

**Dissertation**

**Experimental analysis on relational  
discrimination learning in rats**

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School Registration No. 1121072707

Name: Md. Abu Bokor Siddik

Principal Supervisor: Dr. Tohru Taniuchi

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*To my beloved mother and brothers*

*Mst. Rashida Begum*

*Md. Rafikul Islam*

*Md. Abdullah Shikder*

*To my wife*

*Mst. Yeasmin Akter*

# Acknowledgement

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Md. Abu Bokor Siddik

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## Abstract

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The introductory chapter reviewed the literature of abstract concept learning in nonhuman animals focusing mainly on relational concept. Research on relational discrimination learning has been conducted through matching to sample task, same/different discrimination task, and oddity discrimination task. So far, it has been shown that various species, such as baboons, rhesus monkey, capuchin monkey, parrots, and pigeons can learn abstract S/D relationship. However, studies have failed to show clear evidence of relational concept learning in rats. The prime aim of this thesis was to examine an ability to learn relational concept in rats, especially through oddity discrimination learning and its transfer to novel stimuli. In Experiment 1, rats were trained in a conditional S/D discrimination task in which responses to either of left or right alley were reinforced depending on the S/D relationship of a pair of object. The findings showed that rats learned the task based on stimulus-specific cues such as configurations of the two objects. In Experiment 2, four rats were concurrently trained with multiple oddity tasks consisting of object stimuli (e.g., AAAB).

In oddity discrimination learning, animals are required to choose an odd stimulus from multiple identical stimuli. After attainment of the first task (AAAB), tasks were gradually increased up to 30 oddity tasks consisting of six different object stimuli (A, B, C, D, E, and F). Two (Rat 2 and Rat 4) out of four rats acquired the concurrent training and both rats showed significant transfer of learning to the novel test stimuli. Using similar procedures, cross-modal transfer test (Experiments 3 and 4) was examined with novel odor tasks consisting of six different odors (2221, 1112, 4443, 3334, 6665, and 5556) and with two novel sound tasks (YYYY and XXXY) using one rat (Rat 4) from Experiment 2 as a subject. The rat showed significant oddity performance to odor test stimuli and above the chance performance to the sound test stimuli (For similar cross-modal test on oddity concept learning in children, see Tyrrell, 1974).

The present study showed the first evidence of abstract oddity discrimination learning in rats. However, further examination is needed for several problems. First, determinants of individual difference should be examined. Second, influence of possible artifacts should be examined. That is, different objects used in object oddity discrimination tasks might have different odors. In that case, cross-modal transfer between object and odor stimuli might partly be odor-odor intra-modal transfer. Third, perceptual oddity should be distinguished from conceptual oddity (see in detail in chapter IV). This study expands understanding on phylogenetic origin of concept learning. However, the present experiments showed preliminary evidences. Therefore, further study should be carried out with a larger number of subjects and sophisticated experimental settings as mentioned above.

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### Introduction

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A benchmark of human intelligence is an ability to classify objects and events prevailing around them by using abstract concepts. Like humans, animals also need to make different kinds of responses to the ever changing stimuli for their survival. Various kinds of information or cues are available for animals in their specific environment. For example, multimodal recognition of predators in which animals can understand predators' movement by observing their different features (e.g., some smell or sound of the predators), prey, kin, or the comprehension of alarm and food calls. Animals need to judge whether two bodies of different shapes are same or to understand the number of objects (e.g., food items) is the same irrespective of their arrangement and distribution (Piaget and Inhelder, 1969 cited from Scholtyssek, Kelber, Hanke, & Dehnhardt, 2013). However, by abstracting and generalizing various kinds of information regarding their specific environment, animals take decision in which situation what they should do thus facilitating them to survive.

Hence, it is visible that animal study is inevitable to build a scientific understanding of the evolution and meaning of intelligence. Emphasizing such observation, comparative psychologists have long been paying their utmost efforts to understand the form of intelligence of other species share with humans (Cook, 2001; Darwin, 1897 cited from Blaisdell & Cook, 2005; Wasserman, 1993) that may discover the mechanisms of intelligence of both human and nonhuman animals. Abstract concepts involve relationships between or among stimuli based on a rule (e.g., identity, difference, oddity, and relative magnitude). This rule turns in to an abstract one when it can correctly be applied to novel stimuli. One of its noticeable features is that it is independent from the specific physical properties of the stimuli. To judge relationship transcending stimuli feature is thus considered higher order learning. This unique feature (relationship transcending stimuli feature) makes abstract concept learning unique and different from other forms of concept learning such as natural concept (explained in the later part) that share some common features of the stimuli.

Abstract concept of sameness has prominently contributed to human development (e.g., Daehler & Bukatko, 1985 cited from Katz & Wright, 2006). Children develop cognition in stages and extend their abstract concept of sameness through using number, length, area, and volume (Piaget & Inhelder, 1966/1969). Regarding human's cognition, William James (1890/1950, p.459) stated "the concept of sameness is the very keel and backbone of our thinking" (cited from Katz, Wright, & Bachevalier, 2002). Abstract concepts are of different types such as number, categories, and relationship. The abstract concept of number is the numerical property of stimuli and could be applied to a variety

of stimuli, regardless of their physical features. For example, every human has two hands and two legs thus showing the same number. By contrast, we can count different things with number (e.g., five cars, ten trees). The abstract concept of categories involves two types, one being a natural concept (also called perceptual concept learning) that categorize stimuli especially those found in nature like picture of birds, flowers, cars, trees based on stimulus perceptual similarity in to appropriate categories (e.g., Herrnstein, Loveland, & Cable, 1976; Medin, 1989; Wasserman, Kiedinger, & Bhatt, 1988). There are various kinds of birds (e.g., owls, pigeons, crows, hawks). All members of bird species have wings that make the same perceptual similarities. Conversely, they have some features by which we can differentiate them from each other. Hawks have very big wings compared to other birds. Every bird makes different sound by which we can differentiate them.

It cannot be defined by the presence of a single feature. Rather, complex combinations of properties may be needed to explain this concept. Given that members of a natural category share some common physical features. Therefore, it is sometimes defined as non abstract. Conversely, there are some abstract categories that are defined by function. For example, the concept of “food” or “tool” is defined by its function and members of these categories do not necessarily share any physical similarity. Finally, a relational concept is defined as an abstract relationship among stimuli, such as sameness, difference, relative magnitude (less than or greater than) and so on thus sharing no specific members. For example,



**Figure 1.** Examples of Same/Different relationships among stimuli

In the case of two circles of Figure 1, we can describe these stimuli as “same”. But in the case of two squares, the specific physical features (e.g., shapes) of the component stimuli are completely different from those of the first example. But we can apply the identical relational concept of “same” to describe each of these two cases. The third and fourth examples show a different relationship among stimuli. However, an example of relative magnitude (less than or greater than) may be that the subjects receive 40 foods, 35 foods, and 30 foods as reward for responding to stimulus A; 25 foods, 20 foods, and 15 foods for stimulus B; 10 foods, 5 foods, and 1 food for stimulus C. That means,

reward magnitude is always larger to stimulus A in comparison with other stimuli B and C. One of the most popular and powerful means of studying the relational concept is the same/different (S/D) concept that shows an ability to identify same/different stimulus from item pairs and its successful transfer to novel stimuli. According to Delius (1994), S/D concept was an ability to discriminate the stimuli on the basis of equality and inequality regardless of the particular qualities of the stimuli that should be linkable by suitable instruction or conditioning to any arbitrary pair of responses. Considerable researches with organisms of different species were conducted on the learning of concepts like “same” and “different” (e.g., Wasserman, Fagot, & young’s study with baboons, 2001; The study of Katz et al., with rhesus monkeys, 2002; Pepperberg’s study with parrot, 1987; Katz & Wright’s study with pigeons, 2006). Two much-discussed procedures for exploring this issue involve matching-to-sample and oddity discriminations.

In this thesis, several articles were summarized that used matching-to sample (MTS), same/different (S/D), and oddity discrimination procedures to examine abstract concept learning in primates and other nonhuman animals. My purposes were to show how animal researchers applied the same experimental procedures across different animal species (e.g., the study of Katz et al., with rhesus monkeys, 2002; Katz and Wright’ study with pigeons, 2006; Wright and Katz’ study with monkeys and pigeons, 2006) and demonstrated successful transfer of learning to novel stimuli. These findings revealed that similar cognitive processes and intellectual abilities might prevail across different species. This argument reinforces us to apply the experimental procedures (oddity discrimination) that proved successful evidences with other animal species (e.g., monkeys, pigeons, California sea lion) to rats’ species. My purposes also focused on how animal researches gradually advanced towards achieving abstract concept learning by primates and nonhuman animals, what critical parameter facilitated animals to acquire relational learning, how the findings of animal researches enrich the knowledge on animal intelligence.

### **1.1. Matching-to-sample method**

As a measure of conditional discriminations and concept learning in humans and nonhuman animals, matching-to-sample (MTS) tasks have been using for over a half century. In MTS procedure, at first, a sample stimulus is shown to the subject and then two comparison stimuli one out of which matches the sample and another one is different appeared on the screen. Subjects are reinforced for responding to the stimulus



that matches the sample. As an early evidence of S/D conceptual behavior, Zentall & Hogan (1974, 1976, 1978) trained pigeons to choose a comparison colors (e.g., red) that matched the sample color (red; matching-to-sample task) or to choose a non comparison colors (e.g., green; oddity-from-sample task). Then pigeons were trained on a novel pairs of colors (blue and yellow). Of the pigeons who participated in MTS tasks with red-green stimuli, half of the pigeons received training with blue-yellow stimuli whereas, the remaining pigeons did on the oddity task. With such procedures, pigeons were able to learn the acquisition tasks and showed good transfer. In the subsequent experiments, pigeons could enhance these findings in the transfer test trials across discriminations of color, brightness, and shape.

However, Premack (1978) criticized the procedures of those studies and proposed a nonconceptual explanation (Blaisdell & Cook, 2005). Premack's explanation (1983b) was that short-term familiarity (please see in detail in the latter part of this discussion) that prevailed among the sample and comparison stimuli might be in operation in animals as discriminative cue for solving the MTS tasks. In MTS method, sample is presented twice: Once as a sample stimulus and the next time as one of the two comparison stimuli. With such advantage, the subjects may feel different level of familiarity between the sample and the matching stimuli. There is empirical evidences (Wright & Lickteig, 2010), the first of its kind, in support of Premack's hypothesis (1983b) that when novel-novel test (when both comparison stimuli were novel) was administered, pigeons demonstrated modest transfer (69%). Suppose, both stimuli A and B are novel. Firstly, stimulus A is presented. Then two stimuli A and B are presented. In this situation, subjects may feel short-term familiarity to both stimuli (A and B). Therefore, the subjects may respond to stimulus A resulting in transfer of learning to the familiar stimuli Conversely, when novel-familiar test (when one of two comparison stimuli on transfer trials was one of the training stimuli) was administered, pigeons showed no transfer thus echoing Premack's prediction that familiarity between the sample and the comparison stimuli might control the pigeons' discriminative behavior. As for instance, stimulus C is a training stimulus. It is presented several times to the subjects. By contrast, stimulus D is a novel stimulus that the subjects have never seen before. In this situation, if stimulus D is, at first, presented, then both stimuli C and D are presented, subjects may feel long-term familiarity to stimulus C and short-term familiarity to stimulus D. Such competition of two different familiarity might produce no transfer of learning to the novel stimulus. Additionally, Premack asserted that learning the S/D concept reflected abstract thinking acquired through language training. Thus according to his hypothesis, species without language ability are not able to

acquire abstract concept. These failures of abstract concept learning with pigeons provided a major stimulus for Premack's article (1978). However, reviewing early findings, Premack (1978) claimed in a seminal article titled "on the abstractness of human concepts: Why it would be difficult to talk to a pigeon" that played a vital role in the modern resurgence of animal cognition that abstract concept learning was limited only to primates. Premack's claim stimulated avian researchers and they devised ingenious experimental techniques as a response to Premack's criticism. Therefore, avian researchers have been reporting reliable evidence of S/D concept learning by birds since 1990's (e.g., Cook, Kelly, & Katz, 2003; Blaisdell & Cook, 2005; Wright & Katz, 2006). Most of the previous studies (e.g., Wright, Santiago, Urcuioli, & Sands, 1984; Edwards, Jagielo, & Zentall, 1983) on abstract concepts with nonhuman primates (e.g., pigeons) were handicapped by the small number of stimuli (just two items) as same or different or small number of extremely simple stimuli (Santiago & Wright, 1984) that might be a causal factor for pigeons to fail in learning abstract concept. Two articles summarized in this section. One article (Wright, Cook, Rivera, Sands, & Delius, 1998) implies that larger number of training stimuli may enhance animals' ability to acquire relational learning. Usage of larger number of stimuli made an understanding why previous studies with pigeons failed to show abstract concept learning. The second article (Wright & Lickteig, 2010) provides a new idea that failing to acquire an abstract concept does not always lead to item-specific learning. Animals may attain an alternative learning (restricted-domain relational learning) that changed a long lasting notion.

### **Some reports on MTS method**

#### **1.1.1. Larger number of training stimuli might facilitate an acquisition of relational learning**

**Title: Concept learning by pigeons: Matching-to-sample with trial-unique video picture stimuli**

**Authors: Wright, Cook, Rivera, Sands, and Delius (1998)**

Previous studies (e.g., Cumming & Berryman, 1961; Cumming, Berryman, & Cohen, 1965; Farthing & Opuda, 1974) used small number of stimuli that resulted in failure in acquiring abstract concept learning by pigeons. Wright et al. (1998) assumed that larger number of stimuli might require producing good transfer performances. Moreover, presentation of trial-unique problem (where novel tasks were given in each trial) might

enhance pigeons' ability to acquire abstract concept learning. Overman and Doty (1980) trained pigeons with trial-unique problem involving 100 stimuli and showed good transfer (equivalent to baseline). These manipulations might make the tasks easier for pigeons. Therefore, Wright et al. (1998) designed the present study. Four experimentally naïve White Carneaux pigeons were trained with simultaneous matching-to-sample (SMTS) tasks (where a sample stimulus was, at first, presented and then two comparison stimuli appeared. These three stimuli remained in view until a choice was made to one of them). Two pigeons were given trial-unique problems involving 152 different stimuli daily, whereas the rest two pigeons were given just two stimuli (duck and apple). The rationale for providing training to two groups of pigeons with different number of stimuli was to see the effect of the number of stimuli on pigeons' performances. After acquisition training, transfer test was given to them. Research findings showed that pigeons in the trial-unique group could attain abstract concept learning. On the other hand, 2-stimulus group could not learn the tasks suggesting that the number of training stimuli might play a critical role in acquiring relational learning. These findings refuted the claim made by previous studies (e.g., Carter & Warner, 1978) that pigeons were not able to learn the abstract concept. Wright et al. (1998) pointed out that larger number of training stimuli (152 stimuli in trial-unique group) might facilitate pigeons to learn the SMTS tasks relationally. Notably, this is a relevant issue with my research. I also used larger number of training stimuli (e.g., 12 oddity tasks, 30 oddity tasks) in which rats showed positive transfer to the novel stimuli. But Wright et al. (1998) did not clarify how larger number of stimuli facilitated pigeons to learn the abstract concept.

