Chapter

Environmental Context-dependent Memory

Takeo Isarida[1,*] and Toshiko K. Isarida[2]

[1]Shizuoka University, Faculty of Informatics, Japan

[2]Shizuoka Prefectural University, Shizuoka College, Japan

Abstract

This chapter reviews the theories and empirical findings about environmental context-dependent memory. Environmental context refers to incidental information about the environment in which the focal information is processed. The environmental context is encoded with the focal information into an episodic-memory trace, and is used as a retrieval cue at the time of remembering. Environmental context dependency is one of the most important characteristics of episodic memory. Episodic memory consists of the tracks of an individual's personal history. Clarifying the mechanisms of environmental context-dependent memory addresses a basic mechanism of the human mind. This chapter focuses on environmental context studies after Smith's (1988) review and especially after Smith and Vela's (2001) meta-analysis. Accordingly, this chapter mainly addresses the studies about (1) complex-place context, (2) environmental context-dependent recognition, and (3) various environmental contexts.

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* Correspondent Author: Takeo Isarida, e-mail: Isarida@inf.shizuoka.ac.jp.

INTRODUCTION

Consider the following common experience. You are reading a newspaper in the living room, and you want to cut out an article. However, you realize that you don't have a pair of scissors at hand, but there is a pair in the kitchen. So you go to the kitchen to get the scissors. But you get distracted when you enter the kitchen. When you snap back to reality, you have forgotten the reason why you came to the kitchen, and so you go back to the living room. As soon as you get back to the living room, you remember that you were trying to get a pair of scissors. This is a typical anecdotal example of context-dependent memory in daily life.

The memory involved in context-dependent memory is called *episodic memory*. Episodic memory is related to various contextual information involving time, location, and situations, such as "when", "where", "how" and "with whom". Remembering focal information or a target requires a cue to retrieve, which is called a *retrieval cue*. According to the encoding specificity principle, any information which existed with the target could be encoded into an episodic trace with the target, and this information could serve as a retrieval cue for the target (Tulving & Thomson, 1973). Such information other than the target is called *context*. In brief, target information can be retrieved by using context information as a retrieval cue.

In the opening example, although you were not able to remember the scissors in the kitchen, you easily remembered it as soon as you returned to the living room. What differences are there between the kitchen and the living room? In the living room, there are various physical characteristics (e.g., size, brightness, furniture, and various items such as the newspaper) of the environment in which you thought of the scissors. Such physical information can facilitate the reinstatement of the context of the scissors, which is called *physical reinstatement*. It is difficult to physically reinstate the memory of the scissors in the kitchen, because the physical characteristics of the environment are so different from that of the living room where you thought of the scissors. Consequently, it becomes hard to remember why you came to the kitchen. However, once you are back in the living room, it becomes easier for you to physically reinstate that memory because it was associated with that context.

Physical reinstatement of the original context is not always possible. For example, it is difficult physically to reinstate the environment where we had left our umbrella when we are back home. In these cases, instead of physically reinstating the episodes, we try to retrace the episodes in our memory, and visualize various situations where we might have left the umbrella. Mentally remembering without depending on the physical environment is referred to as *mental reinstatement*. In any case, the environment in which the focal information was processed enhances the remembering of the focal information, even though the environment is incidental to the focal information. This phenomenon is called *environmental context-dependent memory*.

A BRIEF HISTORICAL REVIEW

Early Studies

In early studies about environmental context-dependent memory, the environmental context referred to incidental environmental information about the place, room, or location where participants processed focal information. The flourishing research on environmental context-dependent memory started with Godden and Baddeley's (1975) study using a dramatic environmental change between land and underwater. Steven Smith systematically stimulated various types of environmental context-dependent memory by manipulating the physical features of rooms (see Smith, 1988 for a review). Consequently, various environmental context-dependent phenomena were found:

(1) environmental-context dependent effects were found in free recall but not in recognition (Godden & Baddeley, 1975; Smith, Glenberg & Bjork, 1978);
(2) imaging the study environment facilitated mental reinstatement of study context (Krafka & Penrod, 1985; Malpass & Devine, 1981; Smith, 1979, 1984);
(3) encoding under multiple environmental contexts yielded superior recall compared to a single context (Glenberg, 1979; Smith, 1982, 1984, 1985a; Smith & Rothkoph, 1984).

However, several studies cast doubt on the reliability of environmental context-dependent memory effects. Fernandez and Glenberg (1985) conducted eight experiments on environmental context-dependent effects in recall by manipulating physical features of rooms, and failed to find reliable effects. They concluded that manipulation of the match between the study and test rooms does not capture the critical features of natural changes in context that produce the same-context advantage. They proposed that environmental context studies (1) should deal with memory for events that are perceived to be related to the environment, and (2) should manipulate the environmental context involving the components of the context (environmental, experimental, temporal, subject's goals, etc.) that are likely to be perceived by the participant as relevant to the memory task. Bjork and Richardson-Klavehn (1989) manipulated environmental context within participants, and failed to find reliable effects in two experiments. They concluded that incidental environmental context is not able to produce reliable context-dependent effects. These authors all proposed that incidental context, which is not interactively processed with to-be-remembered items, does not produce reliable context effects.

The doubts cast by influential researchers on the reliability of environmental context-dependent memory involving place may have discouraged further studies. During the 1990s, prior to Smith and Vela's (2001) meta-analysis, we could find only three articles on environmental-place context-dependent memory (Dalton, 1993; Eich, 1995; Russo Ward, Geurts, & Sheres, 1999). However, these doubts may have stimulated context studies of environmental information other than place, such as simple visual context (Dougal & Rotello, 1999; Murnane & Phelps, 1993, 1994, 1995; Murnane, Phelps, & Malmberg, 1999), background-music context (Balch, Bowman, & Mohler, 1992; Balch & Lewis, 1996; Smith, 1985b), and odor context (Cann & Ross, 1989; Herz, 1997; Parker, Ngu, & Cassaday, 2001; Pointer & Bond, 1998; Schab, 1990; Smith, Standing, & deMan., 1992).

The doubts about the influence of the environmental context of place can be interpreted as follows. Any manipulation of physical aspects of the environment may not be sufficient to produce reliable context-dependent memory, even if it involved a complete change of place. In particular, Fernandez and Glenberg's (1985, p. 344) suggested: "From the experimenter's point of view, changing the room produces a massive change in stimulation. The critical feature for the subject, however, may be that the events take place within the context of an experiment, and this feature does not change with a change of room." Accordingly, the functions of internal factors, such as mood or mental context, were highlighted. Eich (1995) demonstrated that mood mediates place-dependent memory. Furthermore, Isarida and his associates manipulated not only physical aspects of the environment but also other factors influencing internal factors, and they reliably found context-dependent memory (Isarida, 1992, 2005; Isarida & Isarida, 2004, 2006, 2010; Isarida & Morii, 1986).

Smith and Vela's Meta-analysis

Smith and Vela (2001) demonstrated the reliability of environmental context-dependent memory across many studies in their meta-analysis. Moreover, Rutherford (2000) successfully found the environmental context-dependent effects that Fernandez and Glenberg (1985) had failed to find and replicate. These studies restored the reputation of environmental context-dependent memory studies.

