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Difficulties in the Learning of Same-Different Discrimination Using Multiple-Item Displays in Pigeons (*Columba livia*)

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Abstract – The biological origin of the same-different concept has been extensively studied especially with pigeons, and attention and memory may be key factors in further understanding the mechanisms supporting the same-different concept formation. The primary goal of the present study was to investigate how the location of changed items affected pigeons' performance on same-different discrimination between two successively presented multiple-item displays using the same training procedure as Gibson et al. (2011). However, after encountering pigeons' difficulty in learning the discrimination (Experiment 1), we shifted our focus to discrimination training itself. The poor performance during training and the resulting pattern in the simplified test suggested that entropy, or degree of heterogeneity, of each display may have been more salient to the pigeons than the abstract same-different relationship between them. In Experiment 2, we switched to the training procedure based on Katz and Wright (2006). This procedure, in which two displays were presented simultaneously, may facilitate learning by allowing pigeons to compare overall perceptual properties rather than relying solely on abstract relational concepts. In this revised task, one display was presented above the other, enabling perceptual comparison between the two displays. Although we observed slight accuracy improvement when single-item displays were used, it remained highly improbable that pigeons would achieve same-different discrimination between multiple-item displays under the current methodology. We discuss our task manipulations and the corresponding changes in pigeons' performance, which may provide useful insights for developing robust training methods that enhance same-different discrimination learning in multiple-item displays.

Keywords – Pigeon, Same-different discrimination, Visual short-term memory, Entropy, Experimental history

The ability to learn abstract concepts like same-different used to be considered unique to humans. In recent decades, many attempts have been made to investigate whether primates are able to learn same-different concepts (e.g., Basile et al., 2015; Flemming, 2011; Flemming et al., 2007; Flemming et al., 2013; Katz et al., 2002; Wasserman et al., 2001; Wright & Katz, 2007), revealing that they have the ability to learn this concept, especially when trained on a large number of item sets. In addition, evidence from pigeons, a species completely distinct from primates ecologically, physically, and phylogenetically, has shown that they are able to learn same-different discriminations and generalize them to novel stimuli (e. g., Wasserman et al., 1995; Young & Wasserman, 1997, 2002; Young et al., 1997).

Based on these positive findings from pigeons, Gibson et al. (2011) used a same-different discrimination task to compare pigeons' and humans' visual memory capacities and found qualitative similarities in visual short-term memory (VSTM) between these species. VSTM is a subsystem of working memory (Luck, 2008), storing visual information for seconds to carry out further perceptual processes, and therefore may play an important role in integrating pieces of visual information separated by eye

movements or blinks into one coherent image. In Gibson et al., the pigeons were confronted with a change detection task, in which both Sample and Test displays, each consisting of eight items, were presented sequentially, and the pigeons were required to report whether the two displays were the same or different by selecting the corresponding choice stimulus. In Change condition during training, all items were different between Sample and Test displays, and in No-change condition, all items were the same between displays. On subsequent test trials, 1-7 of the 8 items on Sample display were changed in Test display. The results from human participants showed that the proportion of "change" reports increased monotonically until the number of changed items reached four, then remained high for larger changes, which is consistent with the models proposed by Pashler (1988) and Rouder et al. (2011). Although the pigeons generally showed a lower rate of "change" reports than humans, the shape of the function ("change" reports as a function of the number of changed items) was similar between humans and pigeons, suggesting that the systems responsible for VSTM were qualitatively similar in the two species.

The task used in Gibson et al. (2011) assumed that pigeons could perform same-different discriminations by attending to and memorizing all the items on Sample display. However, during the training, the pigeons could report same (no-change) or different (change) by merely attending to just some items because the items on Sample display either all changed or all remained the same. Cavoto and Cook (2001) reported that pigeons tend to pay attention to local elements rather than the global whole. Thus, the pigeons may have adopted a strategy of focusing on local areas on both Sample and Test displays when determining whether items changed or not between displays. If the items that fell in the attended area changed, the pigeons could report the change; if the changed items were outside the attended area, on the other hand, they may have incorrectly reported "the same," even if their memory of the items within the attended area was accurate. The apparently lower "change" report rate might therefore have been due to the pigeons' limited attentional area rather than their VSTM capacity. This possibility seems likely when considering that inter-item distance has been found to be critical in the change detection task (Young et al., 2007).

To investigate the effects of spatial-attentional factors in the VSTM task, we attempted to replicate and extend Gibson et al. (2011) by examining whether pigeons' performance varied depending on the location of the changed items. We expected that their performance would be better when changed items were located in specific areas of the display than when they were located in other areas.

Following the procedure used in Gibson et al. (2011), we presented Displays A (preceding) and B (subsequent) sequentially, each containing eight items. In 'No change' condition, all items remained the same between the displays, while in 'Change' condition, all items were different. The test involved additional conditions, in which 1-7 items in Display A were changed in Display B. Through these additional conditions, we aimed to investigate possible biases that item changes occurring in specific areas of the display are reported more frequently than changes occurring in other areas.

Because our original plan was based on the assumption that pigeons could learn same-different discrimination, as shown in Gibson et al. (2011), our pigeons' low performance in the early part of the present study led us to dedicate the rest of the study to improving the pigeons' same-different report by adjusting the procedures step-by-step, focusing on the specification of the critical factor for pigeons to learn the same-different discrimination of multiple-item displays (Experiment 1). In Experiment 2, we attempted once again to replicate Gibson et al., this time training novel pigeons using the same stimuli as those used in Gibson et al. The stimuli were the only major remaining factor that was left different from Gibson et al.'s method in Experiment 1. However, a lack of improvement in the pigeons' performance led us to make a drastic change in our procedure, adopting the method used by Katz and Wright (2006). This adjustment aimed to achieve successful same-different discrimination in the pigeons and to further explore the critical factors involved in this discrimination when dealing with multiple-item displays. This approach, however, ultimately diverted us from our original purpose of replicating Gibson et al. – revealing some location bias in the same-different discrimination task.

Experiment 1

We trained pigeons on a change detection task using the same method as Gibson et al. (2011) to investigate whether the location of presented items affected their performance.

Methods

Ethics Statement

All procedures were reviewed and approved by the ethical review of Chiba University (DO29-156, DO2-221).

Subjects

Four pigeons (LCH, KRN, OSC, and PCL) participated in the experiment. All pigeons had previously participated in other experiments in our laboratory, as listed on Table S1, but had no experience with same-different tasks or the stimuli used in the present study. Training was conducted five or six days a week. The pigeons were maintained at approximately 80-85% of their free-feeding weights, with free access to grit and water in their individual home cages (36 [W] x 39 [D] x 36 [H] cm). There were no perches or toys in the cages. A 12L:12D cycle was maintained in the room containing the home cages.

Apparatus

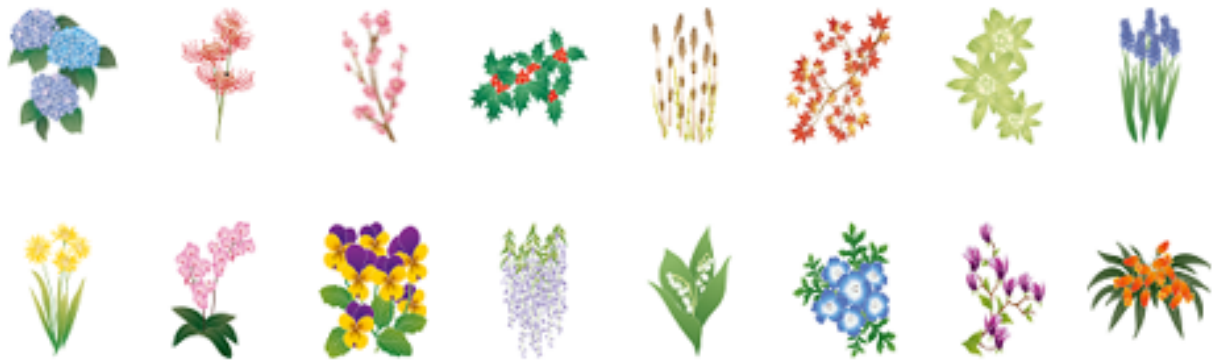
Pigeons were tested in four identical operant chambers (35.5 [W] x 34.5 [D] x 34.5 [H] cm) with aluminum frameworks and acrylic ceilings and walls. A food hopper (Sanso, CJ-44) delivered mixed grain through an opening (2 x 2 cm) on the chamber floor, located 4.5 cm from the center of the front panel of the chamber, and was illuminated by a feeder light (2 W) during reward delivery. Pigeons observed and responded to visual stimuli presented on a 15-in. liquid crystal monitor (EIZO, FlexScan S1501, 60 Hz) through a 23 x 17.5 cm opening, with its bottom segment 10.5 cm above the chamber floor, in the front panel of the chamber. Their pecks were detected by an infrared touch sensor (Touch Panel Systems, Carroll Touch, Model 3497). A house light (3 W), located in the center of the ceiling, was turned on during the intertrial interval (ITI). A computer (DELL, Vostro 200/220, OS: Windows XP) controlled the apparatus and recorded pigeons' responses.