According to my opinion, larger number of stimuli makes much variation that makes the subjects' memory load high. Memorizing strategy is not effective rather an application of relational strategy (to solve the discrimination tasks based on relationship among stimuli) can reduce this high memory load and lead to the solution. Although pigeons used in the study of Wright et al. (1998) seemed to acquire the SMTS learning, the procedures (SMTS) they used were questionable. It is speculated that in SMTS tasks, laws of proximity might be in action in the subjects where neighboring stimuli play a single identity in terms of their proximity and equality that may facilitate the subjects to perceive these ones as a holistic stimuli. In this case, subjects might be attentive to the similarity, proximity of the neighboring stimuli rather than to the relationships. Therefore, in this type of discrimination tasks, subjects have an advantage to manipulate the stimuli. To avoid such possible situation, future study should focus on second-order relationship that is discussed the later part (conclusion) of this section.

### **1.1.2. Animal may acquire abstract concept learning but this learning may be restricted to a domain**

**Title: What is learned when concept learning fails? - A theory of restricted domain relational learning**

**Authors: Wright and Lickteig (2010)**

Failure to acquire the abstract concept has been regarded as the attainment of item specific learning for a half century (e.g., Carter & Werner, 1978; Premack, 1978). But Wright and Lickteig (2010) raised a question whether failure to acquire abstract concept indicated the attainment of item specific learning in all the cases. Therefore, they mainly focused on what animals really learned if they failed to transfer to novel items. With a view to meeting their curiosity, they conducted six experiments in total among of which two with matching to sample task and four with same/different task. In MTS, a sample stimulus was, at first, presented to the pigeons on a computer monitor and then two comparison stimuli among of which one matched the sample and another one did not match were presented. Pigeons were trained to respond to the stimulus that matched the sample one.

In S/D experiment, upper and lower picture were presented to the pigeons and monkeys. If two pictures were same, a touch / peck to the lower picture was rewarded. If different, a touch / peck to the white rectangle was rewarded. Incorrect responses were unrewarded and followed by correction procedure. There were 40 training pairs (8 same, 32 different) and 24 testing pairs (untrained set). Research findings showed that pigeons demonstrated item-specific learning with MTS experiment. On the contrary, pigeons and monkeys showed restricted domain relational learning in S/D experiment. According to Wright and Lickteig (2010), in MTS, the absolute factors of the familiar stimuli associated with reinforcement led pigeons' performances to item-specific responding. In the present article, pigeons showed 69% transfer in the case of novel comparison stimuli (novel-novel test). But in the case of nonmatching comparison stimuli (novel-familiar test), pigeons showed no transfer. Such performances confirmed authors' statement.

In S/D experiment, authors pointed out that the multidimensional nature of the travel slide pictures might facilitate pigeons to acquire restricted-domain relational learning from item pairs. In addition to, color of the stimuli (e.g., apple's color was made purple, the flower green, and the cat pink) might have an important role to maintain relational learning among pigeons and monkeys. Such research findings changed a long lasting

notion that had been prevailing among animals researchers for a half century that failure of novel-item transfer resulted in item-specific learning despite little or no direct evidence (e.g., Carter & Werner, 1978; Premack, 1978). These findings (restricted-domain relational learning) enriched the knowledge to understand animal intelligence and are consistent with my studies. Because restricted-domain relational learning is a possible candidate for rats' behavior (odor-odor transfers). The present article raised a question how the domain became restricted for animals and how it changed. It is still unclear and a big challenge for the animal researchers in future. This question is very significant because its answer may make headway towards acquisition of domain free relational learning by animals. One possible candidate is that when small number of stimuli is presented and the training and testing stimuli share some common features, animal can find similarity among training stimuli pairs that provides an advantage for them to share the same with the testing stimuli. Based on such learning strategy, it is difficult for them to show good performances to the testing stimuli if these ones provide unfamiliar appearances to them. I opine that expanded set of training stimuli (e.g., large number of stimuli involving various domains) and thoughtful size, shape, and color of stimuli may overcome item-specific learning or restricted domain relational learning.

### **1.1.3. Conclusion about the studies of matching-to-sample method**

In MTS procedure, at first, a sample stimulus is given to the subjects and then two comparison stimuli appear. The subjects are reinforced for responding to the stimulus that matches the sample one. This occasion may, in one hand, reduce the flexibility of relationally discriminating novel stimuli and, on the other hand, contribute to the familiarity effect that weakened the reliability of this procedure. Notably, this familiarity effect provoked Premack to argue against accepting the findings of nonhuman animals' conceptual behavior. To avoid such concern, relational matching procedure (second-order relationships) where, at first, a pair of sample stimulus (AA) appears and then two pair of comparison stimuli (BB and CD) appears (Pearce, 2008). Subjects are reinforced to respond to a pair of stimuli that shows the same relationship as that of a pair of sample stimuli (AA). The effect of familiarity is hardly applicable to this procedure. Because no member of comparison stimuli matches with the sample one.

## **1.2. Experiments with S/D procedure**

Recent technological and procedural advances made possible that those species who were thought to be totally deficient in learning abstract concept actually do have this ability (Bhatt & Wright, 1992; Bovet & Vauclair, 2001). Technological and procedural advances also showed that pigeons could transfer performances to novel stimuli following training with substantial number of training stimuli (Wright, Cook, Rivera, Sands, & Delius, 1998; Wright & Katz, 2006).

We know that two items are the minimum requirements for a same-different classification. There were evidences (e.g., Young, Wasserman, & Garner, 1997) that when the number of items was reduced, performances decreased. Some researchers (Wasserman, Hugart, & Kirkpatrick-Steger, 1995) began to think what might occur if more than two items were used. It can be hypothesized that involving more than two items may make the S/D tasks easier for animals. This hypothesis led the researchers (Wasserman et al., 1995) to use 16 items rather than two items that were either all same as one another or all different from one another. With such experimental procedure pigeons showed rapid acquisition and transfer to novel items. But display variability remains a major concern. The studies summarized in this section demonstrated that humans took the display variability in to consideration to make their discriminative responses to the same/different displays. Pigeons and baboons also showed the same tendency to the same/different displays. These suggest that a common tendency might prevail across different species to place their decision on discriminative stimuli.

### **Some reports on S/D procedure**

#### **1.2.1. Humans may process the discrimination tasks based on variability in same/different display**

**Title: Entropy and variability discrimination**

**Authors: Young and Wasserman (2001)**

People's evaluation of categorical variability requires abstract relational judgment among the display items. This abstractness differentiated categorization of stimuli considering its two functional features, for example, visual variability and perceptual similarity. Although substantial number of researches on relational similarities was conducted (e.g., Gentner & Markman, 1997; Thompson, 1995), the dimension contributing to the formation of abstract categorization is yet to be clear among animal

researchers. Therefore, Young and Wasserman (2001) aimed at identifying the dimension responsible for visual variability (especially for humans' sensitivity to variability). It is better to mention that entropy measures the degree of variety in a categorical variable. It depends on the frequency of categories in a display. Low-frequency categories bear much information thus resulting in maximum entropy, whereas common categories did very little information thus producing zero entropy. Hence, a research question may arise how much sensitivity humans contain to variability. Animal researchers were unaware of any clear and unambiguous empirical evidences on the matter. Young and Wasserman (2001) tried to unveil the unawareness by quantifying the sensitivity under different conditions. They anticipated that humans' sensitivity to variability might be continuous function of entropy.

However, in order to meet the purposes of the present study, two experiments were carried on. In Experiment 1, 76 introductory Psychology students were trained to discriminate same from different display. After successful acquisition training, they were tested with displays of intermediate variability and with displays comprising fewer icons. The research findings showed that 80% of the participants responded to various stimuli sets based on categorical strategy and the remaining 20% responded to the stimuli set based on absolute entropy (where subjects classify any same arrays as "same". But they consider the function of the number of items in the display to classify different arrays). These data suggested that all subjects processed the entropy of the sets but 80% of the participants judged S/D tasks by setting threshold to the entropy. According to Young and Wasserman (2001), participants might have used a simple categorical rule (all same vs. some different) that was driven by the pop-out effects (e.g., Treisman & Gormican, 1988; Wolfe, 1994). However, in order to discourage categorical rule, Experiment 2 was conducted using 125 introductory Psychology students as subjects where they were trained to discriminate 16-icon displays with entropy of 1.0 from that of 3.0. After acquisition training, testing phase appeared involving both 16-icon mixture arrays and 2-, 4-, 8-, and 12-icon same and different arrays. Experiment 2 showed that 62% of the participants used entropy strategy (based on visual variability) and 38% used the relative entropy (where subjects classify any same arrays as "same" and any different arrays as "different") as the discriminative dimension. These findings suggested that people were able to discriminate arrays of pictorial items as a continuous function of their variability. Furthermore, participants responded to the discriminative same/different displays in terms of absolute entropy rather than relative one. Hence, we may ask a question what factors may facilitate people to discriminate uniform same arrays from non uniform arrays. Young and

Wasserman (2001) opined that display variability prevailing among the same/different displays might be taken into consideration by the participants to solve the S/D tasks. In addition, local discontinuities like pop-out effect (e.g., a large item pops out of a field of smaller one. Treisman & Gormican, 1988) might be a supplement to solve the discrimination tasks. Whatever the reason, display variability seemed to control subjects' behavior thus posing a remaining problem in the presents study. According to my view, the more number of stimuli a display contains, the much possibility may be generated for variability. For example, a stimulus display containing 16 different icons may contain high variability. In contrast, a stimulus display containing 3 different icons may have low variability. Therefore, decreasing the number of icons in a display may produce a congenial atmosphere for subjects to remove the effect of entropy to some extent. In practical, it is difficult to totally free the subjects from the effect of entropy. As an endeavor to overcome this concern, a better design for future studies might use the technique of employing some modifications in the different display. For example, a different display containing  $\circ\triangle\circ$ ,  $\triangle\triangle\circ$  icons and another different display containing  $\blacklozenge\star\star$ ,  $\blacklozenge\blacklozenge\star$  icons. Such kind of different display contains low variability thus considerably decreasing the possibility of the effect of entropy. Such procedure may be considered a part of the future study. These studies bear much implication to compare display variability in discriminative performances between humans and animals.

### **1.2.2. Avian species may process the discrimination tasks based on variability in a display**

**Title: Effects of number of items on the pigeon's discrimination of same from different visual displays**

**Authors: Young, Wasserman, and Garner (1997)**

Due to using very few stimuli as same or different to train the pigeons, previous studies (e.g., Wright et al., 1984; Edwards et al., 1983) were failed to demonstrate significant transfer to the novel stimuli. Giving importance on such observation, animal researchers (e.g., Wasserman et al., 1995) began to think of how the pigeons' behavior stood if more than two items were used. This regime allowed them to train pigeons with 16-icon same and 16-icon different displays that produced good transfer to novel item. In order to make further advancement towards the matter concerned, Young et al. (1997) set an aim at documenting how increasing number of items affects the pigeons' behavior thus contributing to producing good transfer to novel items. To meet this aim, two experiments were carried on. In Experiment 1, four feral pigeons (*Columba livia*) were



trained to peck to the green area on same trials and to the red area on different trials. After acquisition training, 16 testing sessions involving nondifferential reinforcement and no correction trial were conducted. Research findings showed that fewer icons in a display produced poor performances of the pigeons, whereas larger number of items especially in the different display resulted in good transfer to novel items. These findings suggested that the reason behind the failure of the previous pigeons' studies (e.g., Wright et al., 1984) with same/different visual stimuli was due to the use of only two items. More importantly, these findings made clear that stimulus property, for example, a display entropy (a measure of variability) might control the pigeons' discriminative performances resulting in faster acquisition and stronger transfer in 16-icon different display.

However, in order to generalize the results of Experiment 1, Experiment 2 was carried on. Experiment 2 following the same subjects, apparatus and procedures except some changes in visual stimuli and training and testing procedures confirmed the evidences of Experiment 1. Hence, we may ask a question of why increasing larger number of stimuli produced good transfer. According to Young et al. (1997), pigeons were expected to distribute its responses to the novel icons in accordance with the function of entropy. For example, pigeons might classify displays with entropies closer to 0.0 as same, whereas those with entropies closer to 4.0 as different. It was observed that an entropy of 2-item different display was 1.0 that was closer to that of 16-item same display 0.0 than to that of 16-item different display 4.0.

I conform to the entropy calculation made by Young et al. (1997). Although an excellent clarification as to the reasons behind display variability was showed, it was unclear to them to distinguish conceptual from perceptual dimensions thus posing a remaining problem in the present study. Further investigation should be carried on unveiling the issue concerned. In animal studies, it is very difficult to determine whether the findings are based on conceptual or perceptual factors. Same question was raised in our studies. We are also not sure of whether rats used in our studies performed conceptually or perceptually. We tried to solve the issue with an alternative explanation (please see in the general discussion chapter).

### **1.2.3. Nonhuman primates may solve the same/different displays based on visual dimension of the same/different stimuli**

**Title: Same-different conceptualization by baboons (*Papio papio*): The role of entropy**

**Authors: Wasserman, Fagot, and Young (2001)**

To confirm whether pigeons' significant transfer to the novel stimuli was determined in terms of equality and inequality, several experiments (Young and Wasserman, 1997; Young, Wasserman, & Garner, 1997; and Wasserman, Young, & Nolan, 2000) bringing some modifications (e.g., mix arrays of S/D items) suggested that pigeons appeared to dimensionalize the arrays rather than categorizing thus arguing the claim made by Delius (1994). Earlier, Wright, Santiago, Urcuioli, and Sands (1984) speculated that monkeys could learn abstract concept, whereas pigeons could not. Emphasizing this speculation, Wasserman et al. (2001) made their effort to confirm monkeys' ability to learn abstract concept and whether the nature of monkeys' acquiring concept learning was categorical (learning should be based on equality and inequality regardless of the particular features of the stimuli) offered by Delius (1994) or dimensional (learning based on the effect of entropy, a measure of variability) observed in some previous studies (Wasserman et al., 2000; Young and Wasserman, 1997; Young et al., 1997).

To meet the purpose of the present study, four experiments were conducted. In Experiment 1, six adult Guinea baboons were trained in a two-alternative, force-choice and conditional discrimination procedure. In conditional discrimination training, baboons were required to make discriminative choices to 16-icon same versus 16-icon different arrays in each training session. Following discrimination training, four testing sessions involving 100 baseline training trials with differential reinforcement and plus 16 testing trials with non differential reinforcement were conducted. Experiment 1 demonstrated that baboons transferred to their discriminative responding to arrays of novel icons with higher accuracy (81%). Such findings were supported by previous studies (Young and Wasserman, 1997). According to Wasserman et al. (2001), one plausible explanation was that baboons might, at first, have learned to make higher discriminative choice response and then generalize it to the novel computer icons. This explanation suggests that they possibly kept their attention to the general property of the icon arrays to a great degree.

In contrast, I think, display variability emerged from the same and different displays might play an important role for baboons to make higher accuracy to the novel icons. Therefore, to remove such concern, Wasserman et al. (2001) introduced a mixture

arrays of same/different icons (e.g., 14 same and 2 different; 12 different and 4 same) in Experiment 2 and in Experiment 3 (for example, 13-1-1-1 where 13 same and 3 different stimuli or 10-3-2-1 where 10 same and 3-2-1 different). Both experiments showed that display variability contributed to their discriminative S/D responding. Baboons' graded response profiles closely matched with those of pigeons that were tested with the same mixture displays (Young and Wasserman, 1997, Experiment 3 and 4). I think, when an element of a category is important or seems to provide more information to subjects, this may give them different perception containing maximal entropy, whereas when an element is unimportant or carries no information, subjects may perceive it as same containing zero entropy.

