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# Context-dependent effects of background colour in free recall with spatially grouped words

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Three experiments investigated context-dependent effects of background colour in free recall with groups of items. Undergraduates ($N = 113$) intentionally studied 24 words presented in blocks of 6 on a computer screen with two different background colours. The two background colours were changed screen-by-screen randomly (random condition) or alternately (alternation condition) during the study period. A 30-second filled retention interval was imposed before an oral free-recall test. A signal for free recall was presented throughout the test on one of the colour background screens presented at study. Recalled words were classified as same- or different-context words according to whether the background colours at study and test were the same or different. The random condition produced significant context-dependent effects, whereas the alternation condition showed no context-dependent effects, regardless of whether the words were presented once or twice. Furthermore, the words presented on the same screen were clustered in recall, whereas the words presented against the same background colour but on different screens were not clustered. The present results imply: (1) background colours can cue spatially massed words; (2) background colours act as temporally local context; and (3) predictability of the next background colour modulates the context-dependent effect.

***Keywords:*** Context-dependent memory; Background colour; Free recall; Clustering.

Environmental context refers to incidental information about the environment in which the focal information is processed. According to the encoding specificity principle (Tulving & Thomson, 1973), the environmental context is encoded with the focal information into an episodic memory trace, and may serve as a retrieval cue. Clarifying the functions of the environmental context is essential for understanding episodic memory processes, especially in recall processes. Environmental context studies have used a variety of places (e.g., Godden & Baddeley, 1975; Smith, Glenberg, & Bjork, 1978), or place and other contextual elements such as experimenter and subsidiary task (e.g., Isarida & Isarida, 2004, *2006*; Smith & Vela, 2001). Environmental context

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studies have also used other environmental features, such as background colour (e.g., Isarida & Isarida, 2007; Rutherford, 2004; Weiss & Margolius, 1954), a combination of visual features on a computer screen called simple visual context (e.g., Dougal & Rotello, 1999; Murnane & Phelps, 1993, 1994, 1995), background drawings called rich visual context (Murnane, Phelps, & Malmberg, 1999), background music (e.g., Balch, Bowman, & Mohler, 1992; Smith, 1985), odour (e.g., Cann & Ross, 1989; Herz, 1997), and so forth.

The present study focuses on the context-dependent effects of background colour in free recall. A phenomenon that may be specific to background-colour context is that no context-dependent effects were found when all to-be-remembered items were presented against one common background colour. In contrast, most environmental contexts, such as place, odour, and background music, can produce context effects when all to-be-remembered items are presented within only one context. Paired-associate studies found significant context effects with different background colours for respective pairs (Dulsky, 1935; Weiss & Margolius, 1954), but no effects with a common background colour 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 differently coloured sheet of paper, whereas odour perfuming the sheet produced a significant context-dependent effect.

The elimination of the context-dependent effect with one common background colour can be accounted for by the cue overload principle (see Watkins & Watkins, 1975). Rutherford (2004) examined the effect of the number of background colours (one or three) on context-dependent recognition discrimination. He found a significant context-dependent effect for the three-colour condition but no effect for the one-colour condition. Rutherford explained the elimination of the effect in terms of cue overload. The one background-colour context cue could have been more likely to be overloaded by all the items, whereas each of the three context cues of different background colours would have been less likely to be overloaded by only one-third of the items. This cue-overload account may not necessarily involve a functional difference between background-colour context and other environmental contexts, because other environmental contexts can also suffer from cue overload. For instance, Isarida and Isarida (2006) pointed out that place context can suffer from cue overload with more than 100 items per context.