Stimuli

The items used for Displays A (first display) and B (second display) were 16 flower cliparts (60 x 60 pixels; Net Arrow Co., Ltd., Hana Irasuto Sozai Shu, Figure 1) that were distinct from each other in color and shape. The choice stimuli, corresponding to Change and No-change, were red and green rectangles (45 [W] x 105 [H] pixels). This color assignment and the location of the choice stimuli were counterbalanced across the birds. The birds started each trial by pecking the start stimulus, a black cross measuring 44 x 44 pixels with a 5-pixel line width. All stimuli were drawn on the white display area (460 [W] x 340 [H] pixels) presented against a black background. The resolution of the 15-in. monitor was XGA (1024 x 768 pixels), and 100 pixels on the monitor measured 29.8 mm.

Figure 1

16 Flower Cliparts Used in Experiment 1



Note. Flower cliparts presented on Displays A and B whose color and shape were different from each other.

Procedure

Training

We strictly followed Gibson et al.'s (2011) training procedure in Phase 1 but, as mentioned earlier, the pigeons' chance-level accuracy led us to attempt potential breakthroughs through Phases 2-7 (Table 1). The details are described below. Throughout the phases, a response to the choice stimulus produced feedback (food or timeout); pecks to other stimuli had no programmed contingency. The criterion for pigeons to proceed to the test was 85% or higher accuracy in each condition across two consecutive sessions.

Table 1

Experimental Phases in Experiment 1

Training		
Phase	Number of sessions (adopted for all birds if not specified)	Procedure or changes from the previous phase
1	30	Same-different discrimination between heterogeneous 8-item displays
2	40	Prolonged presentation time (1000 ms to 5000 ms) of the 8-item displays/ The second display B remained when choice stimuli appeared
3	50	Reduced brightness of background
4	20	Shortened ISI between the 8-item displays to 20 ms
5	12	Shortened duration of the first display to 1000 ms
6	20	Homogeneous 8-item displays
7	LCH: 33 KRN: 20 OSC: 20 PCL: 33	Reduced variation in item pool (16 to 2)

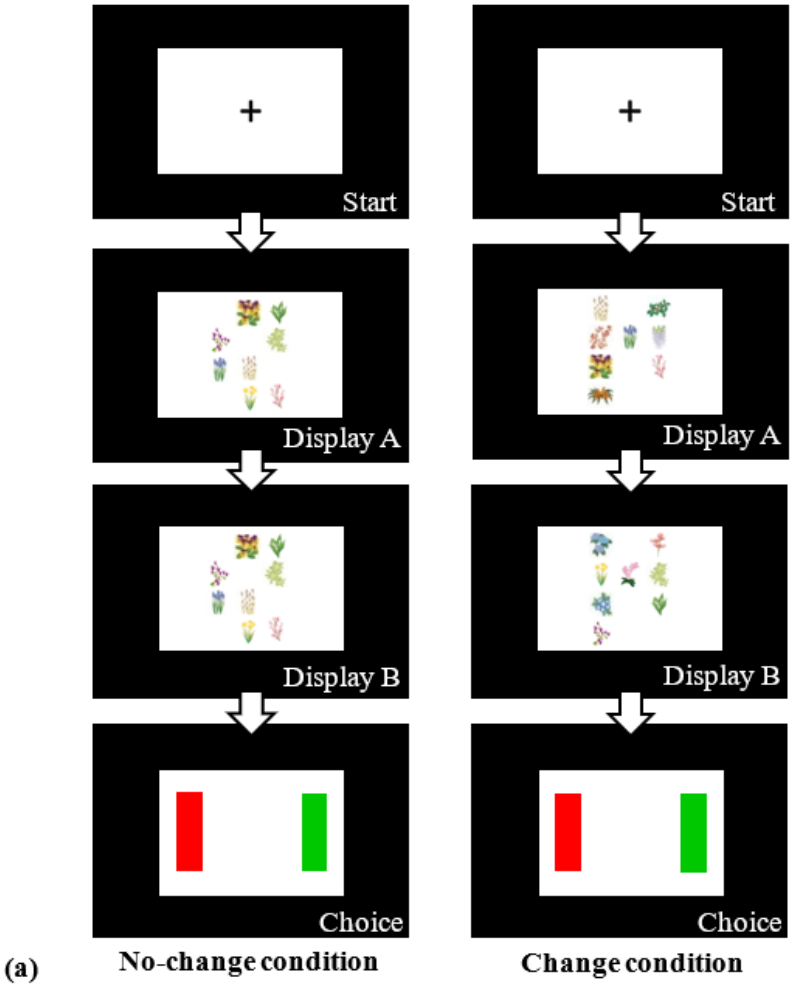
Original-Procedure Phases (Phases 1-5)

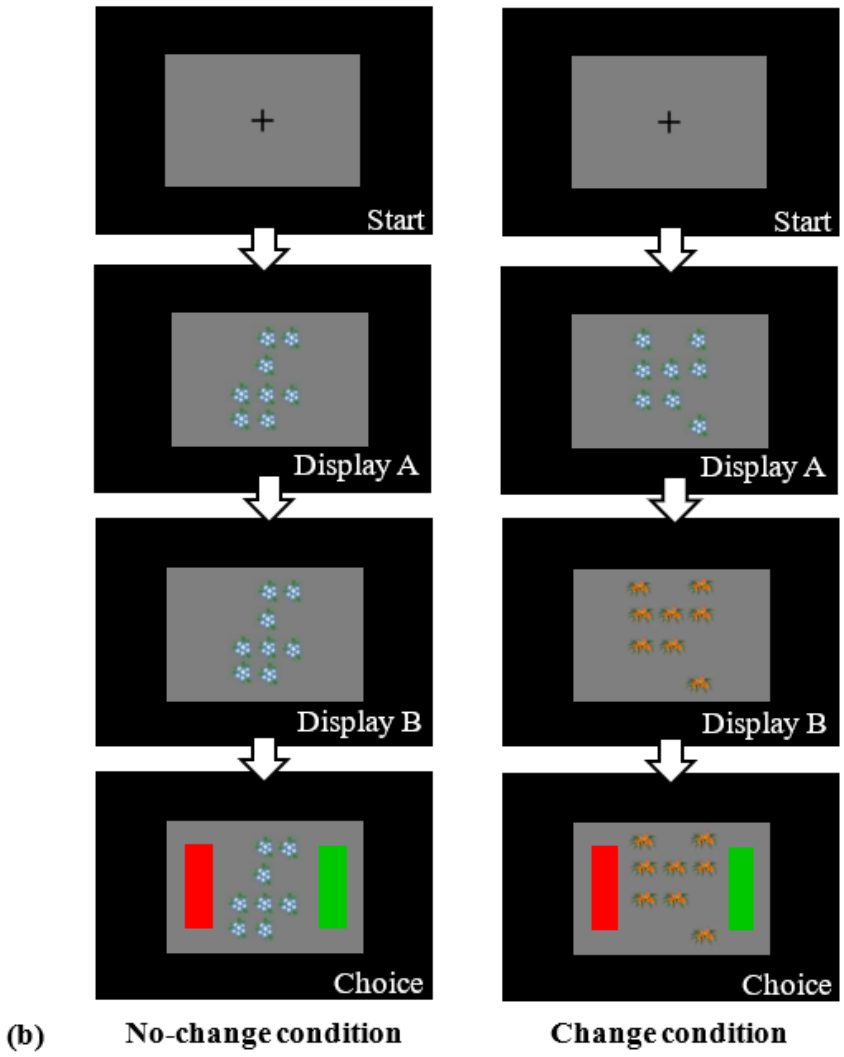
Phase 1. Following a 3000-ms ITI, the start stimulus appeared at the center of the white display area. Pecking the start stimulus sequentially produced Displays A and B, each for 1000 ms, with a 1000-ms interstimulus interval (ISI) in between. The locations of presented items in Displays A and B were the same within a trial – in No-change condition, every item in Display B reappeared at the same location as its counterpart in Display A. In Change condition, each item in Display A was substituted with a different