Furthermore, Smith and Vela compared the weighted effect sizes across various variables. They found the following:

(1) the effect size of the reinstatement paradigm was lower than the other paradigms;
(2) inter-item associative processing pronouncedly decreased the effect size;
(3) the combined manipulation of place and experimenter markedly increased the effect size;
(4) a quite large effect size was obtained with a retention interval of one day or more.
(5) Surprisingly, there were no differences in the effect sizes between recall and recognition, although environmental context-dependent effects in recognition had been more difficult to find than in recall in studies following Smith et al. (1978).

Note that Smith and Vela's meta-analysis did not analyze the data from studies of all types of environmental context. Studies on both background color and simple visual context were excluded in their analysis, because such contexts change quickly whereas place context does not change, or changes slowly. Additionally, studies on internal mood or state (e.g., Bower & Cohen, 1982), posture context (Rand & Wapner, 1967), or odor context (e.g., Cann & Ross, 1989) were not included. Consequently, Smith and Vela's meta-analysis demonstrated the reliability of place-dependent memory, and clarified the effects of various variables of encoding and testing on place-dependent memory. The context-dependent effects of other environmental information still remained open questions.

In any case, Smith and Vela's meta-analysis may have indicated to researchers that the issues of place-dependent memory had been resolved. Since the meta-analysis, research has primarily focused on the contexts excluded from the meta-analysis, such as simple and rich visual contexts

(Gruppuso, Lindsay, & Masson, 2007; Hockley, 2008; Macken, 2002), background-color context (Isarida & Isarida, 2007; Isarida, Isarida, & Okamoto, 2005; Rutherford, 2004; Sakai, Isarida, & Isarida, 2010), and odor context (Ball, Shoker, & Miles, 2010; Isarida, Sakai, Kubota, Koga, Katayama, & Isarida, 2014; Parker et al., 2001; Yamada & Chujo, 2009), and on background-music context (Balch et al., 1992; Balch & Lewis, 1996; Mead & Ball, 2007). Additionally, Isarida and his associates had conducted research on the effect of complex-place context (Isarida, 2005; Isarida & Isarida, 2004, 2006, 2010; Isarida, Isarida, & Sakai, 2012).

Mediation by Internal Factors

Smith and Vela's (2001) meta-analysis confirmed the reliability of place-dependent memory. However, there are still open issues about place-dependent memory. Especially, the elements of places that produce context-dependent effects have not been identified, although some principles were proposed that modulate or attenuate place-dependent effects, such as mental reinstatement (Bjork & Richardson-Klavehn, 1989), overshadowing (Smith, 1994), and outshining (Smith, 1994). In fact, some researchers have argued and provided evidence that certain mental factors rather than the physical place are critical for producing context-dependent memory (e.g., Eich, 1995; Isarida & Isarida, 1999; Smith, 1995).

Mood Mediation of Place-dependent Memory Eich (1995) proposed that mood mediates place-dependent memory and demonstrated this in three experiments. He used a small room in a college building and an open space in a Japanese garden near the college as place contexts. In the encoding task, participants were required to generate autobiographical events, each probed by a noun, orally presented one at a time, and to rate the emotionality, the personal significance or importance, and the vividness of the event. After a two-day retention interval, participants orally recalled the autobiographical events probed by the nouns. Following this free recall test, participants were required to rate the similarity of their mood between the generation task and the testing. The results showed that the free recall performance was correlated with the similarity of mood between the generation task and the free recall test, regardless of whether or not the places of the generation task and the free recall test were matched. He concluded that place-dependent effects were not produced by a direct association between focal events and place, but rather that changes in place could produce mood changes, and then the mood changes would determine the recall of focal events.

However, mood-dependent memory may not be robust enough to mediate the place-dependent memory. Bower, Gilligan, and Monteiro (1981) hypnotically induced mood states, but they only found a mood-dependent effect in one of three experiments. Furthermore, Eich and Metcalfe (1989) found mood-dependent effects in free recall for self-generated words but not for presented words. Almost all the subsequent studies on mood-dependent effects used free recall of self-generated words (e.g., Balch, Myers, & Papotto, 1999; Eich, 1995). In contrast, various environmental context-dependent effects in free recall have been found for both self-generated and presented words (see Smith & Vela, 2001). These findings suggest that explaining the place-dependent effect for presented items as being mediated by mood-dependent effects, which have not been found for presented items, would be implausible.

Mental Context View Smith (1995) proposed theoretically that mental context, rather than mood, mediates context-dependent memory. He argued that environmental context-dependent memory is actually influenced by associations between the mental context and the focal information rather than by associations between representations of the environment and focal information. The mental context proposed by Smith consists of not only mood and representations of ambient environments but also the participant's mental set, physiological events, active memories, and other incidental factors. However, Smith did not conduct any experiments demonstrating the effects of the mental context. His studies were limited to effects of the physical aspects of incidental environments.

Empirically, Isarida and Isarida (1999) separated changes in internal or mental factors (tension, concentration, mood, and so forth between a class and a break in college) from those in places (classroom, corridor, campus grounds, library, and so forth in college). They found that recall was influenced not by changes in place but by changes in certain internal or mental factors. Recently, Isarida et al. (2014) found that the size of odor-dependent effects in free recall did not decrease with decreasing intensity of olfactory sensation because of adaptation. This result implies that the odor-dependent effects do not reflect any association between each item and the olfactory information contiguous to the item, but instead reflect the associations between items and certain global contextual information, such as the mental context of the experimental environment with a specific odor. This finding also supports the mental context view of environmental context-dependent memory.

COMPLEX-PLACE CONTEXT STUDIES

In the previous section, mental factors rather than physical factors of places have been proposed and shown to be critical for place-dependent memory. Note that markedly large changes even in place alone, such as on land and under water (e.g., Godden & Baddeley, 1975) and in a laboratory and at home (Canas & Nelson, 1986), often lead to profoundly large, and possibly functional, changes in context. However, such large changes in place are quite likely to co-vary with certain internal or mental factors, such as nervousness or anxiety under water or in a laboratory, and relaxation on land or at home. If so, researchers should explicitly manipulate certain contextual elements influencing internal or mental factors with place.

Isarida and his colleagues have manipulated the environmental context by place and other contextual elements influencing internal factors, such as subsidiary task and experimenter, which they call *complex-place context* (Isarida, 2005; Isarida & Isarida, 2004, 2006, 2010; Isarida et al., 2012). On the other hand, the environmental context manipulated only by place is called *simple-place context* (Isarida & Isarida, 2010). Place provides a field where focal information is processed, and a subsidiary task can influence the meaning of the learner's processing of focal information during the learning episode. Isarida and Isarida (2004) found that the place alone cannot influence the meaning in the processing of focal information within the place, and that the task can compensate for the lack of the place functions. Furthermore, the experimenter provides social environmental information as well as being a part of the physical environment, and the social environmental information can influence the situational meaning of the learning episode. Thus other elements than place may compensate for the inability of place alone to define a learning episode.

The reinstatement paradigms, used in the majority of environmental-context studies, have consistently shown quantitatively reliable superiority in memory for complex-place context over simple-place context. Empirically, contexts manipulated by the combination of place and experimenter have been found to produce markedly larger sizes of context effects than those manipulated by only place (Smith & Vela, 2001). Also, contexts manipulated by the combination of place and subsidiary task produced a significant context effect, even when the manipulation of place alone produced no effect (Isarida & Isarida, 2004). Moreover, the contexts manipulated by place and subsidiary task and experimenter have consistently yielded reliable context-dependent effects (Isarida, 1992, 2005; Isarida & Isarida, 2006; Isarida & Morii, 1986).