Wasserman et al. (2001) thought that if subjects solved the S/D discrimination tasks depending on the categorization of the stimuli, they might not be affected with the entropy. In contrast, if they made their S/D discrimination based on visual dimension of the stimuli, they might be netted with the effect of entropy. However, to eliminate an alternative explanation of the results of present studies (an appeal to spatial orderliness), Experiment 4 and 5 were conducted. To carry on Experiment 4 successfully, the same subjects and apparatus as those of Experiment 1, 2, 3 were used except some changes in procedure and stimuli (jittered stimuli). Research findings revealed that baboons showed high level of accuracy (averaging 93%) in all the trials. Experiment 5 was started with blurred stimuli keeping all the subjects and apparatus used in Experiment 1,2,3,4 unchanged except some changes in procedure and stimuli. Experiment 5 documented that baboons' performances were profoundly affected by the blurred icons suggesting that their S/D discrimination behavior was not based on spatial orderliness of the visual arrays. However, the present study and the Young and Wasserman's study (1997) confirmed that stimulus control by entropy was not limited to only avian species but it also extended to nonhuman primates. Moreover, so similarity in the performances of such widely different species with that of pigeons strongly suggest that the results of the present study may be applicable to other animals under the same training and testing procedure. These findings might contribute to unearthing much information of general cognitive processes in animal behavior.

#### 1.2.4. Conclusion about the studies with S/D procedure

Due to using extremely simple and very few items, previous studies with S/D concepts (e.g., Edwards et al., 1983; Santiago & Wright, 1984 cited from Young et al., 1997) was unable to produce positive transfer to the novel stimuli. This understanding reinforces Wasserman et al. (1995) to introduce more than two items, a turning point in S/D studies that generated significant transfer to the novel item. But using many items (e.g., 16 same and 16 different) in a display induced a display variability that might be considered a key factor for the significant transfer to the novel stimuli. Therefore, display variability remains a major concern for the discrimination tasks consisted of same/different displays. It's difficult to free the discrimination of visual displays from the effect of display variability. Therefore, as a measure to reduce the amount of entropy (originated from display variability) future study should focus on using the technique of employing some modifications in the different display. For example, a different display containing  $\circ\triangle\circ$ ,  $\triangle\triangle\circ$  icons and another different display containing  $\blacklozenge\star\star$ ,  $\blacklozenge\blacklozenge\star$ . Such kind of different display contains low variability thus considerably decreasing the possibility of the effect of entropy.

### **1.3. S/D concept with two picture method**

To understand which aspects of the procedure led to the acquisition of the abstract concept learning, some prominent researchers (e.g., Katz et al., 2002) thought that the focus on which species do and do not have the cognitive capabilities to acquire abstract concepts should be shifted to the process and mechanisms by which concepts are learned. This shifts involved in some critical parameters (e.g., training set size) for abstract concept learning. Katz et al. 2002 anticipated that if subjects did not learn with a small number of stimuli, stimuli set would be expanded to a larger one. If the expansion of the stimulus set facilitates the subjects to learn abstract concepts, this would be a very strong evidence for the functional and critical role of the set size in abstract concept learning. Based on such anticipation, they, at first, started experiment with stimuli set of 8 items that resulted in item-specific learning.

But when training set size was gradually expanded to 128 item set, monkeys showed the full acquisition of abstract concept learning. More recently, Wright and Katz (2006) carried on experiments with monkeys and pigeons using S/D discrimination tasks. Here also, when 8 item set was used, subjects showed item specific learning. When it was gradually expanded to 64 items, partial transfer was observed. In such manner, when it was increased to 128 items for monkeys and 256 items for pigeons, the full acquisition of abstract concept learning was observed suggesting that set size expansion might facilitate the full acquisition of S/D concept learning. In this study, it was observed that the level of learning strategy by monkeys and pigeons varied by the expanded training set size. Thus training set size might be a controlling factor of learning processes. The articles summarized in this section imply that the number of training stimuli might be in action in animals as determinant of learning process to perform the discrimination tasks. Sometimes in acquiring same/different tasks, individual differences are observed in a species. Different species might have different sensitivity to relational cue. Sensitivity to relational cue might be higher in primates than pigeons.

## **Some reports on S/D concept with two picture method**

### **1.3.1. When small number of stimuli is used, similarities between training and test stimuli become a determinant of transfer effect**

**Title: Abstract-concept learning carryover effects from the initial training set in pigeons (*Columba livia*)**

**Authors: Nakamura, Wright, Katz, Bodily, and Sturz (2009)**

Previous studies (e.g., Cumming et al., 1965; Farthing & Opuda, 1974; Santi, 1978) demonstrated pigeons' acquisition of item-specific learning from the set of stimuli. By contrast, some recent studies (Wright et al., 1998) showed that pigeons could learn the discrimination tasks based on relationships following training with substantial number of training stimuli. This regime allowed Nakamura et al. (2009) to assess whether the degree of concept learning would depend on the number of training exemplars. Therefore, Nakamura et al. (2009) carried on experiments to confirm whether training pigeons with somewhat larger initial sets of stimuli might produce better transfer than that of 8-item set in the prior study. In addition to, they were interested in exploring some factors responsible for carry over effects that might be available in the small sets of stimuli (e.g., 8-item set).

With a view to meeting these purposes, two experiments were conducted. In Experiment 1, four experimentally naïve white Carneaux pigeons (*Columba livia*) were reinforced to peck to the lower picture if the two pictures were same. If different, a peck to the white rectangle was reinforced. After the successful completion of the acquisition training, transfer testing trials consisting of 90 baseline training trials plus 5 same and 5 different trials were given to subjects. Correct responses were reinforced in the test trials. Research findings revealed that the 32-item group demonstrated substantially better performances than 8-item group and 16-item group. Nakamura et al. (2009) opined that the 32-item group might have learned an abstract rule and applied it to other pairs they faced. Therefore, 32-item group showed better transfer than 8-item group. Hence, a question may arise on what factors may be accounted for lesser transfer by 8-item group. According to Nakamura et al. (2009), one of the most plausible explanation was that 8-item group might have learned the item pairs individually. Another possible candidate included domain restricted learning strategy that restricted subjects to apply the abstract relational rule to a small training set and thereby creates resistance to expanding this limited domain. It may be anticipated that progressively expanded set of stimuli may lead subjects to reach full abstract concept learning. To explore this possibility,

Experiment 2 was started. To carry on the Experiment 2, two experimentally naïve pigeons were used as subjects. The apparatus and the procedure were the same as that of Experiment 1 except an increase in the number of training set (64-item set). The research findings demonstrated that the 64-item group showed full concept learning (a learning equivalent to baseline performances with more than 80% choice accuracy) with no carry over effects. Notably, carry over effect is one kind of transfer effect. Some memories of the first trial may affect the learning of the second trial. If the memories of the first trial facilitate the subject to learn the tasks of the second trial, this is called positive carry over effect. On the other hand, if the learning of the first trial makes bar to learn the tasks of the second trial, this is called negative carry over effect. Such successful research findings made Nakamura et al. (2009) more interested in carrying on further research with larger set of training stimuli. Because an evidence of a two-item S/D task with such a large training set by animals was unknown to animal researchers before the present study. Therefore, Experiment 3 was started with a set of 1,024 items and 1,048,576 different stimulus pairs using two experimentally naïve pigeons as subjects. The apparatus and the procedure were identical to that of Experiment 2 except that the 1,024 training set was used from the beginning with group. Like Experiment 2, Experiment 3 also demonstrated the achievement of the full concept learning by pigeons.

Such an excellent research findings made the present study able to prove that the size of the initial training set might vehemently affect the level of transfer. Such stable, high accuracy transfer and baseline performances confirmed that like monkeys, pigeons also were able to learn an abstract concept learning maintaining qualitative equivalence to old and new world monkeys. According to Nakamura et al. (2009), small number of training set that might cause carry over effects in the subjects had a severe detrimental effect on later transfer. When subjects do not learn abstract concept on given item pairs, they must learn item specific learning (when animals learn the discrimination tasks based on some specific physical features of the stimuli or some combinations of the specific items). Because it is the simplest way to learn item specific information on training pairs especially in the case of small number of training stimuli. By contrast, when the number of pairs becomes too many to be learned, they may change the rule of learning strategy leading to abstract concept learning.

According to my view, if small number of stimuli is given to subjects, it is easy for them to memorize some specific physical features of stimuli. On the contrary, if large number of stimuli set is given, the memory load of subjects becomes very high. To reduce such memory load, animals may find an abstract rule to solve the tasks leading

to the attainment of abstract relational concept. However, the present study established that the achievement of the full abstract concept learning is not limited to only in monkeys species suggesting that other species even if with different neural architectures were also able to learn full abstract relational concept.

### **1.3.2. An ability to acquire the relational learning may not prevail equally in a species**

**Title: Individual differences: Either relational learning or item-specific learning in a same-different task**

**Authors: Elmore, Wright, Rivera, and Katz (2009)**

A question may remain if animals simply learn an S/D task rather than doing abstract relational concept, how do they solve the task? Various theories are available to explain this question. One of the most notable suggestions made by Carter and Werner (1978) that there were three learning processes that animals might follow as learning strategy. Firstly, they might solve an S/D task following an if-then rule for each stimulus combination. Secondly, they might learn the task on the basis of configural association. A third possibility was that if they did not follow the prior learning strategies, they might learn the relationship between stimuli but only within a limited context known as restricted-domain relational concept. Considering the three learning strategies, Elmore et al. (2009) set an aim at identifying whether learning was in fact item-specific or relational. To confirm the aim of this study, two experiments were conducted.

In Experiment 1, three experimentally naïve White Carneaux pigeons (*Columba livia*) were trained in a three-item simultaneous S/D tasks. Pigeons were reinforced to peck to the probe when the sample and the probe (lower picture) were the same. By contrast, when the pictures were different, a peck to the white rectangle was reinforced. Research findings showed that pigeons' learning tied to item-specific information as was also found in the Katz and Wright's experiment (2006). When Katz and Wright (2006) trained pigeons with 8-items, pigeons learned these tasks item-specifically. According to Elmore et al. (2009), the use of the stimuli with normal orientation might be the possible cause for the pigeons' learning the task item-specifically. To remove such possibility, a little change involving the alterations of the appearances of individual stimuli (turning the items upside down) was brought in Experiment 2 where the subjects, basic procedure and apparatus were the same as those used in Experiment 1 with an addition of stimulus inversion test. Like Experiment 1, in Experiment 2 too, pigeons learned the S/D task item-specifically except with the development of more generalized rule



suggesting that their processing was relational but restricted-domain. In Experiment 3, Elmore et al. (2009) attempted to explore how restricted or broad the domain was. In order to meet such attempt, Experiment 3 was carried on involving the same subjects, basic procedure and apparatus as those used in Experiment 1 and 2 except some differences in testing procedure. The findings of Experiment 3 supported the notion of restricted-domain relational learning strategy since the pigeons' performances were significantly better than chance. Elmore et al. (2009) thought that when animals fail to learn abstract concept, they must be using some type of item-specific strategy. If animals learn the relational task with restricted domain, such effort may later in development give way to relational factors. I opine that when a small number of stimuli is given, animals can solve the discrimination tasks by just remembering some specific physical features of the stimuli. Such rule may lead animals to solve the S/D task item-specifically. Furthermore, presentation of a small number of stimuli gives animals an opportunity to share some common features of the training stimuli with those of testing stimuli (if the training and testing stimuli share the same domain). As a result, animals may acquire restricted-domain relational learning from item pairs. However, a better design for the future studies might use the techniques of employing expanded set of stimuli (larger number of stimuli of various domains), thoughtful size, shape, and color of the stimuli that may overcome item-specific learning or restricted domain relational learning. Individual differences were also observed in my rats' study. The study of Elmore et al. (2009) facilitated me to explain this issue more scientifically.

### **1.3.3. Sensitivity to relational cue differs across species**

**Title: Mechanisms of same/different concept learning in primates and avians**

**Authors: Wright and Katz (2006)**

Animal researchers emphasized S/D concept learning for the development of abstract cognitive thinking. Because such cognitive thinking might contribute to the formation of the sense of mathematical operations. It might play an important role to facilitate animals to solve some novel tasks. Abstract concept learning that transcends any individual features of the stimuli and depends on the relationship between or among the stimuli is considered higher-order learning. We already know that humans are the most adept species in learning abstract concept and other feats of intelligence processing. Although most of the animals except some ones (monkeys, dolphins that were thought to be partially deficient relative to humans) were thought to be totally deficient in

abstract concept learning (Darwin, 1859; Romanes, 1892), recent technological and procedural advances have made us hopeful that those species who were thought to be totally deficient in learning abstract concept, actually do have this ability (Bhatt & Wright, 1992; Bovet & Vauclair, 2001). Wright and Katz (2006) carried on the present experiment to compare the learning abilities of rhesus monkeys, capuchin monkeys, and pigeons. In addition to, they were interested to explore the critical parameters that control concept learning. Subjects were reinforced to touch/peck to the lower picture if the two pictures were same. If different, then a touch/peck to the white rectangle was correct. Each session contained 100 trials (50 same and 50 different). A 15-s inter trial interval (ITI) separated the next trial. Training continued at each set size until performance was 85% correct and was followed by six consecutive 100-trial transfer test sessions. Following transfer, the training set size was doubled in different phases. Research findings showed that all the three species acquired full abstract concept learning thus showing qualitative similarity and quantitative differences.

Pigeons needed more exemplars (256 items) than rhesus and capuchin monkeys (128 items) to attain full abstract concept learning. Wright and Katz (2006) pointed out that the effect of familiarity process and stimulus generalization might somewhat contribute to acquirement of abstract concept learning by rhesus monkeys, capuchin monkeys, and pigeons. As transfer of learning to the novel stimuli was equivalent to baseline performances (training performances), it is speculated that monkeys and pigeons might have employed relational strategy to solve the S/D tasks. By dint of any effect (e.g., familiarity, stimulus generalization), above the chance level transfer performances may be expected but performances equivalent to baseline may be difficult to be expected.

In the present study, novel stimuli were mixed with some stimuli that monkeys and pigeons had already seen in the previous trial. More clearly, in the case of different trials, one stimulus was novel and another one was old so that animals could learn to respond to the novel or unknown stimuli. In this type of stimuli set, animals might try to find out a match between the novel and old stimuli. This process is called familiarity. In addition, stimulus generalization might contribute to the acquisition of abstract relational concept. Both the transfer and the training stimuli were picture ones. In such case, testing stimuli might share some common properties (e.g., color, shape, size) with those of the training stimuli. Hence, it was speculated that transfer performances may reflect generalization from training stimuli to transfer stimuli. For pigeons, Wright and Katz (2006) pointed out that pigeons needed more variations to attain the full abstract concept learning. They thought that pigeons have very different neural architectures from monkeys that might play a key factor for pigeons to need more exemplars.