item in Display B. Display A consisted of eight different items randomly chosen from the 16 flower cliparts. Each of the eight items was presented at one of eight randomly chosen slots within a 3 [Column] x 4 [Row] hypothetical matrix covering 240 [W] x 340 [H] pixels at the center of the white area. Display B consisted of eight items that were either all the same as in Display A (No-change condition) or entirely different (Change condition, i.e., the other eight items from the 16-clipart set). Note that any responses to Displays A, B, and the interval between them had been recorded but had no programmed contingency, thus indifferently treating the pecks to the items and those to small marginal spaces between the items or no-item (empty) slots. Following Display B and a 100-ms interval, two choice stimuli were presented on the left and right sides of the item area. One of the choice stimuli corresponded to Change condition, and the other corresponded to No-change condition. A correct response resulted in the darkening of the screen and food delivery, with reinforcement time adjusted between 1500-3000 ms according to each pigeon's weight. An incorrect response resulted in screen darkening and a 3000-ms timeout before the ITI (Figure 2a). Following an incorrect response, the same trial was repeated until the pigeons responded correctly (correction procedure). A session consisted of 64 trials (4 blocks x 16 trials per block, each including 8 Change trials and 8 No-change trials). To minimize potential proactive interference, we extended the duration of ITI from 3000 ms to 6000, 10000, and 15000 ms during this phase. In Phase 1, subjects completed 30 sessions.

Figure 2

The Flow of a Trial in Trainings of Experiment 1





Note. a) The flow of a trial in No-change and Change conditions of Original-training Phases which replicated the procedure used in Gibson et al. (2011). b) The flow of a trial in No-change and Change conditions of Homogeneous display-training Phases.

Phases 2-5. In Phase 2, we extended the duration of Display A from 1000 ms to 5000 ms to support encoding and allowed Display B to remain visible during the choice phase to reduce memory load. Because there was a concern that the white display area was too bright for pigeons working in the dark chamber, which may have made it difficult for them to examine the displays, we reduced the brightness from white (RGB: 255, 255, 255) to greyish white (RGB: 128, 128, 128) in Phase 3. In Phase 4, we shortened the ISI to 20 ms to further reduce memory load. Because extending the duration of Display A did not improve accuracy, we gradually returned it to 1000 ms in Phase 5. Through Phases 2-5, subjects completed 122 sessions.

Homogenous Display-Training Phases (Phases 6-7)

Phase 6. In previous phases, both Displays A and B were heterogeneous (i.e., consisting of different items). Previous studies demonstrated that pigeons could readily discriminate heterogeneous and homogeneous displays (e.g., Wasserman et al., 1995; Young & Wasserman, 1997), suggesting that the homo/heterogeneous dimension would be salient for pigeons. However, the pigeons in the present study were required to discriminate between two heterogeneous displays ignoring the homo/heterogeneity of each

display, making the same-different discrimination difficult in pigeons. To address this possible problem, both Displays A and B were altered to be homogeneous in Phase 6, with eight identical items per display. In No-change condition, the same item appeared in both displays (perfectly homogeneous), whereas in Change condition, the item differed between the displays (temporally heterogeneous). In Phase 6, subjects completed 20 sessions.

Phase 7. Because, in Phase 6, the number of the combinations of items for Displays A and B was 256 (${}_{16}P_2 = 240$ for Change condition and 16 for No-change condition), which may have been too numerous for the pigeons, we reduced this number in Phase 7 by using only two of the 16 cliparts (Seemannia and Nemophila) based on color and contour distinctiveness (Figure 2b). All other procedural details remained the same as in Phase 6. LCH and PCL completed 33 sessions and KRN and OSC completed 20 sessions.

Test

Only one pigeon, LCH, proceeded to Test phase. The procedure was the same as in Phase 7, except for the introduction of new Change conditions in which two, four, or six out of eight items were altered between Displays A and B. These conditions were provided as probe trials, in which either choice was reinforced. Each session consisted of 68 trials (four 17-trial blocks each including seven Change trials, seven No-change trials, and three test probe trials for 2, 4 and 6-item Change conditions). Five sessions were conducted.

Results

Training

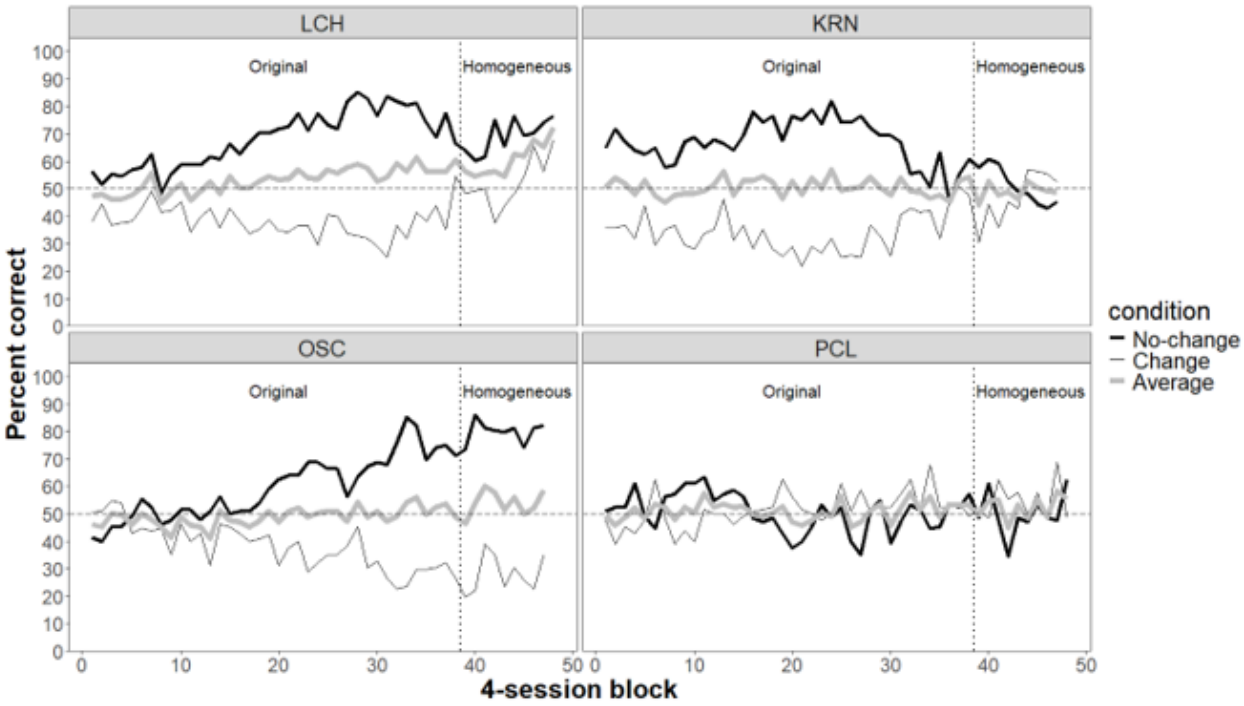
The discrimination accuracy for each bird is shown in Figure 3. Throughout Phases 1-5, the mean discrimination accuracy remained around chance level for all birds. All birds appeared to have a bias for No-change condition (for PCL, this bias was limited to initial sessions), though we cannot specify whether this bias was due to the color or location of the choice stimuli because we counterbalanced the color/side assignment for each condition. There was no obvious improvement in accuracy with homogeneous displays in Phase 6 or when the minimum set size of the items (i.e., two types of items) was used in Phase 7. Although LCH did not reach the 85% accuracy criterion by the 33rd session in Phase 7, we decided to proceed LCH to the test because LCH had already achieved 80% accuracy in each condition across two consecutive sessions.

