issue.

The disappearance of the study-time effect may appear surprising, in comparison with previous memory research where this effect and related effects, such as the repetition effect or the rehearsal effect, have almost always been observed in a variety of studies since Ebbinghaus (1885; cf. Crowder, 1976; Greene, 1992). However, this disappearance in the different context condition does not conflict with the preceding findings, because almost all of the preceding experiments have been conducted either with an immediate recall or in the same context for the recall condition, and not in a different context for the recall condition.

Finally, the environmental context constitutes a distinctive part of an episodic memory trace as an episode-defining context. Thus, environmental context should influence the appearance and the size of several episodic-memory phenomena. The present results have demonstrated this in the case of the study-time effect. Furthermore, other episodic-memory phenomena have also been found to be influenced by the presence or the reinstatement of environmental context. More specifically, the rehearsal effect, the spacing effect in repetition, and the recency effect all have been reported to depend on environmental context (Isarida, 1992; Isarida & Isarida, in press; Isarida & Morii, 1986). On the other hand, inter-item association constitutes a part of an episodic memory trace that is independent of environmental context. Thus, inter-item association can also determine episodic memory phenomena, and the inter-item association elements of the trace will remain if the trace is decontextualised (e.g., Smith, 1988, 1994).

Manuscript received 25 March 2004
Manuscript accepted 22 March 2005

REFERENCES

Bjork, R. A. (2001). Recency and recovery in human memory. In H. L. Roediger II, J. S. Nairne, I. Neath, & A. M. Surprenant (Eds.), *The nature of remembering: Essays in honor of Robert G. Crowder* (pp. 211–232). Washington, DC: American Psychological Association.

Bjork, R. A., & Richardson-Klavehn, A. (1989). On the puzzling relationship between environmental context and human memory. In C. Izawa (Ed.), *Current issues in cognitive processes: The Tulane Flowerre Symposium on cognition* (pp. 313–344). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Bjork, R. A., & Whitten, W. B. (1974). Recency-sensitive retrieval processes in long-term free recall. *Cognitive Psychology*, *6*, 173–189.

Blaney, P. H. (1986). Affect and memory: A review. *Psychological Bulletin*, *99*, 229–246.

Bousfield, W. A. (1953). The occurrence of clustering in the recall of randomly arranged associates. *Journal of General Psychology*, *49*, 229–240.

Clark, S. E., & Gronlund, S. D. (1996). Global matching models of recognition memory: How the models match the data. *Psychonomic Bulletin & Review*, *3*, 37–60.

Crowder, R. G. (1976). *Principles of learning and memory*. Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Dougal, S., & Rotello, C. M. (1999). Context effects in recognition memory. *American Journal of Psychology*, *112*, 277–295.

Ebbinghaus, H. (1885). *Über das Gedächtnis*. Leipzig: Dunker.

Eich, J. E. (1980). The cue-dependent nature of state-dependent retrieval. *Memory & Cognition*, *8*, 157–173.

Eich, J. E., & Metcalfe, J. (1989). Mood dependent memory for internal versus external events. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*, 443–455.

Falkenberg, P. R. (1972). Recall improves in short-term memory the more recall context resembles learning context. *Journal of Experimental Psychology*, *95*, 39–47.

Geiselman, R. E., & Bjork, R. A. (1980). Primary versus secondary rehearsal in imagined voices: Differential effects on recognition. *Cognitive Psychology*, *12*, 188–205.

Glenberg, A. M. (1979). Component-levels theory of the effects of spacing of repetitions on recall and recognition. *Memory & Cognition*, *7*, 95–112.

Greene, R. L. (1992). *Memory: Paradigms and paradoxes.* Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Isarida, T. (1992). Influences of environmental-context changes on rehearsal effects in episodic memory. *Japanese Journal of Psychology*, *63*, 262–268.

Isarida, T., & Isarida, T. K. (2001). *Effects of background color of to-be-remembered items on free recall.* Paper presented at 65th Annual Meeting of The Japanese Psychological Association, Tsukuba.

Isarida, T., & Isarida, T. K. (2004). Effects of environmental context manipulated by the combination of place and task. *Memory*, *12*, 376–384.

Isarida, T., & Isarida, T. K. (in press). Influences of environmental context on the recency effect in free recall. *Memory & Cognition.*

Isarida, T., & Isarida, T. K., & Okamoto, K. (2005). Influences of cue-overload on background-color context effects in recognition. *Japanese Journal of Cognitive Psychology*, *3*, 45–54.

Isarida, T., & Morii, Y. (1986). Contextual dependence of the spacing effect in free recall. *Japanese Journal of Psychology*, *57*, 20–26.

Isarida, T., & Ozeki, K. (2005). Environmental context effects of background colors on recognition memory. *Japanese Journal of Psychology*, *75*, 503–510.

Koyanagi, K., Ishikawa, S., Okubo, Y., & Ishii, E. (1960). The familiarity values of Japanese three-letter nouns. *Japanese Journal of Psychology*, *30*, 49–57.

Light, L. L., & Carter-Sobell, L. (1970). Effects of changed semantic context on recognition memory. *Journal of Verbal Learning and Verbal Behavior*, *9*, 1–11.

Murnane, K., & Phelps, M. P. (1993). A global activation approach to the effect of changes in environmental context on recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 882–894.

Murnane, K., & Phelps, M. P. (1994). When does a different environmental context make a difference in recognition? A global activation model. *Memory & Cognition*, *22*, 584–590.

Murnane, K., & Phelps, M. P. (1995). Effects of changes in relative cue strength on context-dependent recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*, 158–172.

Murnane, K., Phelps, M. P., & Malmberg, K. (1999). Context-dependent recognition memory: The ICE theory. *Journal of Experimental Psychology: General*, *128*, 403–415.

Ogawa, T., & Inamura, Y. (1974). An analysis of word attributes imagery, concreteness, meaningfulness and ease of learning for Japanese nouns. *Japanese Journal of Psychology*, *44*, 317–327.

Rand, G., & Wapner, S. (1967). Postural status as a factor in memory. *Journal of Verbal Learning and Verbal Behavior*, *6*, 268–271.

Smith, S. M. (1979). Remembering in and out of contexts. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 460–471.

Smith, S. M. (1988). Environmental context-dependent memory. In G. M. Davis & D. M. Thomson (Eds.), *Memory in context: Context in memory* (pp. 13–33). New York: Wiley.

Smith, S. M. (1994). Theoretical principles of context-dependent memory. In P. Morris & M. Grünberg (Eds.), *Theoretical aspects of memory* (pp. 168–195). New York: Routledge.

Smith, M. S., & Vela, E. (2001). Environmental context-dependent memory: A review and meta-analysis. *Psychonomic Bulletin & Review*, *8*, 203–220.

Tulving, E. (1962). Subjective organization in free recall of "unrelated" words. *Psychological Review*, *69*, 344–354.