In my opinion, the larger number of stimuli produces much variation that might make their memory load high. Animals may apply relational strategy to reduce such memory load. Though the present study empirically revealed the full acquirement of abstract S/D concept by rhesus monkeys, capuchin monkeys and pigeons with qualitative similarity, quantitative difference across species remained as the concern for the future researchers. The findings of Wright and Katz's study (2006) revealed a general cognitive ability across different species. We speculated that if rats were trained with the procedures of Wright and Katz's study (2006), they would also be able to acquire relational learning. The achievement of Wright and Katz's study (2006) has led me to conduct S/D experiments in rats (please look at Chapter-II for detail about this experiment).

#### **1.3.4. Conclusion about the studies of S/D concept with two picture method**

Evidences of S/D concept with two picture method (e.g., Wright and Katz, 2006) showed that when the number of stimuli were sufficiently large (e.g., 128 item for monkeys and 256 for pigeons), the acquisition of full abstract concept was possible for primates and avian species thus revealing a general cognitive learning ability across different species. These acquisition and transfer results provide promising evidences for the existence of the ability in nonhuman animals to master the S/D tasks. In addition, these findings may term the unique species-abilities approach made by Premack (1978) as misdirected with an addition that if suitable experimental conditions is given, some animals may learn what we expect. These promising evidences on S/D conceptualization also revealed that like primates, nonhuman animals (e.g., pigeons) could exhibit an ability to learn S/D concept once thought to belong exclusively to humans, and possibly, certain nonhuman primates (Premack, 1978). Despite successful findings with two picture method, stimulus generalization seemed to be a facilitating factor for attaining the full abstract concept learning thus posing remaining concern. Therefore, a better design for the future study should use the technique of employing, for example, picture stimuli in the training phase and a different domain of stimuli (e.g., object stimuli) in the testing phase that may eliminate the possibility of stimulus generalization process.

#### 1.4.

#### Oddity discrimination experiments

In an oddity experiment, an odd stimulus and two or more identical non-odd stimuli are presented simultaneously. For example, a stimuli set involves one odd stimulus “blue circle “and two identical stimuli “two red squares”. Animals are required to discriminate an odd stimulus (blue circle) from two identical stimuli (two red squares). If they can discriminate and transfer these experiences to the novel item (e.g., purple square), it is considered that they are able to learn the abstract relational property of the stimuli set. Therefore, transfer of oddity discrimination to novel item can be interpreted as evidence of abstract oddity concept. There are several ways to present an odd stimulus mentioned below:

One odd task: It (e.g., AAB) presents an oddity task in the same manner until the subjects meet the learning criterion. This task could be solved by learning to respond to a specific item.

Two oddity tasks: In these tasks (e.g., AAB and BBA), correct stimuli are exchanged between two problems thereby discounting the possibility of learning by responding to a specific item. But the subjects can solve these tasks by memorizing some configurations of specific items (e.g., AAB, ABA, BAA, BBA, BAB, and ABB).

Multiple oddity tasks: These tasks involved many items as odd items in the stimuli set. In my research, rats were trained with multiple oddity tasks consisted of many odd items (e.g., AAAB, AAAC, AAAD, AAAE, AAAF, BBBA, BBBC, BBBD, BBBE, BBBF, CCCA, CCCB, CCCD, CCCE, CCCF, DDDA, DDDB, DDDC, DDDE, DDDF, EEEA, EEEB, EEEC, EEED, EEEF, FFFA, FFFB, FFFC, FFFD, FFFE). Multiple oddity tasks could not be solved based on single feature learning or configural learning. Because these tasks produce many configurations that are difficult to memorize. Animals can solve these tasks by learning the relationship among stimuli.

Oddity concept is an issue of great interest in animal research. It has been used numerous times to gain an understanding of comparative learning abilities of animals. It has an important implication on revealing evolutionary origin of animal intelligence. Numerous efforts were made to explore oddity discrimination learning in primates and other nonhuman animals. Some studies claimed to have evidences of oddity learning across different species such as pigeons (e.g., Cook, Katz, & Cavoto, 1997; Lombardi, Fachinelli, & Delius, 1984; Wright & Delius, 2005), squirrel monkeys (e.g., Thomas & Frost, 1983), California sea lion (Hille, Dehnhardt, & Mauck, 2006). Previous rats' studies with oddity discrimination tasks followed several oddity procedures (e.g., one-odd task, two-odd tasks) that produced item-specific cues. Learning such

item-specific cues might be simpler and it might prevail in rats. As a consequent, rats might fail to attain oddity concept. Therefore, my research has been developed to defend the non conceptual solutions made by previous studies (e.g. Thomas & Noble, 1988). I introduced some learning strategies in this section. The first, second, and third articles showed an acquisition of learning set that could be solved by win-stay/lose-shift strategy. The fourth experiment showed an acquisition of oddity concept that can be attained by learning the relationship among stimuli.

### **Some reports on oddity discrimination learning by rats and pigeons**

#### **1.4.1. An evidence of single feature learning in rats**

**Title: The formation of learning sets in rats**

**Authors: Koronakos and Arnold (1957)**

Formation of learning set in primates was clearly showed by Harlow and his associates (1949). Investigations with rats (e.g., Marx, 1944) showed that some member of rats' species might have possibility to form learning set. To provide further evidences for phylogenetic comparisons of the ability to form learning sets, Koronakos and Arnold (1957) framed this present experiment. They trained 20 naïve pied rats with eight problems. 20 discrimination choices were offered rats to solve the tasks. When rats could make 16 correct responses out of 20 discrimination choices, they were shifted to the second problem. Research findings showed that five out of 20 rats could demonstrate an accelerated learning. Koronakos and Arnold (1957) believed that some of rats were able to form learning set. Rats' performances were gradually improved. There were two possible candidates. One was rats might learn these tasks by win-stay/lose-shift strategy. Another one was rats might learn these tasks based on oddity discrimination learning. But rats' performances might be explained in terms of simpler win-stay/lose-shift strategy. However, the present study bears some implications that these findings may generate further studies introducing a modified experimental design. As a part of future studies, discrimination tasks with concurrent presentation might be considered.

#### **1.4.2. An evidence of configural learning in rats**

**Title: The solution of oddity problems by the rat**

**Authors: Wodinsky and Bitterman (1953)**

Being reinforced with oddity evidences with monkeys by Kluver and Robinson (1933) Lashley (1938) tried to find out such reaction in rats. He trained rats to choose a cross (x) presented with two circles in a tasks or to choose a circle presented with two crosses (x). Rats could learn the oddity tasks based on a variety of specific combinations rather than oddity relationship among stimuli. Subsequently, Krechevsky (1932) trained rats with a series of rehearsals in a light-dark discrimination tasks and found that rats could shift its choices from light to dark and back. These evidences played a stimulus for Wodinsky and Bitterman (1953) to reexplore the possibility in rats. In the experiment, rats were, at first, trained to choose a black card (positive) from among two white cards (negative). When rats could learn the task with no incorrect response, the task was changed and shifted to white card (positive) versus two black cards (negative). The subsequent odor tasks were given in the same manner. Wodinsky and Bitterman (1953) claimed to have got successful evidences of oddity learning. They also observed gradually improved rats' performances to Problem 4 and 5. Some alternatives might be considered. Rats might employ win-stay/lose-shift strategy to solve the oddity tasks or they might relationally process the oddity tasks. But simpler win-stay/lose-shift strategy might be considered for rats' discriminative performances. A better design for future studies might use of employing multiple oddity tasks with concurrent presentation that might lead rats to acquire oddity discrimination learning.

#### **1.4.3. An evidence of oddity learning set in rats**

**Title: Visual and olfactory oddity learning in rats: What evidence is necessary to show conceptual behavior**

**Authors: Thomas and Noble (1988)**

In the perspective of the importance of oddity concept in animals, several experiments (e.g., Wodinsky & Bitterman, 1953; Koronakos & Arnold, 1957) were carried on and claimed its use by animals. But the procedures those studies followed were questionable due to having some non conceptual solutions. In addition, although previous studies claimed evidences on transfer with new oddity problem, these ones could not make clear whether these transfer evidences occurred on the first-trial of the transfer test, the most crucial point of argument, thus making those claims inconclusive.

According to Thomas and Noble (1988) learning set process might be a facilitating factor for such transfer. Thomas and Noble (1988) believed that learning might be acquired by animals on transfer test trials that was found in the study of Lombardi et al. (1984). However, in order to provide empirical evidence on transfer test trials and to avoid non conceptual solution, Thomas and Noble (1988) carried on two experiments. In Experiment 1, four female hooded rats were trained with 20 oddity tasks in a testing apparatus using visual exemplars of oddity concept.

In Experiment 2, three male hooded rats were trained in the same apparatus as that of Experiment 1 with a little modification that olfactory exemplars were used. Rats were given 300 different combinations sequentially in which choosing an odd item from among two identical stimuli led to the solution of the discrimination tasks. Rats showed chance level performance on the first test trial that could be attained by just win-stay/lose-shift strategy. Rats' performances improved on 2-5<sup>th</sup> trial. Hence, a question may arise why rats failed to acquire oddity concept learning. Thomas and Noble (1988) thought that rats might have followed a kind of rule called win-stay/lose-shift in which the subject stays with a stimulus if it was reinforced (win) and he might shift to another stimulus if the former stimulus was not reinforced. Because rats showed chance level performances on the first test-trial of each task. If rats learned a relationship among stimuli, they are supposed to apply this relational strategy in the first trial of transfer test by associating with relative property of oddity rather than associating reinforcement with specific properties (color, shape, size) of object stimuli.

By contrast, I opine that Thomas and Noble (1988) changed the stimulus pairs regardless of the rats' performance. Therefore, rats could not learn to relationally process the discrimination tasks. Another possibility is the sequential training of tasks. They presented a single task at a time. When rats learned this task (e.g., AAB), the task was changed and shifted to the next task (e.g., CCD). In such manner, EEF, GGH and so on were given to rats. A single task could be solved simply by approaching a specific item. Take, for instances, task AAB could be solved by responding to item B. The same strategy was effective for the next task, CCD, where responding to item D led to the solution. In a sequential training procedure, learning by trial-and-error and responding to a specific item can be simple and effective learning strategy. Abstract relational learning seems unnecessary. Therefore, Thomas and Noble (1988) failed to demonstrate oddity discrimination learning in rats. Single feature learning poses as a concern in their studies. Concurrent training of multiple oddity tasks that I followed in Experiment 2 might be an alternative to eliminate such concern. Thomas and Noble's study (1988) bears much implication to unveil the phylogenetic origin of rats' species by generating

further studies in future. These studies have made me think that if stimulus-specific cues are removed from the stimuli set, rats may acquire oddity discrimination learning.

#### **1.4.4. A positive evidence of oddity tasks on the transfer test-trial**

**Title: Oddity of visual patterns conceptualized by pigeons**

**Authors: Lombardi, Fachinelli, and Delius (1984)**

In spite of having a developed version of MTS (Cumming & Berryman, 1961) for pigeons, research history contained some conflicting evidences (e.g., Carter & Werner 1978; Zentall & Hogan, 1978) whether pigeons had ability to learn abstract relational concept. Therefore, Lombardi et al. (1984) carried on the present study to clarify such conflicting situation. They anticipated that pigeons might be capable of using a generalized identity/oddity rule (Hollard & Delius, 1982) because in order to survive and reproduce, pigeons needed to make a multitude of decisions about the equivalence or non equivalence of a variety of percepts.

However, to successfully conduct the experiment, ten adult homing pigeons (*Columba livia*) were trained with a three-key skinner box dividing them in to two groups. One group, the “few examples group” was trained with five patterns. Another group, the “many examples group” was trained with 20 patterns. At the beginning of the experiment, pigeons were auto shaped to peck the illuminated middle key with food access as reward. The main training began with a pattern, the sample stimulus, being projected on the middle key. A peck at the middle key created two comparison stimuli one of which matched the sample one and another one had a different pattern. When pigeons responded to the odd pattern, they were reinforced. Whereas, when they responded to the identical pattern, they were punished with 3-s time out and the house light extinguished. In a session, 40 trials were conducted. The position of odd pattern was determined by Fellows series (1967). After the successful acquisition training, two series of transfer sessions containing novel patterns were conducted.

Research findings showed that pigeons of many examples group demonstrated concept-like rule to learn the oddity discrimination tasks. In particular, many examples group showed better transfer than few examples groups suggesting that larger number of stimuli might facilitate the acquisition abstract relational concept. These evidences made Lombardi et al. (1984) possible to provide the reliable and best evidences that a non primate animal could acquire oddity learning based on relationship among stimuli. According to Lombardi et al. (1984), familiarity with specific stimuli during training might facilitate pigeons to solve the oddity discrimination tasks correctly. Another



possible candidate was that configuration discrimination or sample-specific rules might have supplemented to the attainment of pigeons' abstract concept. In my opinion, a sample stimulus is shown twice. Twice presentation of the sample stimulus may enhance the differentness of the non comparison stimuli that may facilitate the pigeons to identify the odd stimulus. To overcome such concern, second-order relationships might be considered. In this procedure, at first, a pair of sample stimuli (e.g., AA) is presented. Then two pair of novel comparison stimuli (e.g., CC vs. DF) are shown. Subjects are reinforced for responding to a pair of stimuli that shows the different relationship. The experimental model of this study played a boost for me to conduct Experiment 2 with many exemplars.

#### **1.4.5. Conclusion about the studies of oddity discrimination experiment**

Previous oddity studies showed that small number of training stimuli might produce item-specific learning. Larger number of stimuli (if serially presented) might produce learning set. But with the use of larger number of stimuli (if concurrently presented), some animals might learn oddity concept learning. Because in concurrent presentation, positive stimuli are exchanged with negative ones among tasks. This manipulation makes no stimulus-specific cue. I analyzed Thomas and Noble's study (1988) and introduced concurrent training that showed the positive transfer to the novel stimuli in the present study.

### **1.5. Why is concept learning in rats important?**

In the past 30 years, much research on S/D concept learning using monkeys, e.g., baboons (Wasserman et al., 2001), rhesus (Katz et al., 2002), and capuchins (Wright, Rivera, Katz, & Bachevalier, 2003), and birds, e.g., parrots (Pepperberg, 1987) and pigeons (Katz & Wright, 2006) has been conducted, demonstrating clear evidence of immediate transfer of the conceptual S/D relationship to novel stimuli. In oddity discrimination learning, pigeons (e.g., Cook et al., 1997; Lombardi et al., 1984) and squirrel monkeys' study (e.g., Thomas & Frost, 1983) have offered evidences that primates and other nonhuman animals might have capacity for acquiring this learning.

More recently, positive evidences of oddity discrimination learning were observed across different species e.g., California sea lion (Hille, Dehnhardt, & Mauck, 2006), pigeons (Wright and Delius, 2005). Conversely, a few researches (e.g., Wodinsky & Bitterman, 1953; Koronakos & Arnold, 1957; Thomas & Noble, 1988) have been conducted on oddity discrimination learning in rats but failed to provide clear evidence of learning abstract relational concepts. Therefore, there was no clear evidence of relational concepts in rats. Monkeys and birds' cognitive ability might evolve independently or concept learning ability might evolve in common ancestors of monkeys and birds species. So, these animals might inherit the ability. To compare these two possibilities, examination of concept learning ability in non primate mammals such as rats is important. If I find much similarity in concept learning in rats with monkeys and pigeons, it would support the latter possibility of common origin of concept learning.