Multiple-context Paradigm

In a multiple-context paradigm, memory performance for to-be-remembered items learned repeatedly in multiple contexts is compared with memory performance for items learned repeatedly in a single context. The empirical findings suggest that the simple-place context and the complex-place context have functional or qualitative differences. More specifically, completely reversed phenomena have been found, sometimes favoring single context learning and other times favoring multiple contexts (Glenberg, 1979; Isarida & Isarida, 2005; Smith et al., 1978).

Smith et al. (1978) compared free recall of items learned twice in the same and different simple-place contexts: same- and different-context repetitions. Free recall was tested in a neutral simple-place context. Their results showed superiority in recall for different-context repetition over same-context repetition. Glenberg (1979) successfully replicated the superiority of different-context repetition with the same contextual manipulation and with more participants. Lately, Isarida and Isarida (2005) found superiority in recall for same-context repetition over different-context repetition. They used a complex-place context of place and two contextual elements (encoding task and the social environment of engaging in a task either individually or in a group) and compared free recall of items learned twice in the same- and different-context repetition conditions. Free recall was tested in a neutral context, as in the previous studies. The results of their Experiment 1 showed that recall for the same-context repetition was superior to the different-context repetition, and this superiority of same-context repetition was successfully replicated in Experiment 2. This finding was a complete reversal of the findings of Glenberg and Smith et al. It should be noted that both the inter-study intervals (the interval separating different study periods of the same materials) and the retention intervals (the interval separating the final study periods and a later test) were also different between the previous studies and Isarida and Isarida. Both the inter-study and the retention intervals in Glenberg and Smith et al. were three hours, whereas those in Isarida and Isarida were one week. Logically, the reversal could be caused by any of the differences in the type of context, the inter-study interval, and the retention interval.

Isarida and Isarida (2010) explored the factors determining the reversal by systematically varying the type of context (simple- or complex-place context) and the length of the inter-study and retention intervals (ten minutes or one day). The results, together with previous findings (Glenberg, 1979; Isarida & Isarida, 2005; Smith et al., 1978), indicated that the type of context exclusively determined the reversal. More specifically, when the length of the inter-study and the retention intervals are equal, the simple-place context consistently produced superiority of different-context repetition, whereas the complex-place context consistently produced superiority of same-context repetition. In contrast, when the length of the inter-study interval was much shorter than the retention interval, the superiority of different-context repetition, found with the simple-place context, was eliminated, whereas the superiority of same-context repetition, found with the complex-place context, was maintained.

This asymmetric phenomenon may involve the ratio rule (e.g., Bjork & Whitten, 1974; Crowder, 1976; Glenberg, Bradley, Kraus, & Renzaglia, 1983). The ratio rule states that the probability of recall or the size of the recency effect is proportional to the ratio of the length of the inter-study interval to the length of the retention interval. The simple-place context showed the superiority of different-context repetition when the ratio was 1.0 (10 min/10 min, 3 h/3 h, 1 day/1 day), but not when the ratio was nearly zero (10 min/1 day). These results are consistent with the ratio rule. In contrast, the complex-place context showed the superiority of same-context repetition regardless of whether the ratio was 1.0 (10 min/10 min, 1 day/1 day, 1 week/1 week) or nearly zero (10 min/1 day). These results indicate that the complex-place contexts do not conform to the ratio rule. The superiority of different-context repetition is subject to the ratio rule, but the superiority of same-context repetition is not.

Glenberg et al. (1983) proposed a context-guided retrieval hypothesis to account for the recency effect. In this hypothesis, various types of contexts having different changing rates characterize the recency effect. More importantly, the contexts characterizing the recency effect change within an episode, and the appearance of the context-guided recency effect is subject to the ratio rule. In contrast, Isarida and Isarida (2006) found a recency effect that does not conform to the ratio rule. They found that reinstatement of a complex-place context always produced the recency effect even though the ratio was nearly zero, where no recency effect is predicted according to the ratio rule. As such, a simple-place context can produce phenomena that are subject to the ratio rule, whereas a complex-place context can produce phenomenon that do not follow the ratio rule.

Place is stable throughout a learning episode, so that simple-place context can surround a learning episode. However, manipulation of place alone is not sufficient to reinstate the original learning-episode context, because the context consists of not only place but also the other elements as described above. Consequently, the context manipulated or reinstated by only place could fluctuate episode by episode. In contrast, elements other than place of complex-place context can compensate for the lack of place. As a result, complex-place context does not fluctuate within a learning episode but defines the episode itself.

Remembering Within and Out of Context

In everyday life, people remember episodes out of the context as well as within it. However, in most laboratory experiments, memory has been almost always measured only within the original context. In a typical memory experiment, both the initial study and the later testing of memory are completed within one experimental session, and hence, within one experimental episode. 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 of the learning episode was reinstated at the time of testing. If episodic memory phenomena have been studied only within the original context, researchers may have clarified only half of the characteristics of episodic-memory phenomena. Thus, researchers should examine episodic-memory phenomena out of the context as well as within it.

In many cases, the characteristics of episodic-memory phenomena have been found empirically to be different within and out of the complex-place context (Isarida, 1992, 2005; Isarida & Isarida, 2006; Isarida & Morii, 1986). Isarida (2005) reported that the study-time effect in free recall was markedly diminished when neither the original complex-place context was reinstated nor the inter-item association was suppressed. Also, the study-time effects disappeared when the context was not reinstated and inter-item associations were suppressed. Likewise, when the original complex-place context was not reinstated, both the spacing effect of repetition (Isarida & Morii, 1986) and the recency effect (Isarida & Isarida, 2006) in free recall disappeared. Similarly, the cumulative rehearsal effect in free recall was markedly diminished (Isarida, 1992). In contrast, all of these effects appeared when the contexts were reinstated.

Note that inter-item associations among items may have been suppressed by the repetition of the same items (Isarida & Morii, 1986), and by both the pairwise presentations across serial positions and the incidental learning paradigm (Isarida & Isarida, 2006). Additionally, inter-item associations may not have been suppressed but been enhanced by cumulative rehearsal of items (Isarida, 1992). Thus, these findings may imply that the elements of memory phenomena involving inter-item associations are context independent, whereas those not involving inter-item associations are context dependent.

Regression Analysis of Study-time Effects Within and Out of Complex-place Context

The sizes of the influence of study time on context-dependent effects have been found to differ between complex-place contexts and simple environmental contexts, such as background color, background music, and odor. On one hand, the size of complex-place context-dependent effects in free recall increased as a function of study time (Isarida, 2005). On the other hand, the size of context-dependent effects of background color (Isarida & Isarida, 2007), background music (Isarida et al., 2008), and odor (Isarida et al., 2014) were unchanged with the length of study time.