However, cue overload may not be the only explanation for the elimination of context-dependent effects with one common background colour. The elimination may be also accounted for by the necessity of an item-by-item change in background colour for producing context-dependent effects. Isarida and Isarida (2007) investigated background-colour context-dependent effects in free recall, where the number of items per context was small enough to avoid cue overload—12 items per context. They found that the background-colour context-dependent effect does not require different background colours for respective items but only a simple item-by-item change between two colours. They also found that a necessary condition for eliminating the background-colour context effect is not a common background colour for all items, but only five or more successive presentations of the same background colour. These findings indicate that an item-by-item change in background colours, as well as cue overload, determines background-colour context-dependent effects. In contrast, an item-by-item change in other environmental contexts is unnecessary for producing context-dependent effects. Only one place (e.g., Godden & Baddeley, 1975; Isarida & Isarida, 2004), one odour (e.g., Cann & Ross, 1989; Parker, Ngu, & Cassaday, 2001), or one selection of background music (e.g., Balch et al., 1992; Smith, 1985) is usually presented for all the items as a context, and significant context effects have been found.

The necessity of an item-by-item change in background colours implies that the background-colour context has different characteristics from other environmental contexts. Furthermore, the necessity of an item-by-item change in background colours may indicate that the background-colour context is functionally not global but rather local context. Glenberg (1979) proposed a local/global distinction for contexts in terms of temporal rates of change. Smith and Vela (2001) proposed a local/global distinction for environmental contexts in terms of fast-changing (local) or slow-changing (global) context manipulation, and excluded the local environmental contexts, such as background-colour context, from their meta-analysis.[1] The findings of Isarida

[1] Some researchers made local/global distinctions of environmental context in terms of spatial size; such as room and computer screen (e.g., Rutherford, 2004).

and Isarida (2007), about the necessity of an item-by-item change in background colours, may provide empirical evidence supporting Smith and Vela's (2001) local/global distinction for environmental contexts. In contrast, other environmental contexts function as global context, because they need no item-by-item change in contexts.

Nonetheless, the finding that background colour can produce a context-dependent effect in free recall (Isarida & Isarida, 2007) indicates that a background colour can cue all the items that were presented against the background colour. This further implies that background-colour context functions as a global context in terms of generality of contextual association, although the context also seems to be a local context in terms of temporal rates of change. Here generality refers to the number of items with which a context associates. Glenberg (1979) stated that global contexts are typically unchanging or change very slowly, and are therefore very general. However, a background-colour context has a different characteristic from other global environmental contexts, even if a background-colour context has associative generality. This characteristic is that the items being associated with the same background-colour context do not associate among each other (Isarida & Isarida, 2007). In contrast, various inter-item associations are observed among the recalled items cued by place context, if no distractor task for prevention of inter-item association is imposed between items at presentation (e.g., Isarida, 1992, 2005). As such, there may be other undiscovered characteristics of background-colour context. Accordingly, the present study further investigated the characteristics of background-colour context, by attempting to replicate and to extend Isarida and Isarida's (2007) findings.

First, the present study examined whether six (i.e., more than five) items simultaneously presented against either of two background colours would yield context-dependent effects in free recall. Isarida and Isarida (2007) only sequentially presented a list of items one at a time on a coloured computer screen, and found that five successive presentations of the same background colour eliminated the context-dependent effect. If context-dependent effects disappear with more than five items (i.e., six) simultaneously presented on a coloured computer screen, then this would imply that five or more massed items per context lead to cue overload regardless of whether the items are presented successively or simultaneously. Otherwise, if a context-dependent effect appears, this will indicate that background-colour context can cue five or six items simultaneously presented on a coloured screen but cannot cue successively presented items. Background-colour context is predictable to cue simultaneously presented items, because background colours are visual environmental information, and vision is much more acute for spatial discrimination than temporal discrimination (Oyama, Imai, & Wake, 1994).

Second, we examined whether the sequential patterns of background colours (i.e., simple alternation of colours or random changes of two background colours) would modulate the context-dependent effects. Isarida and Isarida (2007) did not investigate the effects of sequential patterns. They only compared the effects of duration of one colour and random changes of two colours. Sequential patterns should influence the predictability of the background colour on the next screen, because the next background colour is much more predictable in a simple alternation than in random change. More importantly, it is reported that predictability of the next stimulus induces habituation (e.g., Herry et al., 2007), which is proposed to modulate the background-colour context-dependent effects (Dibbets, Maes, Boermans, & Vossen, 2001; Isarida & Isarida, 2007).