Test

Figure 4 shows the probability of LCH's "change" reports as a function of the number of items changed between Displays A and B. Whereas the monotonically increasing function was similar to the results of Gibson et al. (2011), the function in the present study showed a more sigmoidal pattern.

Figure 3

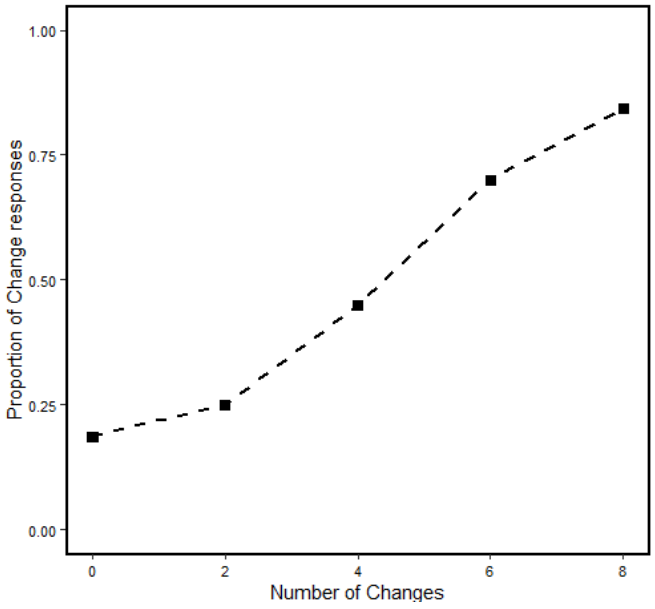
Accuracy in No-Change and Change Conditions During the Training of Experiment 1



Note. The training was conducted 192 sessions for KRN and OSC and 205 sessions for LCH and PCL in Experiment 1. The data is summarized as 4-sesion blocks. Dashed line at 50% accuracy depicts the chance level accuracy.

Figure 4

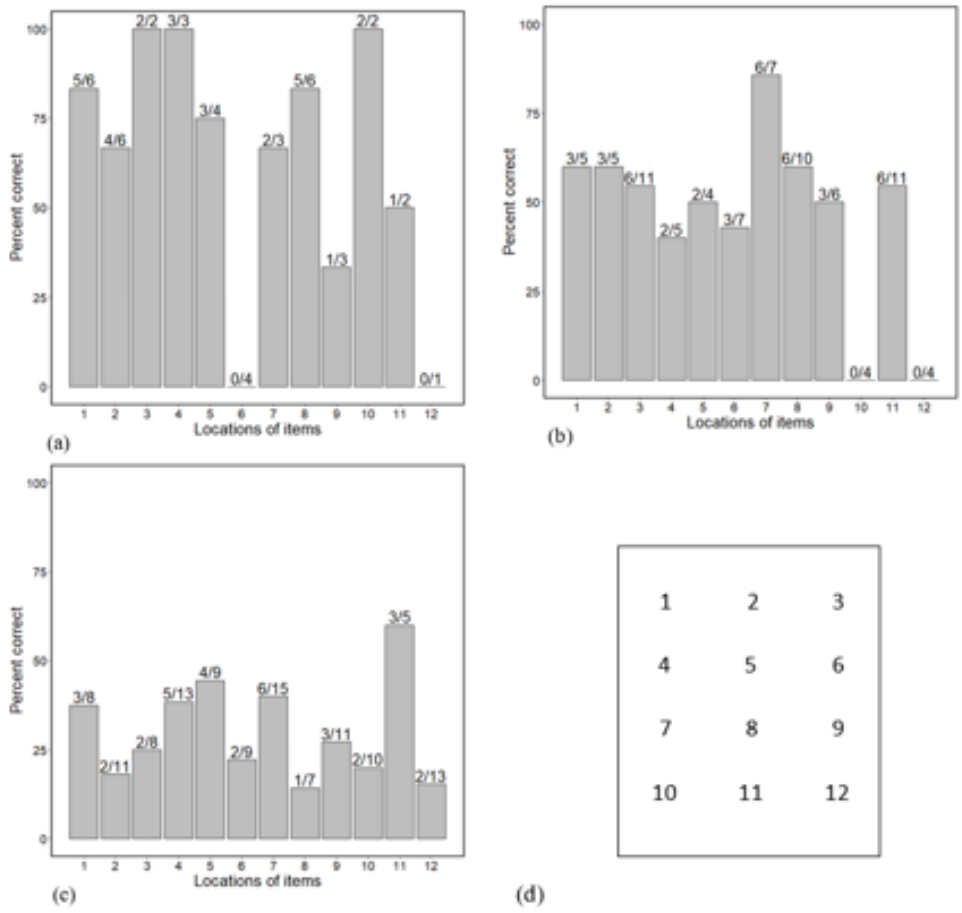
Proportion of "Change" Responses in the Test of Experiment 1



One of the original purposes of this study was to investigate whether pigeons direct attention to specific item locations and consequently detect changes more accurately at those locations. The mean accuracy for each location is shown for 2-, 4-, and 6-item Change conditions in Figures 5a, 5b, and 5c, respectively. Because the locations of the changed items were randomly assigned in each trial, the frequency of each location being designated as a changed item varied, as indicated by the denominators in each fraction on the bars in Figures 5a-c. A comparison of percent correct across the 12 locations suggests that detecting item changes in the lower right locations (#6 and #12 in Figure 5d) was relatively more difficult.

Figure 5

The Mean Accuracy with 2, 4, and 6-Item Change Conditions in the Test of Experiment 1



Note. (a)-(c) (a), (b), and (c) show 2, 4, and 6-item Change conditions respectively. In the function (X/Y) located on top of each data, the number X presents how many times subject responded correctly when an item on particular location changed during the test and the number Y presents how many times an item at each location changed during the test. (d) The locations of item presentation was numbered 1-12 from top left to right bottom.

Discussion

In Experiment 1, we intended to replicate Gibson et al. (2011), which measured pigeons' visual short-term memory (VSTM) capacities in a change-detection task, and to examine possible location biases in change detection. Although we trained pigeons using the same procedure as Gibson et al., our subjects struggled to learn the task. Consequently, our study's focus shifted from analyzing location biases in the testing situation to examining the critical factors affecting pigeons' task learning. Despite multiple attempts

to simplify the task, only one of the four pigeons succeeded in Test phase. Furthermore, the response pattern in the test was distinct from that of Gibson et al. (2011).

Our pigeons underwent 1920 trials in Phase 1, during which we precisely replicated Gibson et al.'s (2011) procedure. In contrast, pigeons in Gibson et al. required between 3200 and 7424 trials to reach Test phase. This suggests that our pigeons may not have received sufficient training. However, because we subsequently trained them with a presumably easier version of the task in later phases, they ultimately completed 12288-13120 trials, making it unlikely that the total number of training trials accounted for their difficulties.