The findings of Isarida (2005) seem to be isolated, although they were confirmed in three independent experiments. To evaluate this further, we conducted a regression analysis of the data from the complex-place context experiments adding data from all the relevant studies of Isarida, and examined whether the results would confirm Isarida's (2005) findings or the prediction from the one-shot hypothesis. The criteria for inclusion in this regression analysis were: (1) the context was manipulated by the combination of place, subsidiary task, and experimenter; (2) the retention interval was 24 hr; (3) the match and mismatch of context(s) were manipulated between participants; (4) no manipulation was made to suppress inter-item associations. Additionally, (1) the respective between-participants conditions were independently analyzed, even if some of them were included in one experiment; (2) when the study time was manipulated within participants, the means of the study times of all the within-participants conditions were used; and (3) when two or more items were simultaneously presented, the total study time was divided by the number of simultaneously presented items. Consequently, the present analysis used the data of both the SC and DC conditions from the following 9 study conditions (*n* refers to the number of participants in each of the SC and DC conditions): Isarida (1988) (n = 30); Experiment 2 from Isarida (1991) (n = 30); Isarida (1992) (n = 30); 2 conditions of Experiments 2 and 3 (n = 30 for each) from Isarida (2005); Isarida and Isarida (1998) (n = 18); and Experiment 1 from Isarida and Isarida (2006) (n = 52).

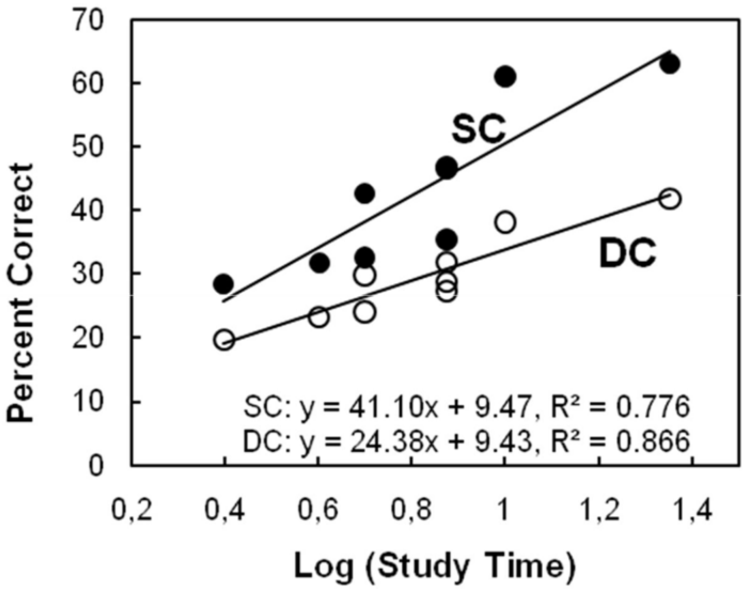

Figure 1. Proportion of correct recall of independent conditions in SC and DC conditions as a logarithmic function of study time (sec).

Figure 1 shows the mean percent of items recalled in the SC and DC conditions of the 9 independent conditions as a logarithmic function of study time (sec). Here a matched condition is called a same-context (SC) condition, and a mismatched condition is called a different-context (DC) condition. The slope of the least-squares regression line for the SC condition was 41.10, and that for the DC condition was 24.38. The SC slope was significantly greater than the DC slope [$t(20) = 2.79$, $p = .013$, $d = 1.641$]. This regression analysis further confirms that the effects of complex-place context increase with study time. Thus, we confidently conclude that the contextual effect size of complex-place context reliably increases as a function of study time.

The one-shot hypothesis of Malmberg and Shiffrin (2005) explains well the influence of study time on the size of context-dependent effects only in simple-environmental contexts but not in complex-place contexts. Their hypothesis predicts that the sizes of context-dependent effects will not change with study time. According to the one-shot hypothesis, even if the strengths of items are increased by massed study, such as an increase in study time, the number of consecutive presentations, or the depth of processing, only a fixed amount, or "one shot", of context will be stored in an episodic-memory trace. Their hypothesis states that a fixed amount of context will be stored within the first one or two seconds, and that the subsequent time for studying will produce additional storage only of content information, such as meaning. Furthermore, the prediction from the one-shot hypothesis is consistent with the context-dependent study-time effect in free recall within and out of simple environmental contexts, such as background color, background-music, and odor.

As described previously, simple environmental contexts may fluctuate within and across learning episodes, so they cannot define the episodes themselves. Such fluctuating contexts may be subject not only to the ratio rule but also to the one-shot hypothesis. In contrast, a complex-place context defines a learning episode, so it may produce phenomena that follow neither the ratio rule nor the one-shot hypothesis.

ENVIRONMENTAL CONTEXT-DEPENDENT EFFECTS IN RECOGNITION

This section addresses environmental context-dependent effects in recognition. On the one hand, environmental context-dependent recall is understood straightforwardly as empirical evidence supporting the episodic-memory theory (Tulving, 1983) and the encoding specificity principle (Tulving & Thomson, 1973). That is, the environmental context is encoded with the focal information into an episodic memory trace, and is used as a retrieval cue at the time of remembering. On the other hand, for recognition testing, there are item-specific cues as well as an environmental context cue. Therefore, context-guided retrieval processes by themselves are not sufficient to explain environmental context-dependent recognition. In fact, the findings of environmental context-place dependent recognition, especially of meaningful words, are too ambiguous to explain only by the encoding specificity principle.

Isarida et al. (2012) have recently reported that the encoding specificity principle can explain well the equivocal findings of place-dependent recognition by adding the outshining principle (Smith, 1988, 1994). On the other hand, the ICE (Item-Context-Ensemble) theory explains environmental context-dependent recognition by the global match of the probe cue and memory information, including items and context, at the time of the recognition test (Murnane, Phelps, & Malmberg, 1999). The ICE theory can explain well recognition processes dependent on various visual contexts (e.g., Hockley, 2008; Murnane & Phelps, 1993, 1994, 1995; Murnane et al., 1999).

Empirical Findings of Place-dependent Recognition

The evidence for place-dependent recognition has been equivocal, especially with meaningful words. Most researchers had previously accepted the proposition that place-dependent effects appear in recall but not in recognition (Baddeley, 1982; Godden & Baddeley, 1975, 1980; Smith et al., 1978). This reflects the empirical findings that place-dependent recognition was not found with the same environmental manipulations where place-dependent recall had been found (Godden & Baddeley, 1975, 1980; Smith et al., 1978). However, many subsequent experiments reported significant place-dependent recognition using meaningful words (Canas & Nelson, 1986; Emmerson, 1986; Smith, 1985, 1986). These findings fatally damaged the well accepted proposition that place-dependent effects appear in recall but not in recognition.

However, there are methodological issues with half of the experiments that found significant place-dependent recognition (i.e., Canas & Nelson, 1986; Smith, 1986). Canas and Nelson manipulated place context between the laboratory and a telephone call at home. There was confounding of context matching and test place, because participants in the mismatched context condition always received the recognition test by phone at home whereas those in the matched context condition always received the test at the laboratory. Smith (1986) manipulated levels of processing at encoding, and found that shallow processing produced place-dependent recognition, but deeper processing did not. However, Smith and his colleagues failed to replicate these findings, and concluded that shallow processing does not produce place-dependent recognition (Smith, Vela, & Williamson, 1988). Thus, it is still uncertain whether recognition of meaningful words is influenced reliably by changes in place context.

The equivocal findings for place-dependent recognition of meaningful words in our review seem to contradict the results of Smith and Vela's (2001) meta-analysis, in which the size of the context-dependent effect in recognition was nearly the same as in recall. However, the data in the meta-analysis included not only meaningful materials but also unfamiliar or meaningless material. Importantly, the unfamiliar or meaningless material produced large effect sizes for context-dependent recognition. The large effect size of recognition in the meta-analysis may be caused by the data from unfamiliar or meaningless material (e.g., Dalton, 1993; Krafka & Penrod, 1985; Malpass & Devine, 1981; Smith & Vela, 1992) and from the problematic studies (e.g., Canas & Nelson, 1986; Smith, 1986).