## 1.6.

### Objectives of the present study

Because of the important implications of the observations of the present study for our understanding of rodents' cognition and intelligence, the experiments reported in this study set the following purposes:

- (1) To examine S/D discrimination learning in rats.
- (2) To examine whether rats can learn multiple oddity tasks concurrently. Concurrent learning might lead to relational learning rather than stimulus-specific learning.
- (3) To examine transfer of oddity discrimination to novel stimuli (intra-modal transfer)
- (4) To examine transfer of oddity discrimination to novel stimuli of different modalities (cross-modal transfer).

To meet these purposes, several experiments were administered with concurrent training of multiple tasks where no specific item could be an effective discriminative cue. My first effort was made to examine conditional discrimination learning of two-object-pairs by rats. Two Long Evans rats were trained in a successive same/different discrimination tasks. Responses to the same/different pair of stimuli were differentially reinforced. The successful findings of Wright and Katz's study (2006) motivated me to conduct Experiment 1. Notably, Wright and Katz (2006) trained monkeys and pigeons with S/D discrimination learning tasks and showed an acquisition of relational concept. As a part of concurrent procedures, firstly, AAAB task was given to rats. After rats had successfully learned this task, they were trained with two oddity tasks (e.g., AAAB, BBBA). Then the tasks were gradually increased to 12 oddity tasks consisted of item A, B, C, and D (AAAB, AAAC, AAAD, BBBA, BBBC, BBBB, CCCA, CCCB, CCCD, DDDA, DDDDB, and DDDC) and 30 oddity tasks consisted of item A, B, C, D, E, and F (AAAB, AAAC, AAAD, AAAE, AAAF, BBBA, BBBC, BBBB, BBBE, BBBF, CCCA, CCCB, CCCD, CCCE, CCCF, DDDA, DDDDB, DDDC, DDDE, DDDF, EEEA, EEEB, EEEC, EEED, EEEF, FFFA, FFFB, FFFC, FFFD, and FFFE). Finally, test trials (e.g., EEEF, FFFE and GGGH, HHHG) were inserted to the training to examine transfer of learning to the novel stimuli. I anticipated that concurrent training of multiple oddity tasks in which a specific stimulus was used as positive odd stimulus in a set and negative non-odd one in another set might facilitate rats to acquire oddity discrimination learning as it contained no item-specific cue. If rats can acquire oddity discrimination learning in object stimuli, they are expected to apply this ability over other novel stimuli (e.g., odor, sound). In other words, I wanted to confirm whether rats' ability of relational processing is limited only to object stimuli or is applicable to novel stimuli of other modalities. This cross-modal test was expected to reveal whether

their oddity discrimination learning was restricted-domain or domain free. Rats were required to have higher order of cognitive ability to perform discrimination tasks. In this reason I planned to provide rats more training and transfer tests involving novel stimuli of other modalities (e.g., odor, sound). Please see in detail in Experiments 3 and 4.

### Experimental reports of the present study Conditional discrimination learning of two-object-pairs by rats

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#### 2.1. Experiment 1

In recent years, the importance of understanding animal conceptual behavior has gradually become one of central topics of the comparative study of intelligence (Cook, 2001). Abstract concepts are at the root of higher order cognitive processing (e.g., language and mathematics). The S/D concept discriminates an abstract relationship, regardless of the specific physical features of the stimuli.

To learn the S/D concept, subjects need to recognize not only several specific features of the stimuli (color, shape, size, etc.) but also the abstract relationship between the stimuli (sameness or difference). If animals learn only specific features in S/D discrimination tasks, their learning will never transfer to novel pairs because the novel pairs of stimuli might not share common specific features with the training pairs. However, if they learn the abstract S/D relationship among stimuli, they will be able to apply it to novel pairs. Therefore transfer of S/D discrimination to novel stimuli can be interpreted as evidence of the abstract S/D concept.

Although early research on S/D concept (e.g., Zentall & Hogan, 1974) claimed some reliable evidences of abstract concepts with nonhuman animals (e.g., pigeons) these ones were questionable due to having some non conceptual solutions (Premack, 1978). Subsequently, handsome number of researches using monkeys, e.g., baboons (Wasserman et al., 2001), rhesus (Katz et al., 2002), and capuchins (Wright et al., 2003), and birds, e.g., parrots (Pepperberg, 1987) and pigeons (Katz & Wright, 2006) showed significant evidence of S/D concept learning. In the case of rats' investigation, little research (e.g., Wodinsky & Bitterman, 1953; Koronakos & Arnold, 1957) has been conducted on abstract concept learning by rodents and it failed to provide clear evidence of learning abstract relational concepts. Thus it is still unclear whether rats have the cognitive ability to acquire the abstract S/D concept. The most notable effort was made by Thomas and Noble (1988) who trained rats with 20 or 300 different combinations serially (e.g., AAB, CCD, EEF) but no improvement of performance was observed (please see in detail in the summary of Thomas & Noble, 1988). In a serial training procedure, a specific item can be a simple and discriminative cue and abstract relational learning seems unnecessary. In the present study, we trained rats in a conditional place discrimination task where the S/D relationship between two item objects could be

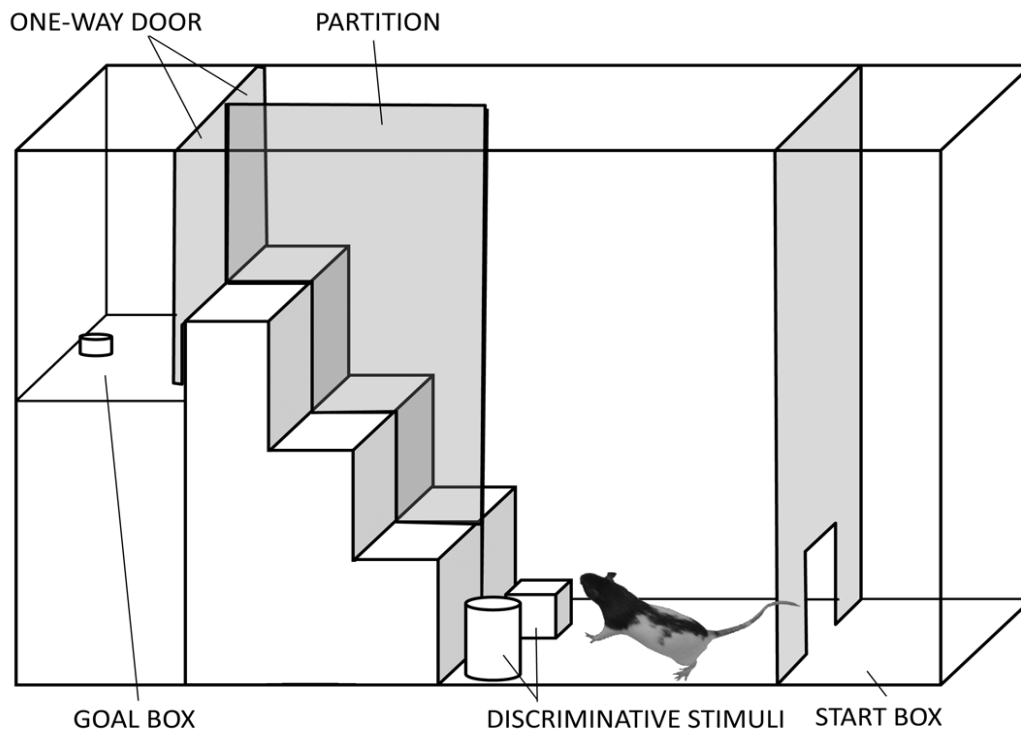
discriminative cues. We first presented the rats with the concurrent discrimination task of AA/BB vs. AB/BA. Because these tasks were given to rats concurrently in a daily session, the existence of a specific single item cue, that is, A or B, could not be an effective discriminative cue. We expected that concurrent training of multiple tasks would facilitate learning of abstract S/D relationships between items. If rats could learn the abstract S/D relationship between two items, transfer of learning to novel pairs would be expected.

## 2.1.1. Method

### 2.1.1.1. Subjects and apparatus

Two experimentally naive Long Evans hooded rats, about 240 days old, were used. They were individually housed with 12 hr light-dark cycles (light phase 9:00-21:00). Experiments took place during the light phase. They were fed 14 g of food daily except for experimental rewards. Access to water was unrestricted except during experimental sessions.

A discrimination box was used. The apparatus, 112 cm long, 61 cm high and 23.2 cm wide, consisted of a start box, a runway, two separate stairs, and a goal box (Figure 2). The main parts of the apparatus were made of wood and painted at gray.



**Figure 2.** Apparatus used in Experiment 1.

Both the start box and the goal box were 18 cm long and 23.2 cm wide. The runway was 35 cm long and 23.2 cm wide. Rats entered the runway from the start box through an opening (10 cm high and 10 cm wide) in the wall between the start box and runway. Stimulus objects were set in front of the bottom step of the stairs. The stairs consisted of three 15 cm high and 10 cm long steps. Rats could enter the goal box by pushing one-way doors at the top of each stairway. At the end of the goal box, a food cup, 1.5 cm in diameter and 0.5 cm in depth, was placed and 20 mg of food pellets was used as a reward.

### 2.1.1.2. Discriminative Stimuli

Discriminative stimuli were selected from clothespins, transparent bottles, magnifying glasses, silver objects, and brown bottles (Figure 3). For Rat 1, stimulus A was a clothespin, stimulus B was a transparent bottle, and stimulus C was a magnifying glass. For Rat 2, stimulus A was a brown bottle and stimulus B was a silver object.



**Figure 3.** A photograph of item objects

### 2.1.1.3. Procedure

During the first 10 days, each rat received daily handling for 7 min. On Days 11-17, each rat was given 10 min individual exploration of the apparatus from which the stairs were completely removed. Ten food pellets were scattered over the apparatus and the food cup. Rats were allowed to eat these food pellets during exploration. Shaping of running response was started on Day 18 and continued for 30 days. Rats were brought into the experimental room by their home cage. At the beginning of shaping, there were no stairs in the apparatus. Rats were put into the start box and allowed to go to the goal box directly and to remain there until they consumed two food pellets from the food cup. Then a low barrier was introduced and rats were trained to go to the goal box by climbing over the barrier. The barrier was made higher until it reached its full size of three stepped stairs. Each stairway was used for the same number of trials by a forced-choice procedure with 24 trials given daily. When rats could climb the stairs reliably, discriminative stimuli were introduced from Day 49 and S/D discrimination training began. The first S/D task was AA/BB vs. AB/BA (Phase 1). The first character of a pair (e.g., AB) represents the left stimulus object (A) and the second character represents the right one (B).

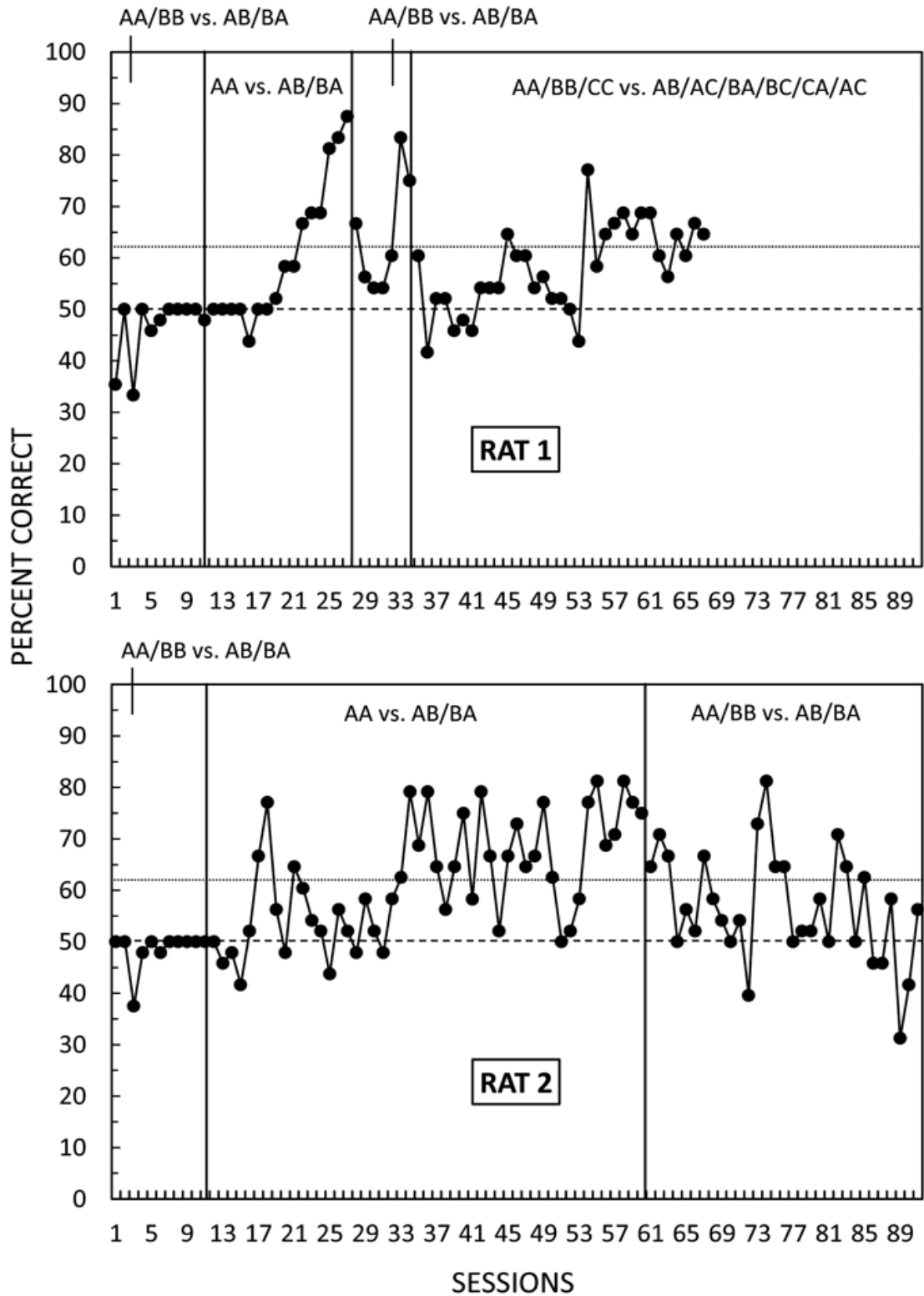
When the two objects were identical (e.g., AA), responding to the left stairway was reinforced by opening the goal door and allowing the rat to consume two food pellets. When the two objects were different (e.g., AB), responding to the right stairway was reinforced. In the case of an incorrect response, the goal door was locked and the rat was removed immediately from the stairs to the home cage without reward. Order of presentation of same and different trials was determined by the Fellows series (Fellows, 1967). Presentation order within the same (AA and BB) or different set (AB and BA) was determined randomly per two trials. Rats were trained in a daily session of 48 trials in total, i.e., 24 same and 24 different trials. A 1 min inter-trial interval (ITI) separated each trial. The learning criterion was 75% correct on two consecutive days of sessions. Due to considerations mentioned in the Results section, pair BB was withdrawn in Phase 2 and the task became AA vs. AB/BA. In Phase 3, pair BB was reintroduced and the task became AA/BB vs. AB/BA again. In Phase 4, stimulus C was added and AA/BB/CC vs. AB/BA/AC/BC/CA/CB training was given. Thus, AA, BB, and CC were presented on eight trials and AB, BA, AC, BC, CA, and CB were presented four times daily.