Previous studies on same-different discrimination in pigeons, mainly from Wasserman's laboratory, suggest that pigeons tend to attend to stimulus entropy, which refers to the degree of visual complexity or variability (e. g., Castro & Wasserman, 2011; Castro et al., 2012; Wasserman et al., 2000; Young & Wasserman, 1997; Young et al., 1997; Young & Wasserman, 2001) and this is the case even when items were presented successively (Young et al., 1997; Young et al., 1999). In both Gibson et al. (2011) and our study in our Original-procedure Phases, two successive displays contained eight different items each, meaning both displays were high in entropy. This required pigeons to make same-different discriminations between two high-entropy displays, regardless of Change/No-change conditions. Given the extensive prior evidence of pigeons' reliance on entropy, the difficulty observed in our pigeons seems expected, whereas the success of Gibson et al.'s pigeons in learning the task is somewhat surprising.

The sigmoidal pattern obtained in the test for the one bird in the present study also seems to support the entropy hypothesis. Sigmoidal response patterns are consistently obtained when subjects are required to make binary decisions between two categories along a continuous dimension, such as size ("large" or "small") or length ("long" or "short"). Therefore, the sigmoidal pattern in the present results, may reflect the pigeon's decision along the dimension of the entropy of the displays, suggesting that the bird paid attention to the whole displays rather than to specific items at a particular location. Although the "change" report rates were not equal across the locations, they did not reveal biases towards particular locations and, thus, a narrow and fixed attention to specific locations seems to be unlikely. On the other hand, the test results in Gibson et al. (2011), showed an arch-shaped accuracy curve as a function of the number of changed items, which was parallel to human cases. The success of the pigeons in Gibson et al. in learning the change detection task is likely due to some training or experience in ignoring the entropy dimension of the display. This dimension, while shown to be salient in the studies by Wasserman and colleagues as well as in our current study, did not hinder their pigeons' performance. We will discuss this issue in General discussion.

Another possibility for the difference between Gibson et al. (2011) and our studies is the difference in the item used. Thus, in Experiment 2, we investigated whether novel pigeons would be able to learn the same-different discrimination by using the same stimuli used in Gibson et al.

Experiment 2

Because the only difference in the method between Gibson et al. (2011) and our Experiment 1 was the stimuli, this was the most likely factor responsible for our pigeons' poor performance in training. In Gibson-procedure Phases of Experiment 2, we used novel pigeons and investigated whether they were able to learn same-different discrimination between the sequentially presented multiple-item displays when using not only the same procedure but also the same stimuli as in Gibson et al.

The results of training in the Gibson-procedure Phases again showed that pigeons had difficulty acquiring same-different discrimination, despite using the exact same method as Gibson et al. (2011). Therefore, we subsequently shifted the training procedure from Gibson et al. to Katz & Wright (2006). In the latter procedure, subjects were required to compare two pictures presented one above the other and peck at the lower one when the pictures were the same or at a rectangle adjacent to the lower item when they were different.

The procedural differences between the two studies (Gibson et al. [2011] and Katz & Wright [2006]) are worth discussing. In the procedure of Gibson et al., pigeons were trained to compare two

multiple-item displays and detect possible differences between them. Thus, the authors described their procedure as a "change-detection" task. However, actually, the birds were required to respond to the stimulus corresponding to either "the same" or "different" based on an abstract relational concept. As discussed in Experiment 1, substantial literature, to which Wasserman and colleagues have greatly contributed, indicates that forming a same-different concept is challenging for pigeons, as the entropy dimension may be more salient for them and may interfere with the same-different dimension.

The procedure of Katz & Wright (2006) may provide a solution to this issue. In the study, two pictures were shown simultaneously, with one presented above the other. The pigeons were trained to peck the bottom picture if it was the same as the top one and to peck a third stimulus if the two were different. This task involves detecting spatially repeated visual patterns, thereby supporting the behavior of same-different discrimination. Therefore, we adopted Katz's procedure to establish same-different discrimination in pigeons as preparation for measuring their visual short-term memory.

Methods

Subjects

Four pigeons (JBS, ISA, BLS, and MTK), different from those used in Experiment 1, participated in Experiment 2. As listed in Table S1, all pigeons had prior experience from other experiments conducted in our laboratory, though these experiments were neither same-different tasks nor used the stimuli in this study.

Apparatus

The apparatus was identical to that used in Experiment 1.

Stimuli

We used 16 cliparts (57 x 57 pixels), identical to those in Gibson et al. (2011). Whereas the original study did not specify the source of the images, we identified them as Microsoft Office clipart (Supplementary Materials) and used the same images in Experiment 2. Details about the start and choice stimuli used in each phase are provided in Procedure.

Procedure

Training sessions were initially conducted according to Gibson et al.'s (2011) procedure in Phases 1-6 and later transitioned to Katz & Wright's (2006) procedure in Phases 7-12 (Table 2). Throughout all phases, the training criterion remained the same as in Experiment 1: pigeons needed to achieve 85% or higher accuracy for both Change/No-change conditions across two consecutive sessions to proceed.

Gibson-Procedure Phases (Phases 1-6)

Phase 1. Training in Phase 1 followed the same procedure as the Original-procedure Phases in Experiment 1 (Figure 6), replicating Gibson et al. (2011). The ITI was 3000 ms, and the color of the display areas was set to light grey (RGB: 189, 189, 189). We planned to conduct 28 sessions for Phase 1.

Phases 2-6. Because the pigeons showed no signs of discrimination learning, we gradually modified the procedure to approximate Katz & Wright (2006). The number of items on both Displays A and B was reduced from eight to four in Phase 2. In Phase 3, similar to the pigeons in Katz & Wright, our birds were required to peck once (observing response) anywhere on each display to proceed. At this phase, any peck anywhere on the display were counted as observing responses. In Phase 4, the number of observing responses per display was increased from one to four. In Phase 5, the ITI and timeout durations were

gradually extended from 3000 ms to 15000 ms. In Phase 6, the start stimulus was changed from a black cross on a grey background to a white cross (44 x 44 pixels, 5-pixel line width) on a black background.

Although above manipulations were designed mainly as the preparation for the next Katz-procedure Phases, they were presumed to enhance the discrimination accuracy also in Gibson-procedure Phases. Thus, we spent 7-21 sessions (details are to be described in Result section) for each phase of Phases 2-5 to check any raises in the pigeons' performance. In Phase 6, we proceeded quickly to Katz-procedure Phases after conducting only three sessions, expecting the pigeons to familiarize themselves with the new start stimulus.

Table 2

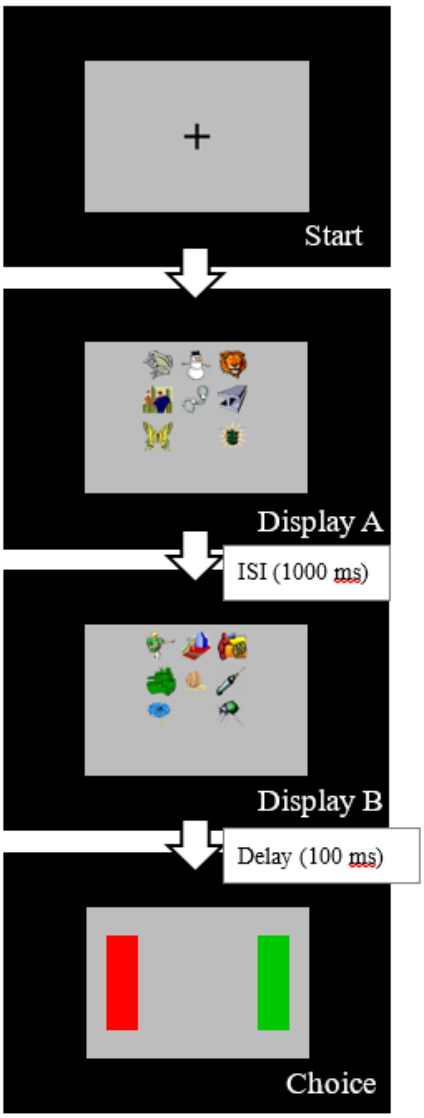
Experimental Phases in Experiment 2

Phase	Number of sessions (adopted for all birds if not specified)	Procedure or changes from the previous phase
		Gibson-Type
1	JBS: 19 ISA: 28 BLS, MTK: 31	Same-different discrimination between heterogeneous 8-item displays
2	7*	Reduced number of items on each display (8 to 4)
3	7*	Observing response required (FR 1)
4	7*	Observing responses required (FR 4)
5	JBS: 8 ISA: 22 BLS: 24 MTK: 21	Prolonged ITI and timeout by 3s every 2 sessions, up to 15s
6	3	Introducing new start stimulus (white cross on black screen)
		Katz-Type
7	6	Displays presented at vertically different location (Display A located at the top of Display B); No ISI between these displays
8	JBS, ISA, BLS: 25 MTK: 24	Display A remained presented when Display B and choice stimulus appeared
9	8	Reduced number of items on each display to 1; Incorrect responses had no programmed contingency
10	15	Limited valid area for observing responses
11	5	Reversed response contingencies
12	JBS: 41 ISA: 52 BLS: 43 MTK: 34	Timeout reintroduced for incorrect responses: Correction procedure resumed