Third, Isarida and Isarida (2007) found that only a few participants intentionally used background colours for encoding and/or retrieval. This finding indicates that unintentional processes produce the background-colour context effects. The present study examined whether this finding would be replicated.

Finally, the present study measured clustering by screens separately from clustering by colours. Simultaneous presentation of several items per screen can help differentiate these two types of clustering in analyses. Unfortunately Isarida and Isarida (2007) could not separate them, because they presented one item per screen. Items presented against the same background colour were not clustered at all (Isarida & Isarida, 2007). The present study further examined whether or not the items simultaneously presented on each screen would be clustered by screens. If no clustering is observed, this implies that a background colour associates separately with respective single items. Otherwise, if clustering by screens is observed, this will imply that a background colour associates not with single items but with correspondent screens.

## EXPERIMENT 1

Experiment 1 examined whether the background-colour context effect in free recall would appear when six (i.e., more than five) items are simultaneously presented against either of two background colours.

## METHOD

*Participants and design.* The participants were 23 undergraduates who were enrolled in an introductory psychology course at Shizuoka University, Hamamatsu, Japan. They received extra course credit for participation. All had normal or corrected-to-normal vision, and did not report having colour blindness.

Experiment 1 used a one-factor, within-participants design. The factor was the context of background colour (same context vs different context).

*Stimuli and apparatus.* As stimuli, 24 two-letter words, whose association values were not less than 90 (Hayashi, 1976), were randomly selected to be as semantically unrelated to each other as possible. These 24 items were randomly assigned to four blocks of 6 items across participants. A pair of background colours was randomly selected from two pairs (light red and light green, or light yellow and light blue) with the restriction that half of the participants received light red and light green and the others received light yellow and light blue.

To-be-remembered items, signals, and background colours were presented in black 72-point MS-Gothic font on a 17-inch LCD monitor with screen resolution set to 1024 × 768 pixels. The computer screen background was completely filled with the selected background colour.

*Procedure.* Participants took part individually in a 15-minute experiment. The participants were presented with four blocks of six items on the computer screen at a rate of 24 s per screen. Inter-presentation interval, during which the screen changed to black without any item, was 0.5 s. The two background colours alternately changed screen-by-screen at study, and then one of the two colours was presented at test. This test background colour was selected randomly from the pairs of colours with the restriction that each colour within the pairs was selected equally across participants. When the background colour at study was the same as at the test, this would be classified as the same-context condition. Otherwise, when the test colour was different from the study colour, this would be classified as the different-context condition. Participants were required to study the items intentionally and were told that they would be asked to remember only the items and not the background colours.

Immediately after the presentation of the last screen a random three-digit number was presented in black against a neutral grey background colour. Participants were required to count back orally from that number by threes for 30 s. Following the counting, a signal "??" was presented in black against the test background colour. Participants were required to recall the items in any order orally for 60 s. The signal and test background colour were presented throughout this test period. Participants were required to look at the computer screen throughout the experimental session. Following the test, participants completed an introspective questionnaire (see Appendix) about their encoding and retrieval strategies, including intentional use of background colours at encoding and/or retrieval.

## Results

Table 1 shows the numbers of words correctly recalled for the same- and different-context conditions. The difference in the number of items recalled between the same- and different-context conditions was not significant, $t(22) = 0.57$, $p > .10$.