Isarida et al. (2012) argue that these equivocal findings could be understood by assuming the following two trends. First, there is a clear trend showing that the appearance of place context-dependent recognition is influenced by the familiarity or meaningfulness of the material. It has been repeatedly reported that recognition of unfamiliar or meaningless material, such as unfamiliar faces and nonwords, is influenced by changes in place context (e.g., Dalton, 1993; Malpass & Devine, 1981; Russo, Ward, Geurts, & Schres, 1999). Furthermore, previous findings of place-dependent recognition of words show a general tendency that place-dependent recognition decreases with increasing study time. Empirically, Isarida et al. (2012) demonstrated the validity of the two trends. More specifically, significant context-dependent effects in recognition discrimination of meaningful words were found in a short (1.5 s/item) study-time condition. On the other hand, significant context-dependent effects in recognition discrimination were found with nonwords even in a long (4.0 s/item) study-time condition where no context-dependent recognition of meaningful words was found.

The Outshining Account

The two trends are clearly explained by the outshining account (Isarida et al., 2012), consisting of encoding specificity (Tulving & Thomson, 1973) and outshining principles (Smith, 1988, 1994). The encoding specificity principle explains the context-dependent effects both in recognition discrimination and in simple recognition (hit and false alarm). According to the encoding specificity principle, reinstating the study context will facilitate the retrieval of the study episode, such that context-dependent effects in recognition discrimination will be found. Furthermore, the retrieved study episode will enhance discrimination between targets and distractors, because participants perceived and encoded the targets within the study episode, but not the distractors. The enhanced discrimination between targets and distractors will increase the hit rates and will decrease the false alarm rates. As a result, a positive context-dependent effect on the hit rate and a reversal of this effect on the false alarm rate will be found.

Furthermore, the outshining principle specifies the conditions under which context-dependent recognition appears or does not appear in terms of the relative strength of item cues compared to context cues. The strength of item cues was found to be increased both by the meaningfulness of the materials (e.g., McGeoch, 1930; Underwood, 1966; Underwood & Shultz, 1960) and by the length of study time (e.g., Glenberg, 1979). Therefore, the item cues are more likely to outshine the context cues with an increase in both the meaningfulness of the materials and the study time. Accordingly, the outshining principle predicts that the probability of context-dependent recognition will decrease both with the meaningfulness of the materials and with study time. Empirically, Isarida et al. (2012) clearly confirmed these predictions in two experiments. Significant context effects for *d*' and hit rates and the reverse for false alarm rates were found in the short (1.5 s/item) study-time condition with meaningful words, and in the nonword condition, but context effects were not found in the condition of long (4.0 s/item) study-time with meaningful words.

The ICE Theory

Murnane et al. (1999) argued that explanations relying on the principles of episode-defining context and encoding specificity may be flawed, because none of the explanations involving these two principles for the variable recognition findings over the past two decades have proven wholly satisfactory. Therefore, Murnane and his colleagues proposed the ICE, positing that recognition of the past episode involves judgment processes based on global activation of the item, the context, and ensemble information.

According to the ICE theory, global match strength is modeled in terms of the individual matches between item (*I*), context (*C*), and ensemble (*E*) in the cue and in memory. Item is defined as any information that is central to the primary cognitive task being performed in the processing environment. Context is defined as any information that is incidental to the processing of items. Ensemble is defined as a type of information that a learner forms by combining or integrating item and context information. Note that ensemble is a unique type of information that is different from either item or context information considered alone. A general formulation for a global memory system is given by

$$= \sum \quad (\; , \; , \;) \qquad (1)$$

where *M* represents global activation or match strength, *K* is the number of activated memory representations, and *f* is the activation function, I_j represents the strength of the match between the *j*th item information in the cue and in memory, *C* represents the strength of the match between associated context information in the cue and in memory, and *E* represents the strength of the match between ensemble information in the cue and in memory.

The respective patterns of match or mismatch between the three types of information (*I*, *C*, *E*) in memory at a typical recognition test are as follows. Item information matches if the test item is old (target) whether the test context is old or new. Similarly, context information matches if an item is tested in the old context whether the test item is old or new (distractor). In contrast, ensemble information only produces a match for old items tested in the old context. This is because the ensemble is a unique integration of the old item and the old context. For the ICE theory, Murnane et al. (1999) made an auxiliary hypothesis about ensemble formation that the probability of ensemble formation is a function of the amount of meaningful content in the context information.

The ICE theory predicts that context matching will increase both the hit and false alarm rates commonly based on a higher memory strength caused by the old context. Without formation of ensemble information, the positive context-dependent effects in hit rates are canceled out by those in false alarm rates, so that context-dependent recognition discrimination disappears. Otherwise, if context information and item information are integrated into an ensemble, only hit rates will increase reflecting the ensemble. Consequently, context-dependent recognition discrimination will appear. To demonstrate the ICE theory, Murnane and his colleagues used simple- and rich-visual contexts. They predicted that the simple-visual context, a unique combination of foreground color, background color, and location on a computer screen, is difficult to integrate with items into an ensemble, because the context is low in meaningful content. In contrast, the rich-visual context, such as background drawings and photographs, is easy to integrate with items into an ensemble because of its high meaningful content. These predictions were successfully confirmed in numerous studies (Dougal & Rottelo, 1999; Hockely, 2008; Murnane & Phelps, 1993, 1994, 1994; Murnane et al., 1999).

According to the dual-process model of recognition (see Yonelinas, 2002 for a review), several researchers had participants classify *old* responses in recognition as *remember* responses, reflecting conscious recollection, or as *know* responses, reflecting familiarity judgments, and found that *remember* responses revealed context-dependent recognition discrimination, but *know* responses did not (Gruppuso et al., 2007; Macken, 2002). This may imply that most visual context-dependent recognition processes also reflect conscious recollection or remembering of past episodes (e.g., Gruppuso et al., 2007; Macken, 2002).

However, further examination of the relevant conditions in detail raises several questions about the dual-process account of recognition (Hockley, 2008). In these studies (Gruppuso et al., 2007; Macken, 2002), false-alarm rates, even for *remember* responses, were almost always higher in the matched-context condition than in the mismatched-context condition. It should be noted that participants remembered nothing about the new items by using the old context, because the new items had not been presented, and hence had not been associated with the old context. Possibly, *remember* responses may reflect a certain subjective sense or feeling of remembering, but not veridical remembering of past episodes. Thus, the recognition processes depending on the visual contexts may be consistent with the ICE theory.

The Outshining Account and the ICE Theory

Murnane et al. (1999) state that the ICE theory can be applicable to any types of context information, although the theory was demonstrated only using simple- and rich-visual contexts (Dougal & Rotello, 1999; Hockley, 2008; Murnane & Phelps, 1993, 1994, 1995; Murnane et al., 1999). Murnane and Phelps (1993) have claimed that simple-visual context meets Bjork and Richardson-Klavehn's (1989) definition of incidental context. That is, visual contexts are independent of the focal information, should not influence the participants' cognition about the focal information, and are not predictive of correct responses at test. As such, Murnane and his colleagues may recognize that rich-visual context also is consistent with the definition of incidental context.