Note. * JBS failed to complete a whole session in these phases

Figure 6

The Flow of a Trial of Gibson-Procedure Phases in Experiment 2



Note. The procedure was the same as that used in Gibson et al (2011) except for the color of the display area.

Katz-Procedure Phases (Phases 7-12)

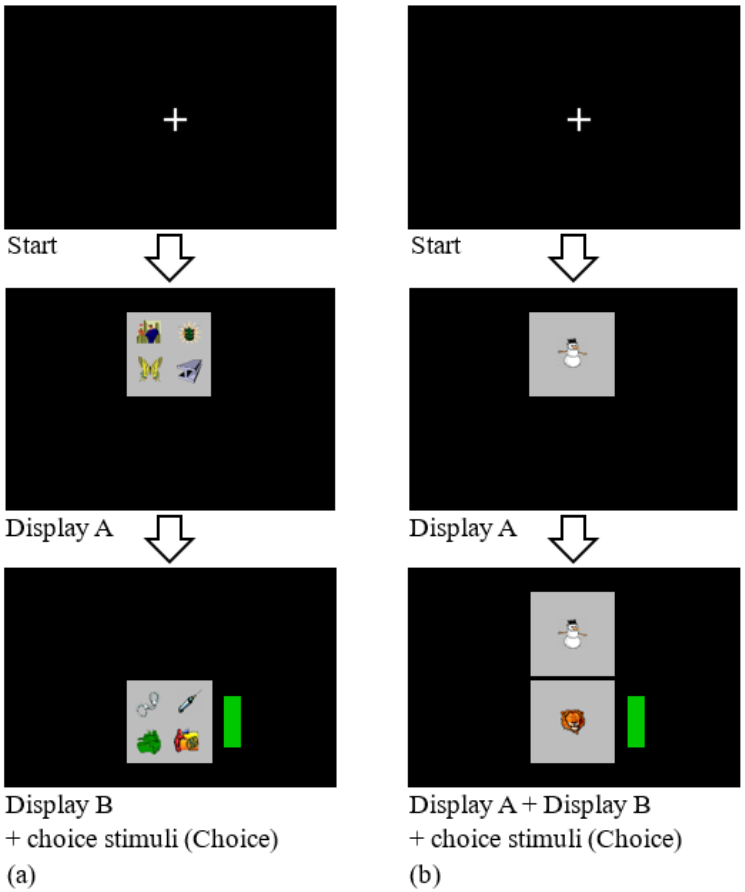
Whereas in Gibson-procedure Phases, Displays A and B were presented sequentially at the same location in the same way as in Experiment 1, the two displays were presented one above the other in Katz-procedure Phases.

Phase 7. In this phase, the areas of Displays A and B were smaller than those of Experiment 1 (260 x 260 pixels), and each appeared just above and below the monitor center, respectively. Following 15000-ms ITI, the start stimulus appeared at the center of the black display area. Pecking at the start stimulus produced Display A. Pecking four times anywhere on the display turned it off, and instantly Display B and the choice stimulus appeared (Figure 7). The choice stimulus, the green rectangle, was located on either the left or right side of Display B, depending on the assigned location in Gibson-procedure Phases for that bird.

Displays A and B each included four different items randomly chosen from the 16 cliparts arranged in a 2 x 2 grid. In No-change condition, all four items of Display B were the same as Display A, and in Change condition, the four items were the different items randomly chosen from the rest of the clipart pool. A peck at the choice stimulus in No-change condition and at Display B in Change condition, as a correct choice, resulted in the darkening of the screen and delivery of the food reward. Incorrect choices resulted in the darkening of the screen and delivering of the 15000-ms timeout. Following an incorrect response, the correction procedure was repeated until the pigeons responded correctly. Note that the choice contingency was reversed from Katz & Wright's (2006), in which pecking at Display B in No-change condition and the choice stimulus in Change condition were considered correct. This is because we thought that responding to the odd location in the display may be easier than conceptualizing "same" or "different" and choosing the corresponding symbols.

Figure 7

The Flow of a Trial of Katz-Procedure Phases in Experiment 2



Note. Trainings started with the procedure shown in (a) and then shifted to the procedure shown in (b) in a stepwise manner.

Phases 8-12. In Phase 8, Display A remained when Display B and the choice stimulus were presented. In Phase 9, to make the task easier, the number of items was reduced from four to one in both Displays A and B, and the pigeons were allowed to peck until they correctly responded (i.e., pecking at Display B in Change condition and the choice stimulus in No-change condition; Figure 7b). Therefore, there were no longer incorrect responses or correction trials. As noted above, up to Phase 9, our program treated responses anywhere on the display area (both items and the light grey background) as observing

responses; thus, it was possible that the pigeons were pecking the empty spaces without actually observing the items. Accordingly, in Phase 10, the areas to which the pecks were accepted were precisely limited to the items. Although we did not record the peck locations, the mean number of pecks to the display area increased from 5.5 in the last four sessions of Phase 9 to 6.9 in the initial four sessions of Phase 10, indicating that the pigeons had pecked the empty spaces on the displays a few times in Phase 9. In Phase 11, the contingency was reversed so that a peck to the items on Display B on No-change trials and to the choice stimulus on Change trials were rewarded (i.e., the contingency was the same as Katz & Wright (2006)). In Phase 12, the number of required pecks was set back to one, and the correction procedure was resumed. We conducted 6, 25, 8, 15, and 5 sessions for Phases 7-11, respectively. In Phase 12, we continued training until we noticed that there was no sign of accuracy improvement, and thus, we conducted 34-52 sessions, depending on individual performance.

Although we had initially planned to conduct the test in which the number of changed items were manipulated after successfully training the birds on a larger number of items included in each display, we discontinued the rest of the plan because the pigeons had already experienced more than 100 sessions by Phase 12 and expected much longer period for further training.

Results

Figure 8 shows each bird's learning curve across the entire training period in Experiment 2.