Table 2 shows the observed and expected values of *screen repetition* and *colour repetition*. We applied the measure of *category repetition*, which is the most basic measurement of category clustering (e.g., Bousfield, 1953; see Murphy, 1979),

**TABLE 1**
Number of words correctly recalled for the same-and different-context conditions in Experiment 1

| | Number of words correctly recalled | |
|---|---|---|
| *Context* | *M* | *SE* |
| Same | 4.83 | 0.49 |
| Different | 4.57 | 0.35 |

**TABLE 2**
Observed and expected values of *screen* and *colour repetitions* in free recall in Experiment 1

| | *Screen repetition* | | *Colour repetition* | |
|---|---|---|---|---|
| | *Observed* | *Expected* | *Observed* | *Expected* |
| *M* | 3.96 | 1.88 | 5.5 | 4.17 |
| *SE* | 0.59 | 0.15 | 0.61 | 0.33 |

to measure clustering by screens (*screen repetition*) and by colours (*colour repetition*). *Category repetition* refers to the number of times that two items presented within the same category appear adjacently in a free-recall protocol. The adjacency of the same-category items in a free-recall protocol is assumed to reflect the adjacency of the items in mind. Accordingly, the observed values of *screen repetition* or *colour repetition* refer to the number of times that two items presented on the same screen (*screen repetition*) or against the same background colour at study (*colour repetition*) appear adjacently in a recall protocol. The expected value, $E(\text{r})$, is given by $[(E-1)(n-1)]/(N-1)$. $N$ is the number of to-be-remembered items presented, $E$ is given by $N$ divided by the number of screens or colours presented, and $n$ is the number of items recalled. The differences between the observed and expected values of *screen repetition*, $t(22) = 4.41$, $p < .01$, and of *colour repetition*, $t(22) = 3.90$, $p < .01$, were significant. On the questionnaire only one participant reported having used the background colours intentionally for encoding items.

## Discussion

The results of Experiment 1 show no context-dependent effect when six items were presented simultaneously on each screen and the background colour was changed alternately screen-by-screen. The null effect of background-colour context in this experiment could be caused by the simultaneous presentation of six items and/or by the alternation in background colours. Regarding the first possibility, the background colour may not facilitate the retrieval of several items simultaneously presented against one background colour. Similarly, Isarida and Isarida (2007) found that the background colour did not facilitate retrieval of several items presented serially against the same background colour. Regarding the second possibility, the simple alternation of background colours may make it easy to predict the next background colour. This easy predictability of the next background colour may lull participants into inattention or habituation to the background colours, so that the background colours do not associate with the items. These possibilities were examined in Experiment 2.

Clustering by background colour was found. These results are inconsistent with the findings of Isarida and Isarida (2007). This background-colour clustering may reflect a clustering by screens because one background colour consisted of only two different screens, so that clustering by screens could easily increase the degree of clustering by colours. This possibility was also examined in Experiment 2.

# EXPERIMENT 2

Experiment 2 examined whether the predictability of the next background colour determines the background-colour context-dependent effect. Predictability was manipulated by changing the sequence of the background colours: a simple alternation or a random change. It should be noted that investigating the effects of sequential patterns of presentation requires the use of many coloured background screens. The presentation of many screens with more than five items per screen necessarily increases the number of to-be-remembered items. Too many items per background colour may lead to cue overload, which eliminates context-dependent effects (Isarida, Isarida, & Okamoto, 2005; Isarida & Ozeki, 2005; Rutherford, 2004). Thus the present study was limited to 15 items per background colour, which did not produce cue overload in Isarida and Isarida (2007).

To increase the number of coloured screens with the limited number of items, we presented items twice in Experiment 2. Twice-repeated presentations of items necessarily double the number of presentations of screens, without increasing the number of items to be recalled or producing cue overload. A total of 10 screens with the two background colours were changed one-by-one at random or in alteration. The 10 screens consisted of 8 ($4 \times 2$) screens and a screen imposed before and after the 8 screens; these two additional screens served as primacy and recency buffers. In Experiment 2 the total presentation time for each screen, on which the same six items were presented, was adjusted to be equal to the presentation time in Experiment 1. Each screen was presented for 12 s twice, whereas each screen was presented for 24 s once in Experiment 1.

Furthermore, in Experiment 2 clustering could be measured separately by colours and by screens more effectively than in Experiment 1, because each background colour was used with four screens in Experiment 2, instead of only two in Experiment 1.