However, there has been evidence contrary to the ICE theory. Rutherford (2004) argued that visual context-dependent recognition discrimination could be explained not by the ICE theory but by cue overload (see Watkins & Watkins, 1975). He found a significant background-color dependent effect in recognition discrimination when old items were presented against one of three background colors but not when all of the items were presented against one background color. Note that both background-color and simple-visual context have only a small amount of meaningful content, so that any ensemble is difficult to form. Rutherford explained the lack of the context-dependent effect in the one-color condition in terms of cue overload. The one background color could have been overloaded by all the old items, whereas each of the three colors would not have been overloaded by only one-third of the items.

Rutherford's no context-dependent effect in the one-color condition could be caused either by cue overload, as Rutherford claimed, or by the persistence of one background color. In previous studies, no context-dependent effects were found when all the items were presented against one background color, whereas a significant context effect appeared when background colors changed item-by-item (Dulsky, 1935; Petrich & Chiesi, 1976; Pointer & Bond, 1998). Isarida and his colleagues found that background-color dependent effects in recognition discrimination appeared when six background colors were used, but disappeared when only two colors were used (Isarida et al., 2005; Isarida & Ozeki, 2005). In these studies, background colors changed item-by-item in both conditions, and the two-color condition was more likely to be overloaded than the six-color condition. These results indicate that cue overload actually suppressed the background-color dependent recognition discrimination. Note that the no context-dependent recognition discrimination found by Isarida and his colleagues (Isarida et al., 2005; Isarida & Ozeki, 2005) were caused by the no context-dependent effect both in hit rate and false alarm rate, as also reported in Rutherford (2004). Thus, it may be concluded that the results involving cue overloaded were consistent with the ICE theory, whereas that the not-overloaded results were consistent with the encoding specificity principle.

Furthermore, as previously discussed, place-dependent recognition cannot be explained by the ICE theory, but can be explained by the outshining account (Isarida et al., 2012). Furthermore, background-music dependent recognition was reported to reveal the same pattern of results as complex-place context (Nishimura, Isarida, & Isarida, 2010). That is, significant context effects for CRS (a measure of recognition discrimination) and hit rates and the reverse for false alarm rates were found in the short study-time condition, but no context effects for CRS, hit rates, or false alarm rates were found in the long study-time condition. Accordingly, we conclude that environmental context-dependent recognition can be generally explained by the encoding specificity principle with another auxiliary principle, such as the outshining principle (place and background music) or the cue overload principle (background color).

We argue that the methodologies used to demonstrate the ICE theory have limitations. First, simple- and rich-visual contexts were exclusively used for the demonstration. However, the other environmental contexts, such as place context (Isarida et al., 2012), background-color context (Isarida et al, 2005; Rutherford, 2004), and background-music context (Nishimura et al., 2010) may favor the encoding specificity principle and its auxiliary principle rather than the ICE theory. In fact, different environmental contexts often have different functions.

Second, the experiments for demonstrating the ICE theory used large number of items, so that the old items are likely to suffer from cue overload. Experiments 1 to 3 of Murnane and Phelps (1993) used 12 items or more per context, repeated the experimental sessions 10 times using the same contexts, and analyzed the mean of the 10 sessions. Therefore, the cue load per item may have been functionally quite large. In their Experiments 4 and 5, the cue load per context was 36 items or more. Other studies have basically followed the methodology of their Experiments 4 and 5 (e.g., Dougal & Rotello, 1999; Hockley, 2008; Murnane & Phelps, 1994,1995; Murnane et al., 1999).

Third, Murnane and his colleagues, and their followers, presented a pair of items per context to minimize the associations between the items (pairs) and their preceding and following contexts (e.g., Dougal & Rotello, 1999; Murnane & Phelps, 1993, 1994,1995; Murnane et al., 1999). Pair presentation of items should facilitate the association of items within the pairs, which may suppress the associations between preceding and following contexts. If so, the associations between the items and the corresponding context would be also suppressed by the pair presentation. Thus, in the experiments of Murnane and his associates, the items and the correspondent contexts are more difficult to be associated than in the other experimental methodologies. Thus, items and contexts could be processed independently, as the ICE theory states, rather than be processed associatively or integratively.

CONTEXT-DEPENDENT EFFECTS OF VARIOUS TYPES OF ENVIRONMENT INFORMATION

In the preceding section, we reviewed the effects of various visual contexts for recognition: simple-visual context (e.g., Murnane & Phelps, 1993, 1994, 1995), various rich-visual contexts (Gruppusoet al., 2007; Hockley, 2008, Murnane et al., 1999), and background-color context (e.g., Isarida et al., 2005; Rutherford, 2004). In this section, we review studies on context-dependent effects of various environmental contexts, such as background color, background music, ambient odor, and background video.

Background-color Context

A phenomenon that may be specific to background-color dependent recall is that no effect was found when all to-be-remembered items were presented against one common background color. More specifically, paired-associate studies found significant context-dependent effects with different background colors for respective pairs (Dulsky, 1935; Weiss & Margolius, 1954), but no effects with a common background color for all pairs (Dulsky, 1935; Petrich & Chiesi, 1976). Pointer and Bond (1998) found no context effect for sentence recall when the to-be-remembered sentences were printed on one colored sheet of paper. In contrast, most environmental contexts, such as place, odor, and background music, can produce context effects when all the items are presented within only one context.

The elimination of the context-dependent effect with one common background color can be accounted for by cue overload and/or by the necessity of an item-by-item change in background color. Isarida and Isarida (2007) investigated background-color dependent free recall, where the number of items per context was small enough to avoid cue overload. They found that the background-color dependent effect does not require different background colors for respective items but only a simple item-by-item change between two colors. They also found that a necessary condition for eliminating the background-color dependent effect is not a common background color for all items but only five or more successive presentations of the same background color. Thus, these findings indicate that an item-by-item change in background colors, as well as cue overload, determines background-color dependent effects.

The finding that the two different background colors produced a context-dependent effect in free recall (Isarida & Isarida, 2007) can be interpreted as showing that one background color can cue half of the list of items. This may further imply that background-color context functions as a global context in terms of generality of contextual association. There is a local/global distinction for contexts in terms of the generality of contextual associations (Glenberg, 1979). Generality refers to the number of items that a context associates with. Various contexts have different temporal rates of change: changing rapidly or slowly. The typically unchanging or slowly changing contexts are processed with many items, so that they are very general or global. Accordingly, these contexts are called *global context*. In contrast, rapidly changing contexts are processed with only one or so items, so that they are very specific or local. Accordingly, these contexts are called *local context*.

There is evidence showing that the background-color context functions as local context rather than as global context. Isarida and Isarida (2007) presented one item per screen, and found that the items presented against the same background color did not cluster among each other. Sakai et al. (2010) simultaneously presented 6 items per screen, and found that recalled items were clustered by screens but not by background colors. These findings imply that each item was associated not with the one common color but with the respective screen on which the item was presented. Thus, no global episodic-memory trace may be encoded with the same color and the items, but rather the items may be encoded with the corresponding screens on which the items were presented into separate local episodic-memory traces.