Gibson-Procedure Phases

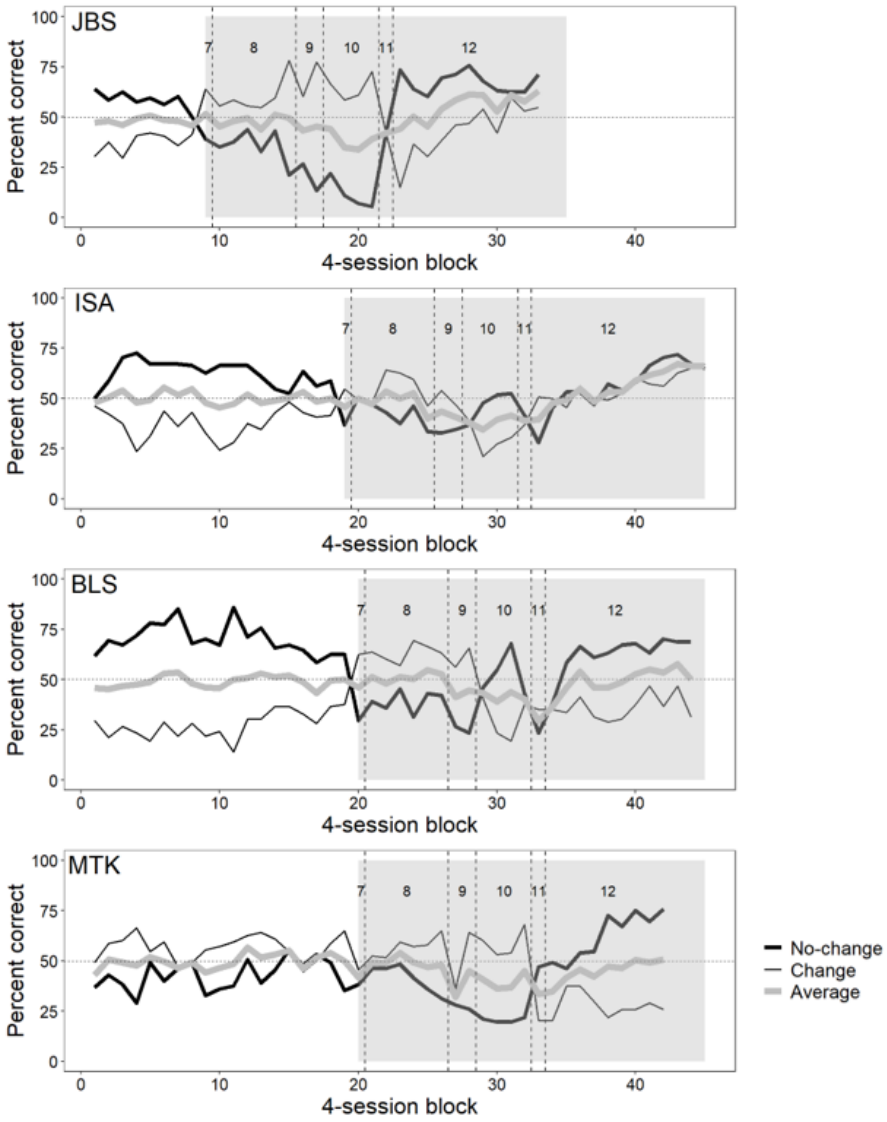
We basically conducted 28, 7, 7, 7, and 21 sessions for Phases 1-5, respectively, though some birds in some phases experienced additional sessions until the preparation for the next phase was completed (Table 2). In the 19th session of Phase 1, JBS showed reluctance and was unable to complete one session. JBS experienced some trials of Phases 2 through 4, but never completed a full session and then moved on to Phase 5, resulting in a training history that differed from the other birds. The mean accuracy for JBS, ISA, BLS, and MTK was 48.0%, 50.1%, 48.9%, and 49.7%, respectively. None of the subjects met the training criterion in these phases.

Katz-Procedure Phases

The shaded portion of the learning curves in Figure 8 represents data from Phases 7-12. For Phases 9-11, accuracy was calculated based on only the first response for each trial. Discrimination accuracy remained at or below chance level for most of the training period and showed only minor improvement during Phase 12. None of the subjects reached the 85% accuracy criterion.

Figure 8

Accuracy in No-change and Change Conditions During the Training in Experiment 2



Note. The areas covered in grey present the accuracy in Katz-procedure Phases and the numbers 7-12 indicate each training phase. Dashed lines at 50% accuracy depict the chance level accuracy. Because JBS could not accomplish a training from 19th to 22th in Gibson-procedure Phases, those data were not included in Figure 8.

Discussion

In Experiment 2, we first examined whether the differences observed between the results in Experiment 1 and Gibson et al. (2011) were due to the difference in stimuli by using novel pigeons. However, no improvement in discrimination accuracy was observed. This suggests that the stimuli used in Experiment 1 were not the critical cause of our pigeons' inability to acquire discrimination. We then investigated whether pigeons' performance would improve if they were trained using Katz and Wright's (2006) procedure, in which perceptual dimensions could aid same-different discrimination. Even with this new task, the pigeons' discrimination accuracy did not reach the training criterion.

As previously discussed, studies have shown that entropy plays a key role in pigeons' learning of same-different discrimination (e.g., Castro & Wasserman, 2011; Castro et al., 2012; Wasserman et al., 2000; Young & Wasserman, 1997; Young & Wasserman, 2001; Young et al., 1997; Young et al., 1999). Considering these findings, the difficulty pigeons experienced in training, where they were required to discriminate between two high-entropy displays, seems reasonable. Readers may suspect that certain aspects of our subjects' experimental histories could have interfered with their ability to discriminate multiple-item displays in a same-different context. As fully described in Table S1, our subjects have never undergone any training on relational concepts or with multiple-item displays; therefore, their experimental histories have not impacted the relational same-different discrimination. It is unclear whether Gibson's pigeons had prior experience with tasks that require holistic processing of heterogeneous displays while ignoring entropy-based cues. Nonetheless, experimental histories of the pigeons, including whether they were experimentally naïve or not, have not been specified there.

The importance of experimental history and training background may also account for the results observed in Katz-procedure Phase (Phases 7-12). Our pigeons failed to learn same-different discrimination, even when the task had shifted to Katz and Wright's (2006) procedure, which allows judgments based on the spatially repeated visual patterns to aid discrimination. The failure to acquire the discrimination may have been due to prior training experience under Gibson et al.'s procedure, which may have interfered with learning under Katz and Wright's procedure. If our pigeons had been trained with Katz and Wright's procedure from the beginning (and if our pigeons were experimentally naïve as Katz and Wright described their pigeons), they might have acquired same-different discrimination and subsequently transferred their discrimination behavior to Gibson et al.'s (2011) procedure.

Aside from differences in individual experimental histories, procedural differences between Katz and Wright (2006) and our experiment may also explain the pigeons' poor performance. One such difference is that Katz and Wright required pigeons to peck the top display 20 times before the bottom display and choice stimulus appeared, whereas we required our pigeons to peck Display A only four times. Pigeons and other species may have difficulty learning abstract concepts with a small number of observing responses (e.g., Katz et al., 2002; Wright et al., 1988), suggesting that the number of observing responses we required may have hindered their learning of the same-different discrimination. Nevertheless, it remains unclear how this difference may have affected our pigeons' performance. Another notable difference is that in Phases 7-10, the correct response assignment was reversed compared to Katz and Wright. In our study, pigeons were rewarded for pecking the bottom display in Change condition and the choice stimulus in No-change condition, whereas the reverse contingency was applied in Katz and Wright. Reversing this contingency for our pigeons in Phase 11, such that they now experienced the same assignment as Katz and Wright's pigeons, did not significantly improve discrimination accuracy at this stage. However, in Phase 12, two pigeons (JBS and ISA) showed an improvement in discrimination accuracy when timeout and correction procedures were reinstated. This suggests that the combination of the correct response assignment (i.e., responding to the choice stimulus in Change condition and the bottom display in No-change condition) used in Katz and Wright's study, along with the timeout/correction procedure, may be crucial for successful learning. Because order effects cannot be ruled out in this study, further research is needed to validate these hypotheses.

General Discussion

In the present study, we attempted to replicate the method of Gibson et al. (2011) and investigate how the location of changed items on multiple-item displays affected pigeons' performance. In Experiment 1, although we followed the same procedure as Gibson et al., our pigeons had difficulty in learning same-different discrimination. In Experiment 2, we used not only the same procedure but also the same stimuli to replicate Gibson et al. but still did not observe the acquisition of same-different discrimination. We then decided to prioritize the acquisition of same-different discrimination behavior and trained the same pigeons by assimilating the procedure to that of Katz and Wright (2006). However, our pigeons did not show a substantial improvement in discrimination performance.