## Method

*Participants.* The participants were 46 undergraduates who were enrolled in an introductory psychology course at Shizuoka University, Hamamatsu, Japan. They received extra course credit for participation. All had normal or corrected-to-normal vision, and did not report having colour blindness. None had participated in Experiment 1.

*Design.* A $2 \times 2$ mixed factorial design was used. The first factor was the sequence of background colours (random vs alternation) as a between-participants factor. The second factor was the context of background colour (same context vs different context) as a within-participants factor. Participants were randomly assigned to one of the two between-participants conditions: random or alternation sequence. Consequently, each condition consisted of 23 participants.

*Stimuli and apparatus.* As stimuli, 30 two-letter words, whose association values were not less than 90 (Hayashi, 1976), were randomly selected to be as semantically unrelated to each other as possible. These 30 items were randomly assigned to five blocks of 6 items across participants. Otherwise, the stimuli and apparatus were identical to those in Experiment 1.

*Procedure.* Participants took part individually in a 15-minute experiment. The participants studied the five blocks of six items twice. Each block of items was simultaneously presented in a $3 \times 2$ matrix on the computer screen at a rate of 12 s per screen (inter-presentation interval was 0.5 s). The sequences of background colours and blocks of items were $A_0B_1A_2A_3B_4A_2B_1B_4A_3B_0$ for the random sequence condition and $A_0B_1A_2B_3A_4$-$B_1A_2B_3A_4B_0$ for the alternation sequence condition. $A$ or $B$ refers to the background colour of each screen, and subscripts 0 to 4 refer to the blocks of six items. Block 0 represents the blocks of primacy and recency buffers, and Blocks 1 to 4 represent the blocks of to-be-remembered items. The six items of the same numbered blocks were the same, but the spatial positions of the six items in the $3 \times 2$ matrix were randomly changed block-by-block. Otherwise, the procedure of Experiment 2 was identical to Experiment 1.

## Results

Table 3 shows the numbers of words correctly recalled as a function of sequence $\times$ context. A $2 \times 2$ (sequence $\times$ context) ANOVA was computed. Neither the main effect of sequence, $F(1, 44) = 1.71$, $MSE = 2.29$, $p > .10$, nor context, $F(1, 44) = 1.74$, $MSE = 2.26$, $p > .10$, was significant, but the interaction was significant, $F(1, 44) = 4.63$, $MSE = 2.26$, $p < .05$. The context effects were analysed separately for the random- and alternation-sequence conditions because the interaction between sequence and context was significant. The number of items recalled in the same-context condition was significantly greater than in the different-context condition for the random sequence condition, $F(1, 44) = 6.03$, $MSE = 2.26$, $p < .05$, but there was no difference for the alternation sequence, $F(1, 44) = 0.35$, $MSE = 2.26$, $p > .10$.

Table 4 shows the observed and expected values for *screen* and *colour repetitions*. The difference between the observed and expected values for *screen repetition* was significant for both the random sequence, $t(22) = 4.76$, $p < .01$, and the alternation sequence, $t(22) = 3.42$, $p < .01$,

**TABLE 3**
Number of words correctly recalled as a function of sequence (random or alternated) and context (same or different) in Experiment 2

| | | *Number of words correctly recalled* | |
|---|---|---|---|
| *Sequence* | *Context* | *M* | *SE* |
| Random | Same | 4.35 | 0.26 |
| | Different | 3.26 | 0.30 |
| Alternated | Same | 3.26 | 0.41 |
| | Different | 3.52 | 0.25 |

**TABLE 4**
Observed and expected values of *screen* and *colour repetitions* in free recall as a function for random and alternated sequences in Experiment 2

| | | *Screen repetition* | | *Colour repetition* | |
|---|---|---|---|---|---|
| *Sequence* | | *Observed* | *Expected* | *Observed* | *Expected* |
| Random | *M* | 2.35 | 1.42 | 3.48 | 3.12 |
| | *SE* | 0.22 | 0.07 | 0.27 | 0.16 |
| Alternated | *M* | 1.83 | 1.23 | 2.77 | 2.78 |
| | *SE* | 0.22 | 0.10 | 0.27 | 0.21 |

conditions, but the difference for *colour repetition* was not significant for the random sequence, $t(22) = 1.80$, $p > .05$, or the alternation sequence, $t(22) = 0.05$, $p > .10$, condition. On the questionnaire only two participants, both in the alternation sequence condition, reported having used the background colours intentionally to encode or to retrieve items.