### 2.1.2. Results

Figure 4 shows the rats' performance in the experimental sessions, where 62.5% correct (30/48) represents a statistically significant performance in a session ( $p < .05$ , binomial test, one-tailed). In Phase 1 (AA/BB vs. AB/BA), the rats' performance was at around chance for 11 sessions and there was no sign of improvement. Therefore, to make the task easier, pair BB was withdrawn in Phase 2 (AA vs. AB/BA). Then their performance improved gradually and reached learning criterion after 16 sessions for Rat 1 and 47 sessions for Rat 2 (Because of experimenter error, Rat 2 was shifted to Phase 3 after attaining three consecutive 75% correct sessions). When pair BB was reintroduced in Phase 3 (AA/BB vs. AB/BA), although the rats' performance was at above the significant level during first session for Rat 1 and three sessions for Rat 2, it subsequently deteriorated to chance. Table 1 shows the rats' performance on the first five sessions of Phase 3 for the previously trained pairs AA, AB, BA, and newly introduced pair BB. Detailed analysis revealed that the initial significant performances were due to enduring correct responses to pairs AA, AB, BA that had been trained continuously from Phase 2, whereas poor performance below the chance level was shown for the newly introduced pair BB. As performance on trial BB increased to the chance level, trials of AA, AB, BA conversely deteriorated to chance ( $r = -.91$  and  $-.46$  for Rat 1 and Rat 2, respectively). Although Rat 2 could not learn the Phase 3 task within 32 sessions, Rat 1 recovered its performance quickly and attained the learning criterion within seven sessions.

Acquisition performances of Rat 1 and Rat 2



**Figure 4.** Percentage of correct responses in each training phase. Broken lines represent a chance level (50%) and dotted lines represent a statistically significant performance level (62.5% correct,  $p < .05$ ) in a session.

When object C was added in Phase 4 (AA/BB/CC vs. AB/BA/AC/BC/CA/CB), however, Rat 1's performance deteriorated to chance. Although Rat 1 sometimes performed significantly better than chance, its performance was not stable and did not meet the learning criterion.

Table 1. Percentage of correct responses on first five sessions of Phase 3 for previously trained pairs (AA, AB, and BA) and newly introduced pair (BB).

PHASE 3		TOTAL	AA, AB, BA	BB
SESSION 1	RAT 1	66.67	83.33	16.67
	RAT 2	64.58	77.78	25.00
SESSION 2	RAT 1	56.25	69.44	16.67
	RAT 2	70.83	83.33	33.33
SESSION 3	RAT 1	54.17	55.56	50.00
	RAT 2	66.66	83.33	16.67
SESSION 4	RAT 1	54.17	55.56	50.00
	RAT 2	50.00	52.78	41.67
SESSION 5	RAT 1	60.42	72.22	25.00
	RAT 2	56.25	75.00	0.00

### 2.1.3. Discussion

For the initial training set (AA/BB vs. AB/BA), the performance of both rats was at around the chance level and did not improve. Because the task of the first phase seemed to be too difficult for the rats, pair BB was withdrawn in Phase 2 to make the task easier (AA vs. AB/BA). As a result, both rats attained the learning criterion of Phase 2. Although Rat 2 could not learn the next task in Phase 3, where pair BB was introduced again (AA/BB vs. AB/BA), Rat 1 learned this task reliably and attained the learning criterion. Attainment of the easier task in Phase 2 might contribute to learning the more difficult task in Phase 3. There are three possible processes in learning the tasks in this present experiment. The first possibility is abstract relationship learning, where abstract S/D relationships between two object stimuli are represented and used as discriminative cues. However, the results of Phase 4 do not support this possibility. When novel item C was added to the task in Phase 4, the performance of Rat 1 declined to chance level. If Rat 1 had learned to respond to the abstract S/D relationship of the pairs, this learning should have transferred to the task in Phase 4, where novel item C was added

(AA/BB/CC vs. AB/BA/AC/BC/CA/CB). Therefore, this suggests that Rat 1 was not able to respond to the Phase 3 task (AA/BB vs. AB/BA) on a conceptual basis.

The second possibility is to learn a specific single bit of information so that the absence or presence of a single item can be used as an effective discriminative cue. For example, the presence or absence of item B could be an effective discriminative cue in Phase 2 (AA vs. AB/BA). Rats could respond to pairs that did not contain item B as “same” and pairs that contained item B as “different”. However, this learning strategy was not effective in Phase 3, where not only different pairs (AB/BA) but also the same pairs (AA/BB) contained items A and B.

Therefore, the acquisition of the task in Phase 3 by Rat 1 cannot be interpreted in terms of single specific information learning. The third possibility is that rats might learn the configuration of two-object stimuli as discriminative cues. It has been reported that pigeons learned configurations of two photographs out of eight photographs as unique item-specific discriminative cues (e.g., Katz & Wright, 2006). This may be true for Rat 1’s performance in Phase 3, where it could solve the task by remembering four different configurations (AA, BB, AB, and BA) and learning to differentially respond to these configurations. That is, Rat 1 might follow if-then rules to learn the Phase 3 task, “if the presented pair was AA or BB, respond to left stairs, and if the pair was AB or BA, respond to the right stairs”. Because these if-then rules could not be applied to novel configuration, Rat 1’s performance deteriorated to chance when the task was changed from Phase 3 to Phase 4. In Phase 2 (AA vs. AB/BA), both rats learned to respond correctly to the pairs of objects. But they seemed to learn this task on the basis of single item-specific information. This interpretation is supported by the results of the shift from Phase 2 to Phase 3. Analysis of initial significant performances on Phase 3 revealed both rats had a tendency to respond to BB below the chance level (responded as “different”), whereas they responded correctly to AA, AB, and BA. This is exactly what the if-then rule, based on existence of item B, predicts. As performance on trials of BB increased to chance, that on trials of AA, AB, and BA deteriorated to chance. Rats might have abandoned the if-then rule based on the existence of B because responding based on the if-then rule always received non-reinforcement on the BB trial. Abandonment of the if-then rule explains the reason for the negative correlation of performance between BB and AA/AB/BA on initial trials of Phase 3.

Both rats' performance completely deteriorated to the chance level after pair BB was introduced in Phase 3 (AA/BB vs. AB/BA). If the rats had learned the Phase 2 task (AA vs. AB/BA) on the basis of an abstract S/D relationship, they should have been able to transfer this learning to the next phase (AA/BB vs. AB/BA). This result also discounts

the possibility of configural learning. If they had accomplished the Phase 2 task by learning three unique configurations (AA vs. AB/BA), they should have responded to the pair BB randomly, at around chance, but not at below chance. Thus the initial tendency to respond to pair BB below the chance level is also inconsistent with the configural learning explanation. Therefore, the result contingent with the shift from Phase 2 to Phase 3 seems to be in favor of the single item-specific learning explanation. We might ask why Rat 1 learned the single item feature in Phase 2 and the configuration of two objects in Phase 3.

Given that learning a single item feature requires learning about just that single feature, whereas configural learning requires encoding multiple items and remembering multiple configurations, single feature learning seems to require simpler information processing and less memory load for learning than configural learning. Also we may explain the relative ease of configural learning versus abstract S/D concept learning for rats in terms of the demands of abstract encoding. That is, configural learning requires encoding of concrete item-specific information, whereas abstract S/D concept learning requires encoding abstract relational information between items. Considering the abundant evidence of concrete or absolute feature learning and the limited evidence of abstract or relative feature learning in rats (e.g., Thomas & Noble, 1988), configural learning that requires only processing of concrete features of stimuli seems to be next strategy for learning. Hence, when there is no effective single item feature cue in a task, rats may adopt configural learning. However, the memory load required for configural learning will increase as a function of the number of configurations to be learned. Conversely, if rats can learn the abstract S/D relationship between items, they can reduce this increased memory load because the abstract S/D rules can be applied for all pairs of items appropriately. Rats may select a learning strategy based on such a hierarchy of learning processes to learn two-item S/D discrimination tasks. There is experimental evidence to support this hierarchical strategy hypothesis. First, Thomas and Noble (1988) trained rats with oddity discrimination tasks, where a single task (e.g., AAB) was used per session and the task was then shifted to next single one (e.g., CCD), and they failed to prove the abstract relational oddity concept. Therefore, approaching a single positive stimulus was an effective learning strategy.

Then, Elmore et al. (2009) trained pigeons on a two-item S/D discrimination task and suggested that one of the three pigeons learned item-specific configural cues given that the pigeons learned the acquisition task, where no single item-specific cue was available, but showed chance level performance to novel stimulus pairs on test trials. This finding suggests that animals can learn two-item conditional discrimination, not based on

abstract S/D relationships between the items, but by responding to an item-specific configuration as discriminative cues. Even when a single item-specific cue is not available, animals seem to learn item-specific configurations if there are a small number of stimuli. When a small number of stimuli are used for training, it may not be difficult for non-primate animals to learn and retain specific configurations in long-term memory. In other words, when a stimulus set consists of a small training set, non-primate animals seem to learn item-specific information, even if they have the ability to learn abstract S/D relationships.

However, when there are a large number of stimuli and, therefore, stimulus pairs, animals seem to search for abstract S/D relationships that can be applied to all stimulus pairs. There is clear evidence to support that the degree of transfer to novel stimulus pairs is correlated with the number of stimuli used in training. Wright and Katz (2006) showed that a smaller set of training stimuli led to item-specific rote learning and a larger set of exemplars prompted abstract S/D concept learning. They demonstrated that rhesus monkeys, capuchin monkeys, and pigeons showed chance transfer performance of S/D discrimination of two colored pictures following acquisition training with eight stimuli. When the training set size was increased to 32 stimuli, monkeys showed evidence of partial S/D concept learning but pigeons showed no sign of transfer to the novel stimuli. With the further expansion of the training set size to 128 stimuli, monkeys showed good performance with novel test stimuli, comparable to their performance on the training stimuli, and pigeons showed partial S/D concept learning. Pigeons needed 256 stimuli to fully acquire the abstract S/D concept. These findings suggest that if rats have an ability to learn abstract S/D relationships between stimuli and if we can train them with a large number of stimuli, they may show evidence of transfer to novel pairs of stimuli. It has been shown that increasing response cost leads to good performance in some discrimination tasks by making rats' response criterion stricter (e.g., Brown & Huggins, 1993; Brown & Lesniak-Karpiak, 1993; Fortin, Wright, & Eichenbaum, 2004). That is, when some effort is required for discriminative responses, rats seem to give their attention to discriminative stimuli and choose their response more carefully.

In the present study, we also imposed response cost on discriminative responses by requiring rats to climb over stairways to enter the goal box. Although increased response cost might contribute to discriminative performance in the present study, such an effect could not be evaluated appropriately because there is no adequate control condition where a particular response cost was not imposed. To improve basic performance of discrimination learning of object pairs in rats, factors that affect

response criterion or attention to the discriminative stimuli should be examined further in terms of apparatus and training procedure. We must improve our protocol for testing the ability of rats to learn the abstract S/D relationship by eliminating access to single item cues, by increasing the stimulus set size to facilitate encoding of the abstract S/D relationship, and by increasing the number of items presented at one time so as to make the quantitative S/D relationship more salient. Knowledge about the presence or absence of cognitive ability for S/D concept learning in rats would contribute to elucidating the phylogenetic origins (regarding the evolution of animal intelligence) of information processing of abstract relationships among stimuli.

### Oddity Discrimination Learning of Object Stimuli in Rats

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#### 3.1. Experiment 2

Experiment 2 used the concurrent training of multiple oddity tasks instead of conditional place discrimination tasks used in Experiment 1. In this experiment, an oddity task consisted of one odd and three non-odd identical stimuli. Animals get an opportunity to check both identical and odd stimuli at a time. As a result, such presentation of stimuli may facilitate them to compare two kinds of stimuli (one odd and three non-odd identical stimuli). This comparison may enhance their ability to understand the relationships among stimuli. These advantages were not available to the discrimination tasks used in Experiment 1. Object stimuli were selected in this experiment as it bore more importance rather than picture one for rats. It is worth recalling that rats have visual limitation. It can see well at 1 m as humans do at 10 m (e.g., Minini & Jeffery, 2006; Douglas, Neve, Quittenbaum, Alam, & Prusky, 2006). Therefore, it can see object stimuli better than picture ones. Because object stimuli containing different features (e.g., shape, size, metal) offers a special advantage for rats to gather various information about the stimuli as rats can touch or play with these ones.

Four naive Long Evans hooded rats were trained and tested for the acquisition of oddity discrimination concept learning. Long Evans hooded rats are the standard laboratory species and human model for much of the cognitive neuroscience research. They are now being widely used in the field of higher order of cognitive thinking as they are considered to have sharp intellectual abilities. As compared to the previous studies with rats (e.g., Wodinsky & Bitterman, 1953; Thomas & Noble, 1988), the present study used four objects (e.g., AAAB) instead of three object stimuli (e.g., AAB). It is proposed that using more number of identical stimuli in a set might make an odd stimulus more salient (Cook et al., 1997). This saliency may contribute to making the tasks easier for the subjects to learn the discriminative tasks. Cook et al. (1997) observed such findings in pigeons' study. Cook et al. (1997) reinforced five pigeons for discriminating odd-item different display (e.g., five same vs. one odd stimuli) from same display (e.g., all stimuli were identical). With these procedures, Cook et al. (1997) were able to demonstrate the promising evidence of the significant transfer of learning to the novel odd stimuli. Same may be applicable to the rats used in the present study. Based on such speculation, we have planned to use many items. In addition, four objects were used to reduce the chance level. If we use three objects, the chance level is 33.33% that could be reduced to 25% by using four objects. With higher chance level involving



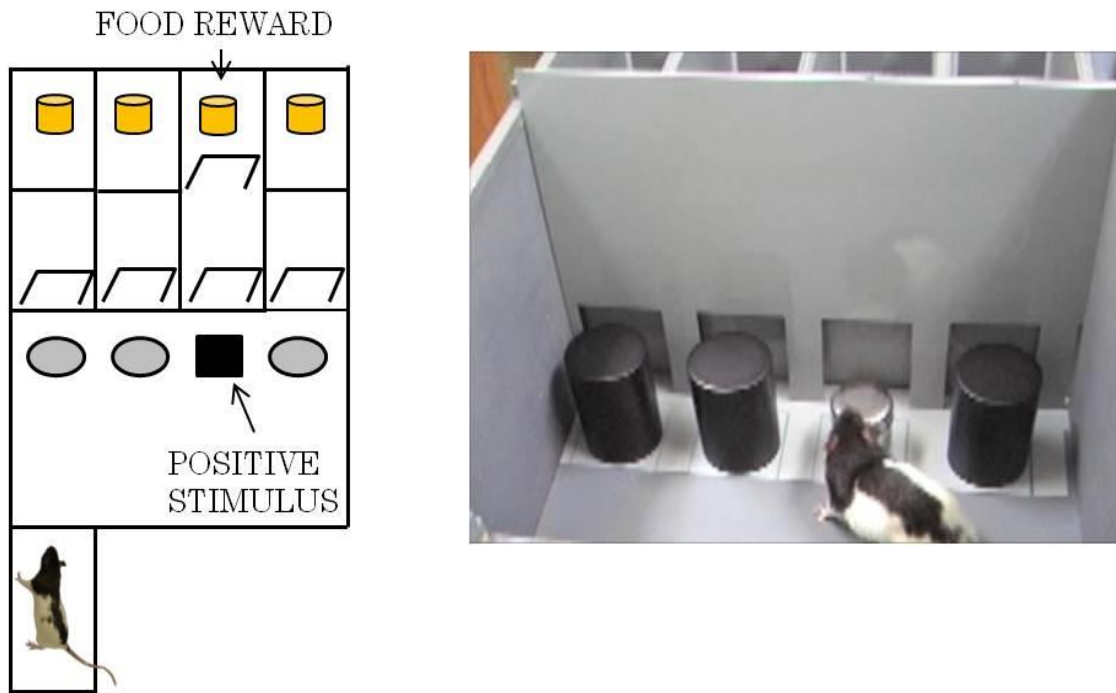
difficult tasks, rats frequently abandon learning the tasks and respond randomly because they have possibility to get reward frequently. There is no formal scientific report on this phenomenon but our laboratory has preliminary results (Okajima, 2010, unpublished data). This was possible by setting an odd stimulus only in either of central two positions (ABAA, AABA). In this condition, we could observe single oddity task. So, I decided to reduce the chance. I used increasing number of training stimuli (e.g., 12 oddity tasks, 30 oddity tasks) in the present study. One purpose was to examine the role of larger number of oddity tasks in relation to the acquisition of oddity discrimination learning. These considerable modifications might in turn be indicative of how these tasks were learned and the degree of oddity discrimination learning. Some recent studies (e.g., Wright & Katz, 2006) demonstrated that monkeys and pigeons could successfully learn abstract concept when training set size was expanded (128 items for monkeys and 256 items for pigeons). Lombardi et al. (1984) trained pigeons with multiple oddity tasks comprising 5 or 20 different stimulus and observed reliable transfer to the novel oddity stimuli.