Background-music Context

Background-music context is the only auditory environmental context that has been studied. We found only four articles on background-music context effects (Balch et al., 1992; Balch & Lewis, 1996; Mead & Ball, 2007; Smith, 1985). The most recent three of them demonstrated that mood mediates the background-music dependent effects in free recall. These studies seem to have investigated mood-dependent memory using background music rather than to have investigated the effects of auditory environmental context on memory. Balch and his colleagues found that changes in music tempo determined background-music dependent effects in free recall (Balch et al., 1992; Balch & Lewis, 1996). More specifically, neither the music form or genre (jazz vs. classical) nor instrument timbre (piano vs. brass) but only music tempo (fast vs. slow) determined the music-dependent effects. They concluded that mood (arousal dimension) determined the tempo-dependent effects. Mead and Ball (2007) found that changes in music tonality (major vs. minor key) determined background-music dependent effects in free recall. They also analyzed the rating data for mood, and concluded that mood (pleasantness dimension) determined the tonality-dependent effects.

It is plausible that background-music dependent effects might reflect associations between items and a global image of a piece of music, such as mood, rather than associations between each item and the physical stimulus and the accompanying sensation of the piece contiguous with the item. In a typical experiment of background-music dependent effects, one piece of music is presented throughout the study and/or test session. Although the physical stimulus of the piece changes from moment to moment, participants recognize the successively presented stimuli as one piece of music. At test, participants may not necessarily use the measure or phrase that had been presented contiguously with each item at study as a retrieval cue. Additionally, music usually induces a certain mood (see Västfjäll, 2002).

However, the mood-mediation account for background-music dependent memory may have the same problem as that for place-dependent memory. As discussed previously in the section on *Mood Mediation of Place-dependent Memory*, a mood-dependent effect might not be robust enough to mediate a context-dependent effect. Moreover, Balch and Lewis (1996) reported that music tempo influenced the arousal dimension of mood, which further influenced free recall. In contrast, Balch, Myers, and Papotto (1999) concluded that the pleasantness dimension influenced memory, not the arousal dimension. These conflicting results indicate an unreliability of mood-dependent effects in memory.

Furthermore, the phenomena supporting the mood-mediation account of background-music dependent effects, tempo-dependent effects, and tonality-dependent effects should be re-examined because of two methodological problems. First, although musical selections belong to a large group of random sampling variables, all of the previous studies on background-music dependent effects selected only one piece of music per music dimension, such as tempo, form, and timbre. Thus, it is still unclear whether the results reflect the labeled music dimensions or characteristics specific to the selected pieces.

Second, Mead and Ball (2007) selected only one piece of music, and played the original minor-key piano score or the major-key score transposed from the original score. The ratings of the participants confirmed that they did not perceive oddness about the piece played at the time of study, regardless of whether the piece was the original or the transformed version. This may be because the piece was unfamiliar to the participants. However, at the time of test, the participants may have felt something odd or changed, if they listened to the piece in a different key from the key at study, and the feeling of change or oddness might have confounded the change in background-music contexts. Although Mead and Ball imposed a 3-min retention interval filled by a birdsong, it is unclear whether the filled interval wiped out the feeling of change or oddness. Unfortunately, oddness ratings of the piece played at the time of test were not conducted. Recently, Isarida and his colleagues used four or more musical selections per music dimension, and found that neither tempo nor tonality influences the size of the background-music dependent effects in free recall (Isarida, Matsunaga, & Isarida, 2012; Zhou, Ikegaya, Isarida, & Isarida, 2011).

Background-music dependent effects are more detectable in incidental-learning paradigms than in intentional-learning paradigms. Three of the four previously discussed studies used only incidental-learning paradigms (Balch et al., 1992; Balch & Lewis, 1996; Mead & Ball, 2007). However, Smith (1985) used an immediate free recall of intentionally learned words and found no background-music dependent effect. Two days later, participants received an unexpected final free recall test. It is unclear whether the final test was the second test for the intentionally learned words or the first test for the incidentally experienced episode of the initial recall test. Isarida et al. (2008) directly compared the background-music dependent effects in intentional- and incidental-learning paradigms, and found that the effect was found in the incidental-learning paradigm but not in the intentional-learning paradigm.

There are still many characteristics and functions remaining to be elucidated for background-music contexts. First, the effects of retention intervals are still unclear. Smith found background-music dependent effects with a two-day delayed test but not for the immediate test, whereas Balch et al. (1992) found the effects not with the two-day delayed test but for the immediate test. Second, previous research on background-music dependent effects has been conducted only using free recall, but not using other memory tests such as recognition. Recently, Nishimura et al. (2010) found background-music dependent effects in recognition. However, this finding is reported in only one experiment, and has not been published yet. This is an area where there are plenty of opportunities for future research.

Odor Context

We found seven articles on odor-dependent effects published in professional journals over the past 25 years (Ball, Shoker, & Miles, 2010; Cann & Ross, 1989; Herz, 1997; Parker, Ngu, & Cassaday, 2001; Pointer & Bond, 1998; Schab, 1990; Smith, Standing, & deMan, 1992). These studies had various purposes, but did not attempt a systematic investigation of odor-dependent effects. These studies used various memory paradigms: four used recall (Herz, 1997; Parker et al., 2001; Pointer & Bond, 1998; Schab, 1990), two used recognition (Cann & Ross, 1989; Parker et al. 2001), two used relearning (Parker et al. 2001; Smith et al., 1992), and one used a word-completion task (Ball et al., 2010). The only variable common to most studies were long (24 hr to 4 weeks) retention intervals, and only one study used a short (5 min) retention interval (Pointer & Bond, 1998). The possible reason for the use of the long retention-intervals may be that changing odorants would be difficult without changing environments, such as rooms or experimental booths, if the retention intervals were short. Chemical stimulation does not terminate after removal of the stimulus, because the chemical stimulus is not cleared from the peri-receptor environment by the stimulus removal (Dalton, 2000).

In the previous studies, there are several concerns that may confound the appearance of odor-dependent effects. First, odor-dependent effects are likely to be confounded by olfactory adaptation. The sensitivity to one odorant gradually decreases over time if the odorant is consistently presented, such as an odor context. This decreasing sensitivity is well known as adaptation. In contrast, sensations of the other environmental information, such as vision and audition, are not likely to elicit adaptation. For example, the visual image does not vanish unless one uses a stabilized retinal image, even if the visual stimulus is consistently presented (see Heckenmüller, 1965). Auditory stimuli, such as background music and background sounds of video clips, change from moment to moment, so that adaptation does not occur for typical auditory stimuli.

Second, most of the previous studies about odor-dependent effects in recall and recognition used very long retention intervals (Cann & Ross, 1989; Herz, 1997; Parker et al., 2001; Schab, 1990; Smith, Standing, & de Man, 1992). However, the long-retention-interval procedures pose the following two problems. One is that participants bring different odors on different days into a laboratory, because participants often come to the laboratory after eating different meals, with or without sweat, and wearing different clothing, colognes, or scented personal products, and so forth. These extraneous odors accompanying the participants may confound the sensation of the experimental odors, regardless of whether or not the participants are aware of the extraneous odors because of adaptation. The other problem is that participants often encounter the same odor as the experimental odor during the long retention interval if the experimental odors are familiar. Such encounters can evoke rehearsal of the experimental episode, which confounds the free-recall performance.