## Discussion

The results of Experiment 2 show a significant background-colour context-dependent effect in the random sequence condition, but not in the alternation sequence condition. These results imply that the predictability of the next background colour modulates the background-colour context-dependent effect. Isarida and Isarida (2007) compared free recall between the conditions where background colours randomly change screen-by-screen and where the same background colour was successively presented across a number of screens. However, they did not examine whether context-dependent free recall was found when the background colours alternately changed. The present results extend Isarida and Isarida's (2007) findings by showing that a random sequence can produce background-colour context-dependent effects in free recall, but an alternation sequence does not. However, before drawing conclusions, another possibility, that the significant effect was caused by the twice-repeated presentations of items, should be examined.

Experiment 2 separated clustering by colours from clustering by screens. The recall protocols showed significant clustering by screens but not by colours. These results confirm and extend the previous finding in Isarida and Isarida (2007), which could not show whether items were clustered by screens because they presented only one item per screen. The present results imply that a set of items associate with only the corresponding screen on which the items were presented, but the items do not associate with the other items presented against the same background colour.

# EXPERIMENT 3

The purpose of Experiment 3 was to examine whether a single presentation of each item would produce a significant effect of background-colour context. For this purpose Experiment 3 used 10 screens, as in Experiment 2, because the random sequence condition requires 10 screens or more. Presenting 6 different items on 10 different screens of two colours would require 60 items per context, which certainly leads to cue overload.

One possible manipulation is to reduce the number of items per screen, such as three instead of six items per screen. However, this manipulation decreases the cue load per screen, from six items per screen to three items per screen. If the results of Experiment 3 were to be different from those of Experiment 2, it would not be clear whether the differences were caused by the single presentation of items or by the decreased cue load. Therefore we used coloured screens for calculation tasks between the screens for the to-be-remembered items in order to increase the number of coloured screens, while not increasing the number of to-be-remembered items and not changing the cue load. Also, on both the first and the last screen, the same six items were presented as primacy and recency buffers. The 24 to-be-remembered items were presented at a rate of 6 items per screen on four screens, and the remaining four screens were used for calculation tasks.

## Method

*Participants.* The participants were 44 undergraduates who were enrolled in an introductory psychology course at Shizuoka University, Hamamatsu, Japan. They received extra course credit for participation. All had normal or corrected-to-normal vision, and did not report having colour blindness. None had participated in Experiments 1 or 2.

*Design*. A 2 × 2 mixed factorial design was used. The first factor was the sequence of background colours (random vs alternation) as a between-participants factor. The second factor was the context (same context vs different context) as a within-participants factor. Participants were randomly assigned to one of the two between-participants conditions: random or alternation sequence. Consequently each condition consisted of 22 participants.

*Stimuli and apparatus*. The stimuli and apparatus were identical to those in Experiment 2.

*Procedure*. Participants took part individually in a 15-minute experiment. The participants were presented with 10 coloured screens at a rate of 24 s per screen. The sequence of background colours (*A* or *B*) was *ABAABABBAB* for the random sequence and *ABABABABAB* for the alternation sequence. The first and the last screens were used for primacy and recency buffers, on which the same six items were presented. Four of the remaining screens were used for the presentation of to-be-remembered items, and the other four were used for calculation tasks. The sequence of item screens and calculation screens was randomised, with the restrictions that no more than two successive screens were the same type.