### **3.1.1. Method**

#### **3.1.1.1. Subjects, apparatus, and stimuli**

Four Long Evans hooded rats of 60 days old were used. They were individually housed with 12 hr light-dark cycles (light phase 9:00-21:00). Experiment took place during the light phase. They were fed 16 gram of food daily except for experimental rewards. Access to water was unrestricted except during experimental sessions.

A wooden made discrimination box was used (Figure 5). The apparatus had several parts such as one start box, one run way, and four goal boxes with four doors. Rats could enter in the goal boxes by just pushing these doors. Four object stimuli were set in front of the door of the goal boxes. At the end of the goal boxes, four food cups were placed and three rice puffs were used as reward. Eight different objects were used as stimuli.



**Figure 5.** Apparatus used in Experiment 2.

### **3.1.1.2. Procedure**

#### **3.1.1.2.1. Preliminary training**

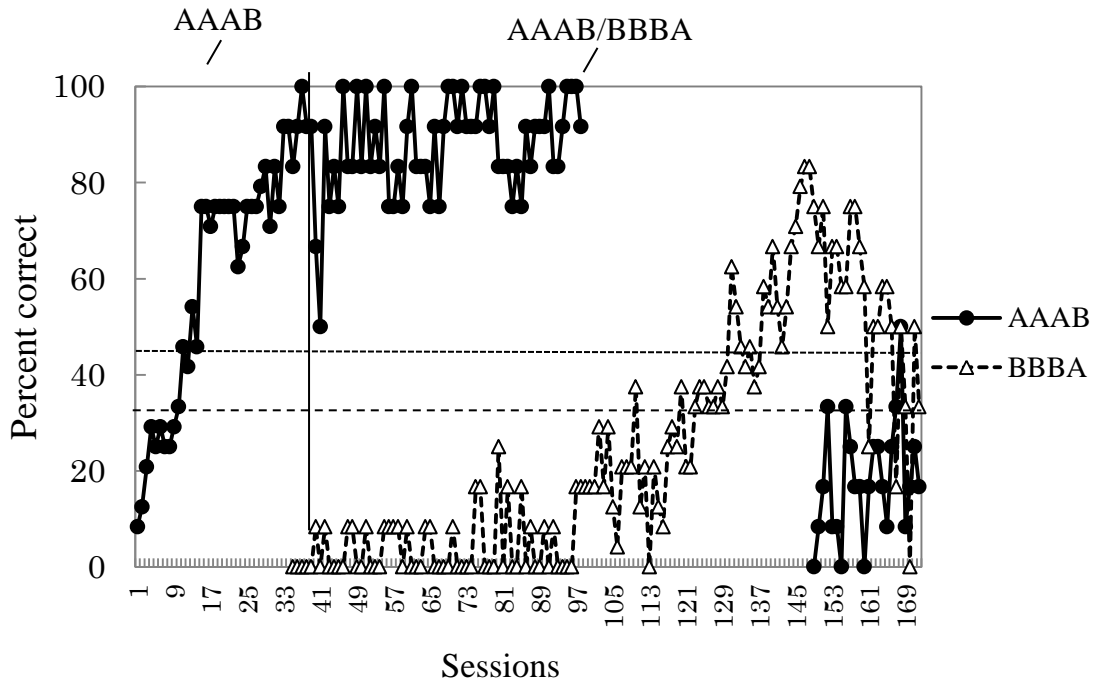
During the first three days, each rat received daily handling for 5 minutes. On days 4-6, each rat was given 20 minutes' individual exploration of the apparatus. Three rice puff were scattered in the goal boxes, three in the start box, and six in the run way. Rats were allowed to eat these food pellets during exploration. When rats felt no hesitation to enter in the goal boxes, exploration was finished. In forced choice training procedure, one door was kept open and the remaining three doors were kept closed. It was started on Day 7 and continued for 7 days. Correct goal door leading to reward was determined randomly. Force choice training was first started with 4 trials for each rat in a session and continued for two days. When rats felt no hesitation to enter in the goal box, 8 trials were conducted for each rat in a session. In such manner, number of trials was increased to 12, 16, 20, and finally 24 depending on the improvement of their performances. When the number of trials stood at 24, all the doors remained fully closed. Rats could enter in the goal boxes by just pushing these doors. When rats could perform reliably, discriminative stimuli were introduced from Day 14.

### 3.1.1.2.2. Acquisition training and transfer testing

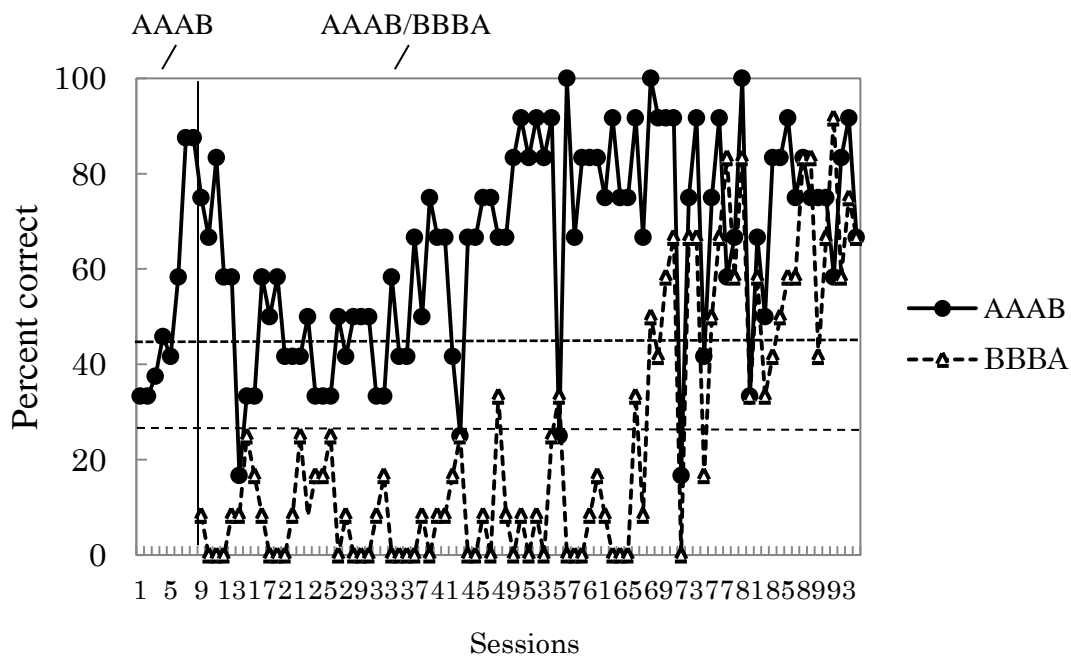
In Phase 1, AAAB task involving three same non-odd stimuli (AAA) and an odd stimulus (B) was presented. Responding to odd stimuli was reinforced with three rice puffs. In the case of incorrect response, rats were kept in the goal box for 10 seconds and removed to their home cage with no food. The position of an odd stimulus was counterbalanced. Rats were trained in a daily session of 24 trials in total. A 1 minute inter-trial interval (ITI) separated each trial. The learning criteria was 20/24 (more than 80%) correct responses on two consecutive sessions that allowed rats to be promoted to the Phase 2 in which the tasks of AAAB and BBBA were given to the rats concurrently. 12 trials for each task were conducted daily. Due to rats' dissatisfactory performances, block trial training (e.g., 12 trial block, 6 trial block, 3 trial block, 2 trial block) was introduced in which, for example, in 12 trial block, the first 12 trials involved AAAB task and the remaining 12 trials did BBBA task. In two days, when rats could make 16 correct responses out of 24 trials in AAAB task and 16/24 in BBBA task, they were shifted to 6 trial block in which the first 6 trials contained AAAB task and the next 6 trials did BBBA task. In such manner, 24 trials were conducted. In the same way, 3 trial block and 2 trial block were conducted. After the successful completion of the block trial training, rats entered in the main acquisition training where AAAB and BBBA tasks were given to rats randomly. When rats made 17 correct responses for each task (AAAB and BBBA) in two days, Phase 3 was started. In Phase 3, 12 oddity tasks consisted of item A, B, C, and D were concurrently given to rats. In a session, six trials for each task were administered.

On completion of learning criterion (36/48 correct responses in two days) in Phase 3 tasks, transfer test 1 was administered. In transfer test 1, the novel task of EEEF or FFFE was inserted to the training of AAAB, AAAC, AAAD, BBBA, BBBC, BBBB, CCCA, CCCB, CCCD, DDDA, DDDB, and DDDC tasks. Two test trials for each task were administered daily. It continued for ten days. After the completion of the transfer test 1, EEEF and FFFE were incorporated in to the main training that made Phase 4 in which 30 oddity tasks (AAAB, AAAC, AAAD, AAAE, AAAF, BBBA, BBBC, BBBB, BBBE, BBBF, CCCA, CCCB, CCCD, CCCE, CCCF, DDDA, DDDB, DDDC, DDDE, DDDF, EEEA, EEEB, EEEC, EEED, EEEF, FFFA, FFFB, FFFC, FFFD, and FFFE) involving item A, B, C, D, E, and F were given to rats. When rats attained a learning criterion of 75% choice accuracy in five days block, they were shifted to transfer test 2 that included the novel stimuli set of GGGH and HHHG. Two test trials for each task were administered daily following the same way as that of transfer test 1. On test trials,

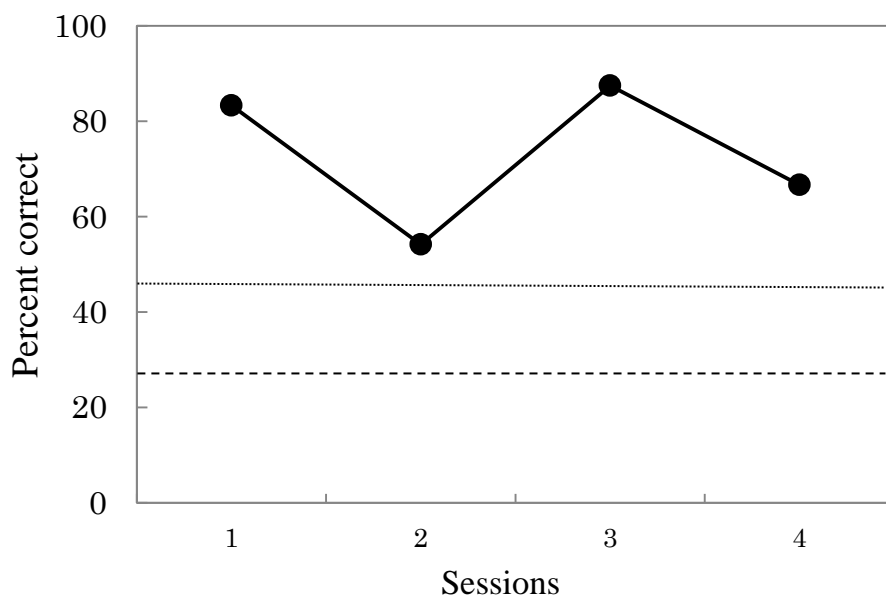
responses to both odd and non-odd objects were nondifferentially reinforced.



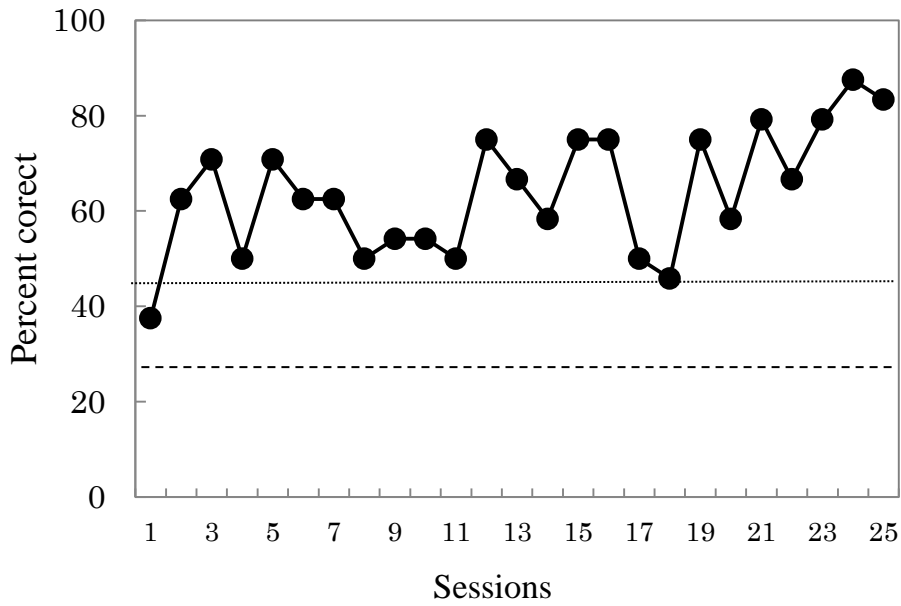
**Figure 6.** Acquisition training of one odd task (AAAB) and two oddity tasks (AAAB/BBBA) by Rat 1. Broken line represents a chance level (25%) and dotted line represents statistically significant performance level (45.83% correct,  $p < .05$ ) in a session.