To avoid these problems, researchers should use a short retention interval so that the experiment can be completed in a one-day session. However, short retention intervals pose another problem. There is less recovery from adaptation within short retention intervals than within long retention intervals. In order to investigate the odor-dependent effects clearly, there must be complete recovery from adaptation before the memory test. Unless sensitivity to the adapted odor is recovered, the same odor as at study would not serve as a retrieval cue, and hence no odor-dependent effect would be found. However, this null effect cannot differentiate whether the odor did not produce context-dependent effects or whether a potential context-dependent effect was masked by adaptation.

Isarida et al. (2014) implemented a new method for recovery from olfactory adaptation within short retention intervals. In this recovery method, a dissimilar odor to the adapted odor was briefly presented at the beginning of the retention interval. This method was based on anecdotal examples that supplying fresh air to noses or smelling another odor dissimilar to the adapted odor facilitated the recovery from adaptation. Olfactory adaptation at the periphery was found to be considerably durable, because the chemical stimulus is not cleared from the peri-receptor environment by the stimulus removal. Both a fresh air supply and smelling another odor may displace the remaining chemical stimuli. Isarida et al. empirically confirmed the anecdotal examples and demonstrated the validity of this new method for recovery from adaptation.

Furthermore, another concern involves the method of selecting odorants. Although odor stimuli belong to a large group of random sampling variables, almost all of the previous studies on odor-dependent effects have arbitrarily selected one odor stimulus or one pair of odor stimuli (Ball, Shoker, & Miles, 2010; Cann & Ross, 1989; Herz, 1997; Parker et al., 2001; Pointer & Bond, 1998; Schab, 1990). Furthermore, a few studies proposed that certain dimensions or aspects of odors produce odor-dependent effects, although they sampled only one odor per dimension (Ball et al., 2010; Herz, 1997). In any case, it is unclear whether the findings of these experiments can be generalized to whole groups of odors, or are specific to the selected odor(s). At least two or more odors or odor pairs must be used in order to generalize the findings to a variety of odors. Therefore, Isarida et al. (2014) selected the experimental odors from 14 familiar odors by using semantic-differential ratings and cluster analysis.

Moreover, Isarida et al. changed the experimental booths between study, retention interval, and test. There were two reasons for this modification. One was to prevent the same visual environmental information from serving as a retrieval cue for the study episode along with the odor-context cue at the time of test. Otherwise, the visual environmental information may confound the odor-dependent effect. The other reason was that staying in the same room or place, in which some chemical remnants of an experimental odorant may still be present, makes it difficult to change odorants between study and test, because the chemical stimulation does not terminate after removal of the stimulus.

There are plenty of opportunities for future research on odor contexts, as well as background-music contexts, because there have been few systematic studies. These contexts are particularly interesting and important to understand because they have a wide applicability to learning and memory in many different commercial and real life settings.

Video Context

Smith and Manzano (2010) first investigated the context-dependent effects of video context. They presented target words one-by-one in red letters superimposed over 5-s video clips of real scenes with sound. At test, half of the studied video clips were sequentially presented as retrieval cues, and participants were tested using free recall for the words. The results showed a profoundly large video-dependent effect, and the effect size increased with a decrease in the number of words per video context.

Smith and Manzano suggested three reasons for the large effect size. First, the number of words presented per video context that can be manipulated is quite small: a minimum of a 1:1 ratio of each context to words. Note that the cue strength is assumed to be a reciprocal of the number of items associated with one cue (Watkins & Watkins, 1975). Second, the large number of contexts made it difficult for the participants to mentally reinstate all of the context cues. Third, according to the ICE theory, the video contexts provide a good mnemonic basis for encoding, because they are perceptually rich; the video contexts consist of moving visual information and related background sounds.

However, there are some concerns about Smith and Manzano's methodologies. First of all, they required participants to try to remember both the words and the movie scenes for a later memory test in both Experiments 1 and 2. Additionally, they required participants to think of a relation or association between the word and the scene, and instructed that making these relations might help on the subsequent memory test in Experiment 2. We argue that intentionally processed information is not background context but rather is focal information, and the association between focal information A and B is paired association but not contextual association. Likewise, Hockley (2008) argued that Gruppuso's et al. (2007) methodology emphasizing the processing of both the item and the context is, in essence, a paired-associate learning task. We believe that such methodology is inappropriate to investigate the functions of incidental context, although studies on semantic or interactive context have used the same methodology (e.g., Light & Carter-Sobell, 1970).

Furthermore, the written free-recall test used by Smith and Manzano is inappropriate for video context research. First, participants cannot watch the test video clips while they write recalled responses, because they look around at their responses being written. Second, the written responses can serve as other retrieval cues for the following responses, so that the responses cued by the preceding responses would confound the video-dependent effects.

Sakai, Miyamoto, Isarida, and Isarida (2011) investigated video-dependent effects in free recall. They compared free recall of participants who were encouraged to associate between items and their contexts and those who were not, using a 1:1 ratio of each context to words and an oral free-recall test instead of a written free-recall test. They found video-dependent effects in both of the conditions. This implies that the associative instruction is not necessary to produce the video-dependent effects, at least when an oral free-recall test is used. Furthermore, Sakai, Yamamoto, Isarida, and Isarida (2012) used a 1:1 ratio of each context to words and an oral free-recall test, and found that the size of video-dependent effects in free recall did not change as a function of study time. Morii, Yoshino, Isarida, and Isarida (2013) compared free recall between the video context, the still image of the video context, and a gray background condition. There was no difference between the video context and the still image condition, and the recall levels for the video context and the still image condition were higher than for the gray background condition. This suggests the significance of sequential presentation of half of the study video contexts at the time of a free-recall test. Video context is an important area for future research on environmental context-dependent memory.

CONCLUSION

Environmental context-dependent memory, especially place-dependent memory, was confirmed to be reliable by the meta-analysis of Smith and Vela (2001). However, there are still open issues about place-dependent memory. Many of the elements of the contexts that produce context-dependent effects have not been identified. Certain mental factors, such as mental context, rather than the physical features of place have been proposed and demonstrated to be critical for producing context-dependent memory. Complex-place context, manipulated by place and other contextual elements influencing internal factors such as subsidiary task and experimenter, defines a learning episode, and is useful in distinguishing episodes because it can contain many defining features of an episode. The characteristics of complex-place context were found to be functionally different from those of simple-place context (manipulated by only place) or simple environmental contexts, such as simple- and rich-visual contexts, background-music context, and odor context.

The encoding specificity principle can straightforwardly explain environmental context-dependent effects in free recall, but not in recognition. There are item-specific cues as well as an environmental context cue in a recognition test, whereas there is only a context cue in a free recall test. In fact, the findings about environmental context-place dependent recognition are too ambiguous to be explained only by the encoding specificity principle. However, by adding another auxiliary principle, such as the outshining principle or the cue overload principle, the encoding specificity principle can generally explain environmental context-dependent recognition. In contrast, the ICE theory can explain recognition processes dependent on various visual contexts, although it may have methodological and explanatory limitations.

We reviewed studies on the effects of various environmental contexts, such as background color, background music, ambient odor, and background video. These contexts have not been extensively investigated, and there remain many unresolved issues.

In the last decade, research on environmental context-dependent memory has not been as active as in the decade after Godden and Baddeley's (1975) study. More research on environmental context-dependent memory is needed to elucidate episodic memory processes. In particular, promising areas for future research include complex-place and various environmental contexts, especially video contexts. Complex-place context functions as an episode-defining context, and video context has only recently begun to be investigated.

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Natia D.