For the calculation task the participant was shown a three-term addition or subtraction problem on the computer screen, and was required to indicate the first digit of the solution by clicking the corresponding numeric key presented on the computer screen with the mouse as quickly and correctly as possible. The "Microsoft chime" tone was feedback for each correct response, and the "Microsoft chord" tone was feedback for each incorrect response. The feedback tone was immediately followed by the presentation of the next problem. Otherwise, the procedure was identical to that in Experiment 2.

## Results and discussion

Table 5 shows the numbers of words correctly recalled as a function of the sequence × context.

**TABLE 5**
Number of words correctly recalled as a function of sequence (random or alternated) and context (same or different) in Experiment 3

| | | *Number of words correctly recalled* | |
|---|---|---|---|
| *Sequence* | *Context* | *M* | *SE* |
| Random | Same | 4.18 | 0.39 |
| | Different | 2.96 | 0.31 |
| Alternated | Same | 3.27 | 0.41 |
| | Different | 3.36 | 0.38 |

A 2 × 2 (sequence × context) ANOVA was computed. Neither the main effect of the sequence, $F(1, 42) = 0.34$, $MSE = 3.95$, $p > .10$, nor context, $F(1, 42) = 3.17$, $MSE = 2.24$, $p > .05$, was significant, but the interaction was significant, $F(1, 42) = 4.27$, $MSE = 2.24$, $p < .05$. The context effects were analysed separately for the random and alternation sequences, because the interaction between sequence and context was significant. The number of recalled items in the same-context condition was significantly greater than in the different-context condition for the random sequence condition, $F(1, 42) = 7.41$, $MSE = 2.24$, $p < .01$, but there was no difference for the alternation sequence condition, $F(1, 42) = 0.04$, $\mathrm{MSE} = 2.24$, $\mathrm{p} > .10$.

Table 6 shows the observed and expected values for *screen* and *colour repetitions*. The difference between the observed and expected values for *screen repetition* was significant for both the random sequence, $t(21) = 2.57$, $p < .05$, and the alternation sequence, $t(21) = 3.18$, $p < .01$, conditions, whereas for *colour repetition* it was not significant for the random sequence, $t(21) = 1.72$, $p > .05$, or the alternation sequence, $t(21) = 0.89$, $p > .10$, condition. On the questionnaire one participant in the alternation sequence condition and one participant in the random sequence condition reported having used the background colours intentionally to encode or to retrieve items.

Experiment 3 successfully replicated the findings of Experiment 2 with the items presented only once. A random sequence of background colours produced context-dependent effects, but an alternation sequence of background colours did not. The recall protocols showed clustering by screens but not by background colours. These results imply that the findings in Experiment 2 are not caused by the repeated presentation of the to-be-remembered items.

**TABLE 6**
Observed and expected values of *screen* and *colour repetitions* in free recall for random or alternated sequence in Experiment 3

| | | *Screen repetition* | | *Colour repetition* | |
|---|---|---|---|---|---|
| *Sequence* | | *Observed* | *Expected* | *Observed* | *Expected* |
| Random | *M* | 2.68 | 1.33 | 3.55 | 2.94 |
| | *SE* | 0.60 | 0.12 | 0.53 | 0.26 |
| Alternated | *M* | 2.73 | 1.20 | 2.96 | 2.63 |
| | *SE* | 0.57 | 0.14 | 0.58 | 0.30 |

## GENERAL DISCUSSION

The present results confirm and extend the findings of Isarida and Isarida (2007) for background-colour context-dependent effects in free recall. First, the present study found that background colour can produce context-dependent effects in free recall when groups of six items are simultaneously presented on sequentially presented coloured screens. Significant context-dependent effects were found for the twice-repeated presentation of items in Experiment 2, and also for the single presentation of items in Experiment 3, indicating that this finding is reliable. In contrast, previous experiments found no context-dependent effect when five or more successive items were presented one-by-one against the same background colour (Isarida & Isarida, 2007, Experiments 3 and 4). The present and previous findings indicate that spatially massed (five or more) items can produce background-colour context-dependent free recall, but temporally massed items do not.