Despite our efforts to align our training method with that of Gibson et al., some researchers may criticize us for the minor differences in parameters, such as timeout duration and the number of required responses. Additionally, we may have used a different model series for our apparatus. Because we pursue reliable, scientific evidence of animal cognition, findings should be robust enough to withstand repeated replication even when there are minor variations in parameters. This stance is particularly important for species comparison, which inevitably involve subtle differences in parameters such as reward type, number of trials, and daily schedules. For example, Gibson et al. conducted tests with both humans and rats using the same procedure, albeit with slight methodological variations, and discovered qualitatively similar results between the two species.

As discussed earlier, the reason why Gibson et al.'s pigeons showed different results from our pigeons may be in the differences of the experimental histories, rather than some slight parameter differences. Full details of the experimental histories of subjects would provide new insights into understanding the factors affecting discrimination learning. For future studies, clarifying complete experimental histories and learning curves of subjects would be valuable for identifying effective training procedures for acquiring same-different discrimination behavior. Such an approach will be important for understanding the mechanisms of short-term memory for multiple-item displays in pigeons and other non-human animals.

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Conflict of Interest: The authors declare no conflict of interest.

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References

Basile, B. M., Moylan, E. J., Charles, D. P., & Murray, E. A. (2015). Two-item same/different discrimination in rhesus monkeys (*Macaca mulatta*). *Animal Cognition*, *18*, 1221-1230

Castro, L., & Wasserman, E. A. (2011). The dimensional nature of same–different discrimination behavior in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, *37*, 361-367

Castro, L., Wasserman, E. A., & Young, M. E. (2012). Variations on variability: effects of display composition on same-different discrimination in pigeons. *Learning & Behavior*, *40*, 416-426

Flemming, T. M. (2011). Conceptual thresholds for same and different in old- (Macaca mulatta) and new-world (*Cebus apella*) monkeys. *Journal of Experimental Psychology: Animal Behavior Processes*, *86*, 316-322

Flemming, T. M., Beran, M. J., & Washburn, D. A. (2007). Disconnect in concept learning by rhesus monkeys: judgement of relations and relations-between-relations. *Journal of Experimental Psychology: Animal Behavior Processes*, *33*, 55-63

Flemming, T. M., Thompson, R. K. R., & Fagot, J. (2013). Baboons, like humans, solve analogy by categorical abstraction of relations. *Animal Cognition*, *16(3)*, 519-524

Gibson, B., Wasserman, E., & Luck, S. J. (2011). Qualitative similarities in the visual short-term memory. *Psychonomic Bulletin & Review*, *18*, 979-984

Katz, J. S., & Wright, A. A. (2006). *Same/Different* Abstract-Concept Learning by Pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, *32(1)*, 80-86

Katz, J. S., Wright, A. A., & Bachevalier, J. (2002). Mechanisms of same/different abstract-concept learning by rhesus monkeys (*Macaca mulatta*). *Journal of Experimental Psychology: Animal Behavior Processes*, *28(4)*, 358-368

Luck, S. J. (2008). Visual short-term memory. In S. J. Luck & A. Hollingworth (Eds.), *Visual memory* (pp. 43–86). Oxford University Press.

Pashler, H. (1988). Familiarity and visual change detection. *Perception & Psychophysics*, *44(4)*, 369-378

Rouder, J. N., Morey, R. D., Morey, C. C., & Cowan, N. (2011). How to measure working memory capacity in the change detection paradigm. *Psychonomic Bulletin & Review*, *18*, 324-330

Wasserman, E. A., Hugart, J. A., & Kirkpatrick-Steger, K. (1995). Pigeons show same–different conceptualization after training with complex visual stimuli. *Journal of Experimental Psychology: Animal Behavior Processes*, *21*, 248-252

Wasserman, E. A., Young, M. E., & Fagot, J. (2001). Effects of number of items on the baboon's discrimination of same from different visual displays. *Animal Cognition*, *4(3-4)*, 163-170

Wright, A. A., Cook, R. G., Rivera, J. J., Sands, S. F., & Delius, J. D. (1988). Concept learning by pigeons: Matching-to-sample with trial-unique video picture stimuli. *Animal Learning & Behavior*, *16(4)*, 436–444.

Wright, A. A., & Katz, J. S. (2007). Generalization hypothesis of abstract- concept learning: learning strategies and related issues in *Macaca mulatta*, *Cebus apella*, and *Columba livia*. *Journal of Comparative Psychology*, *121(4)*, 387-397

Young, M. E., & Wasserman, E. A. (1997). Entropy detection by pigeons: Response to mixed visual displays after same-different discrimination training. *Journal of Experimental Psychology: Animal Behavior Processes*, *23(2)*, 157-170

Young, M. E., & Wasserman, E. A. (2002). The pigeon's discrimination of visual entropy: A logarithmic function. *Animal Learning and Behavior*, *30*, 306-314

Young, M. E., Wasserman, E. A., & Ellefson, M. R. (2007). A theory of variability discrimination: Finding differences. *Psychonomic Bulletin & Review*, *14(5)*, 805-822

Young, M. E., Wasserman, E. A., & Garner, K. L. (1997). Effects of number of items on the pigeon's discrimination of same from different visual displays. *Journal of Experimental Psychology: Animal Behavior Processes*, *23*, 491-501

Supplementary Materials

Table S1

Experimental Histories of Pigeons in Experiments 1 and 2

Experiment 1		
Subject	Experimental Histories (Theme; Task; Stimuli)	
LCH	1	Motion discrimination; Visual search for static item among dynamic items; Geometrical figures
	2	Decoding of symbolic locational cue; Matching color-shape combination to location; Geometrical figures
	3	Human face discrimination; Visual search; Human face photographs
	4	Object-based attention; Color discrimination between sequentially-cued rectangles; Geometrical figures
KRN	1	Sound pitch discrimination; Matching color to sound; Color squares and sounds
	2	Motion discrimination; Visual search for static item among dynamic items; Geometrical figures
	3	Human face discrimination; Visual search; Human face photographs
	4	Navigation; Searching for specific location on computer monitor using landmarks; Geometrical figures
	5	Object-based attention; Simple response to target; Geometrical figures
OSC	1	Motion discrimination; Visual search for static item among dynamic items; Geometrical figures
	2	Metacognition; Matching-to-sample with second-choice available; Vertical/Horizontal gratings
	3	Human face discrimination; Visual search; Human face photographs
	4	Navigation; Searching for specific location on computer monitor using landmarks; Geometrical figures
	5	Object-based attention; Simple response to target; Geometrical figures
PCL	1	Polymorphous concept; Symbolic matching-to-sample; Multiple-color-component stimuli, vertical/horizontal gratings
	2	Priming; Visual search with prior cue; Alphabetical characters
	3	Human face discrimination; Go/No-go; Human face photographs
	4	Kanizsa illusion; Brightness discrimination; Geometrical figures (truncated disks)
	5	Navigation; Searching for specific location on computer monitor using landmarks; Geometrical figures
	6	Object-based attention; Simple response to target; Geometrical figures
Experiment 2		
JBS	1	Metacognition; Location matching with self-prolonged sample presentation; Geometrical figures
ISA	1	Modal and amodal completion; Symbolic matching-to-sample; Geometrical figures
BLS	1	Navigation; Searching for specific location on computer monitor; Photos of arena
MTK	1	Symbolic matching-to-sample; Discrimination between intact rectangles and partly truncated rectangles; Geometrical figures

Figure S1

Items Retrieved from the Classical Microsoft Office Clipart Library

Note. Items that were originally horizontal were adjusted to have an aspect ratio of 1:1, similar to those used in Gibson et al. (2011).

Figure S2

Item Retrieved from the Website

Note. Retrieved from (https://www.freepik.com/premium-vector/snail_5086018.htm).

Figure S3

Item Purchased at the Website

Note. Purchased at (https://pixta.jp/illustration/48556617).

Figure S4

Item Retrieved from the Website (Broken Link)

Note. Retrieved from (https://myrealdomain.com/images/black-caterpillar-hunter.gif).