Second, the present study found that the sequential pattern of background colour (random change or simple alternation) determines the background-colour context-dependent effect for simultaneously presented items. Context-dependent effects appeared when the background colours randomly changed screen-by-screen (Experiments 2 and 3) but not when the colours simply alternated (Experiments 1, 2, and 3). Unfortunately, Isarida and Isarida (2007) did not use a simple alternation condition, but only used random change and persistence in background colours. The present results suggest that background-colour context effect would be eliminated if the colours simply alternated screen-by-screen when items were presented one item per screen. However, if the cue load of context interacted with the sequential pattern, then the simple alternation would produce the context-dependent effect when the cue load was low enough, such as one item per screen. Further research is needed.

Third, in the present study only a few participants intentionally used background colours for encoding and/or retrieval, as was also found in Isarida and Isarida (2007). Therefore the results indicate that unintentional processes produce the background-colour context effects. As previous studies have proposed that unintentional processing is involved in habituation (Dibbets et al., 2001; Isarida & Isarida, 2007), then this implies that habituation may account for colour context effects. Furthermore, the present experiments found that the sequential pattern of background colours (i.e., random change or simple alternation) influences context-dependent free recall. This sequential pattern should affect the predictability that can influence habituation (e.g., Herry et al., 2007). However, it should be noted that the notions of habituation (see Thompson & Spencer, 1966) and inattention (e.g., Underwood, 1970; Waugh, 1970) are quite similar to each other. Furthermore, the notion of involuntary attention is often used as an unintentional process of attention (see Prinzmetal, Ha, & Khani, 2010), so that inattention (e.g., Underwood, 1970; Waugh, 1970) may account for the background-colour context-dependent effects as well. The crucial point is that unintentional processes that are influenced by the predictability of the next background colour may determine the production of background-colour context-dependent effects, regardless of whether the processes should be called habituation or inattention.

Fourth, the present experiments separately measured clustering by screens from clustering by background colours. The results showed that recalled items were clustered by screens but not by background colours. This finding confirms and extends the finding of Isarida and Isarida (2007) that the recalled items were not clustered by background colour, regardless of whether the background colours were sequentially blocked or randomly presented. These findings imply that clustering of recalled items is determined by whether items are presented against a background colour simultaneously or sequentially. In other words, spatially contiguous items presented against a background colour can cluster among each other, but temporally contiguous items cannot.

As described above, a common background colour can cue all the items presented against the colour. However, no global episodic-memory trace may be encoded with the colour and the items, but rather the items may be encoded with the correspondent screens on which the items were presented into separate local episodic-memory traces. This was empirically supported by the fact that there was no clustering by colours, but by screens. Moreover, no global trace could be constructed with two background colours, because one colour could not cue the other colour items. Possibly, a common background colour may only mediate retrieval of respective local episodic-memory traces consisting of respective screens and items. Thus background colours may not function as a global context, but rather as a local context.

In summary the present study, along with Isarida and Isarida (2007), found that background-colour context has different characteristics or functions from other environmental contexts, such as place (e.g., Isarida & Isarida, 2004; Smith & Vela, 2001), background music (e.g., Balch et al., 1992; Smith, 1985), and odour (e.g., Cann & Ross, 1989; Herz, 1997). If various environmental contexts do not have the same functions, then empirical data from limited types of incidental environmental contexts may not generalise to all types of contexts. Therefore it is necessary to clarify the characteristics or functions of respective environmental contexts and to classify them empirically for explication of the mechanisms of episodic memory.

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# APPENDIX

## The post-test questionnaire used in the present experiments

*1. Encoding: Did you use any strategy to help you encode the words?*

a. repeated the words in your mind
b. made an association between the words
c. created a image for the words
d. made a story with presented words
e. made an association between the words and the background colour
f. other

*2. Retrieving: Did you use any strategy to help you retrieve the words?*

a. retrieved impressive words at the start
b. cued by association or means
c. cued by previously retrieved items
d. cued by the background colour filled in test screen
e. other

*3. Do you remember the background colour on test screen?*

Yes, the colour was________/No.