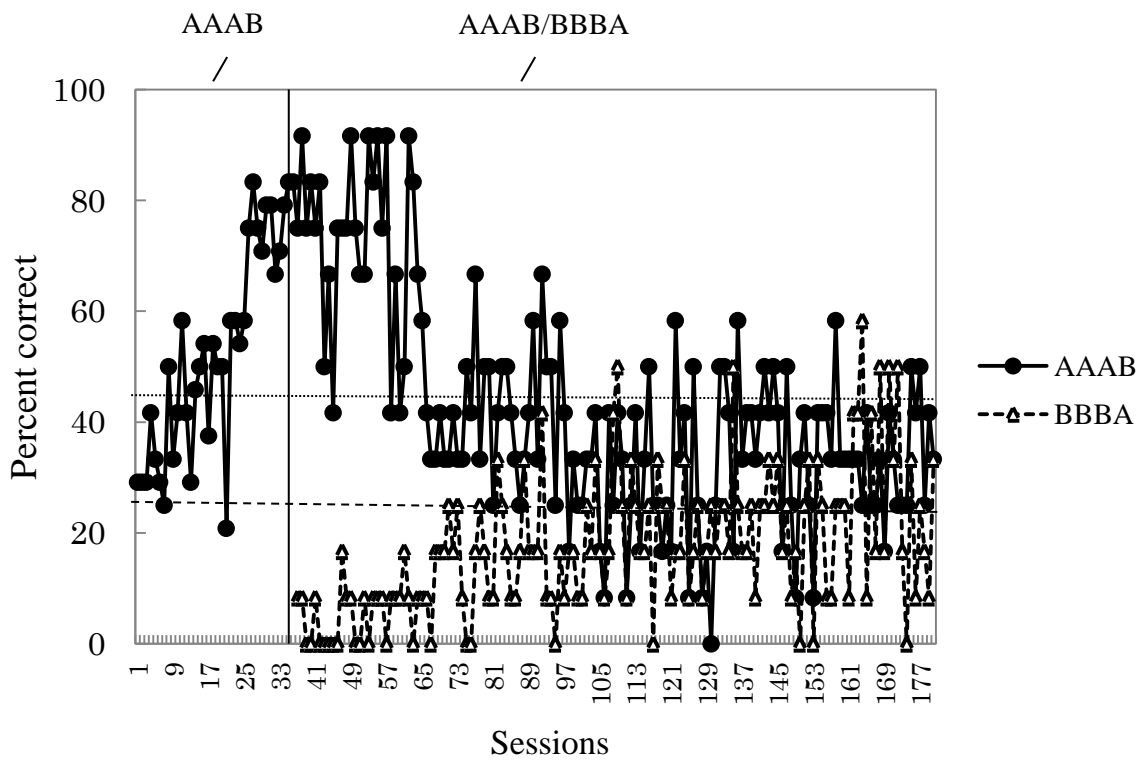
**Figure 7.** Acquisition training of one odd task (AAAB) and two oddity tasks (AAAB/BBBA) by Rat 2. Broken line represents a chance level (25%) and dotted line represents statistically significant performance level (45.83% correct,  $p < .05$ ) in a session.



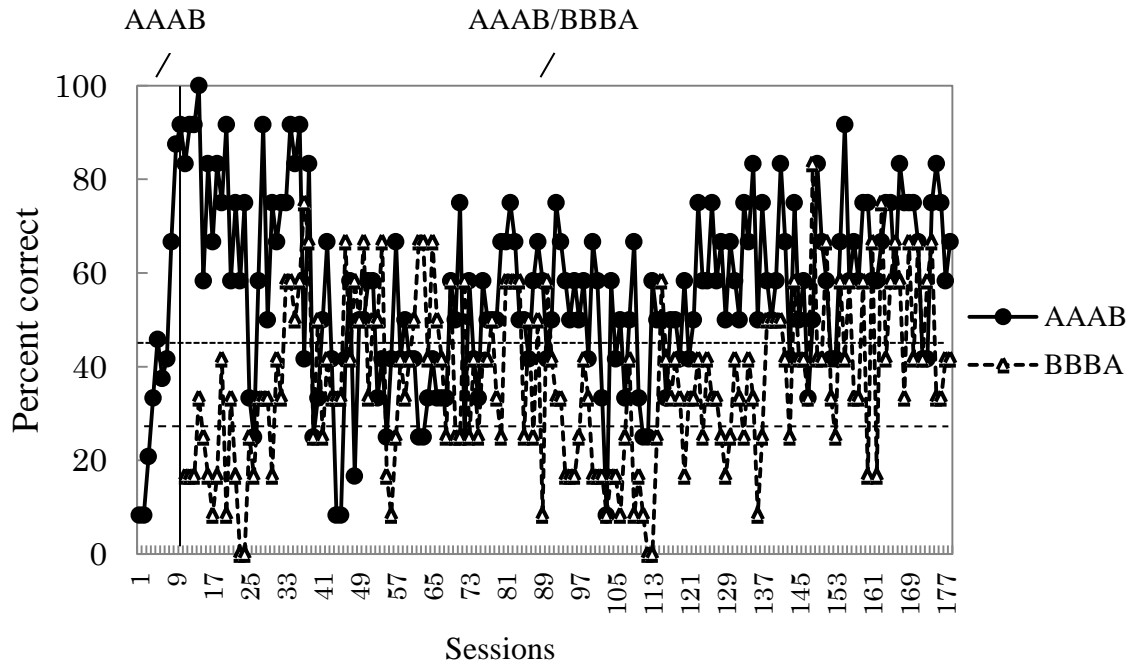
**Figure 8.** Mean performance of 12 oddity tasks by Rat 2. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level ((45.83% correct,  $p < .05$ ).



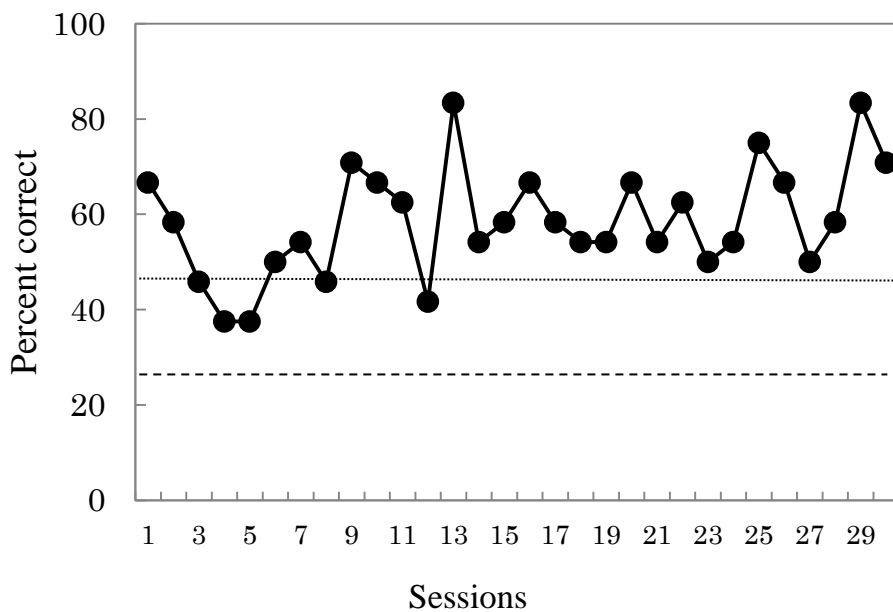
**Figure 9.** Mean performance of 30 oddity tasks by Rat 2. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level ((45.83% correct,  $p < .05$ ).



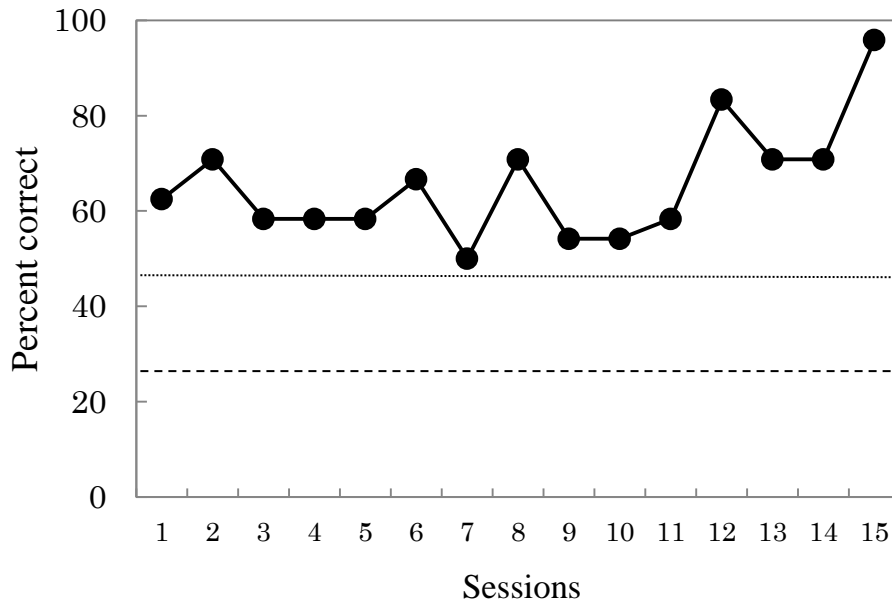
**Figure 10.** Acquisition training of one odd task (AAAB) and two oddity tasks (AAAB/BBBA) by Rat 3. Broken line represents a chance level (25%) and dotted line represents statistically significant performance level (45.83% correct,  $p < .05$ ) in a session.



**Figure 11.** Acquisition training of one odd task (AAAB) and two oddity tasks (AAAB/BBBA) by Rat 4. Broken line represents a chance level (25%) and dotted line represents statistically significant performance level (45.83% correct,  $p < .05$ ) in a session.



**Figure 12.** Mean performance of 12 oddity tasks by Rat 4. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level ((45.83% correct,  $p < .05$ ).



**Figure 13.** Mean performance of 30 oddity tasks by Rat 4. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level ((45.83% correct,  $p < .05$ ).

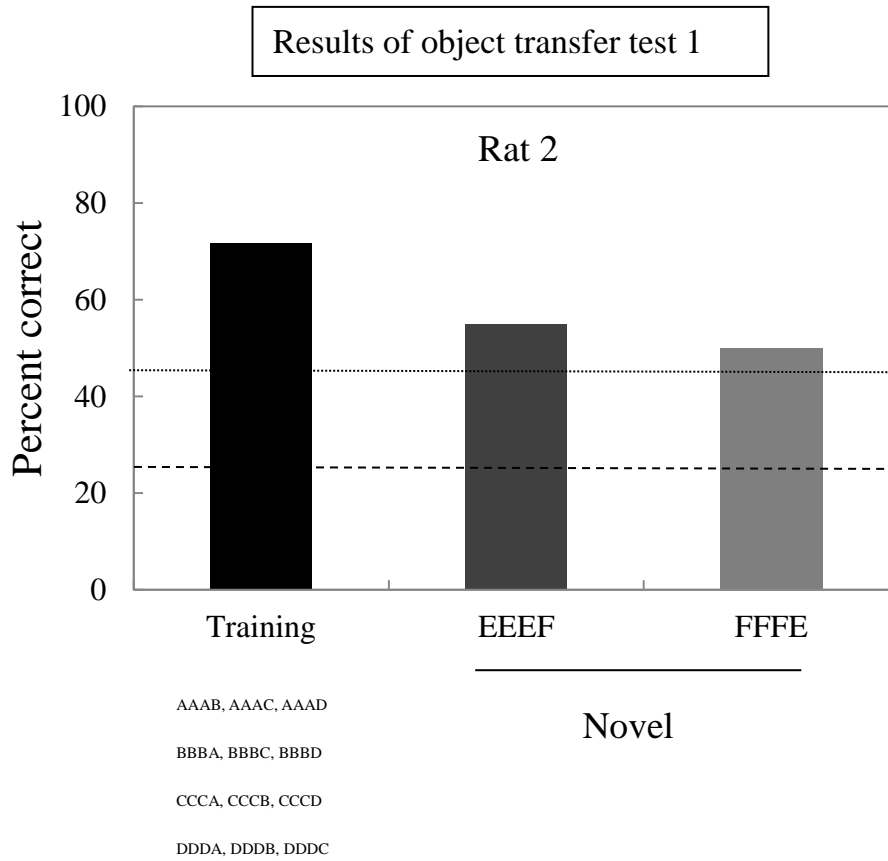
### 3.1.2. Results

#### 3.1.2.1 . Acquisition

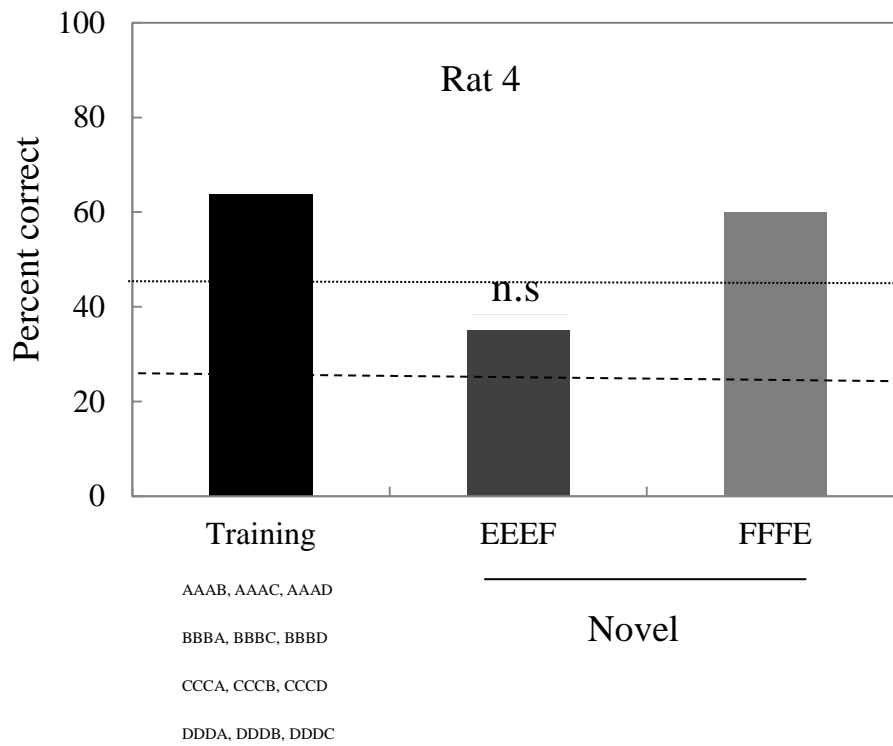
Figure 6, Figure 7, Figure 10, and Figure 11 show performances of rats during acquisition phases, where 45.83% correct represents a statistically significant performance in a session ( $p < .05$ , binomial test, one-tailed). Rat 2 and Rat 4 quickly learned the AAAB task but single feature (i.e., B) seemed to be a discriminative stimulus, because rats' performances deteriorated below the chance level (25%) when BBBA task was introduced in phase 2 (although their performances to AAAB task were maintained), suggesting that rats had an avoiding tendency to item A in BBBA task. To make the task easier, block trial training (e.g., 12 block trials in which the first 12 trials involved AAAB tasks and the rest 12 trials did BBBA tasks) was initiated that might facilitate rats to learn AAAB and BBBA tasks. However, when the number of tasks (e.g., C and D) was increased, rats' performances recovered and mean performance on a concurrent training of 12 oddity tasks consisted of item A, B, C, and D was maintained. 8 sessions, 94 sessions, 4 sessions, and 25 sessions required for Rat 2 to learn the one odd task (AAAB), two oddity task (e.g., AAAB, BBBA), 12 oddity tasks (AAAB, AAAC, AAAD, BBBA, BBBC, BBBD, CCCA, CCCB, CCCD, DDDA, DDDB, and DDDC), and 30 oddity tasks (AAAB, AAAC, AAAD, AAAE, AAAF, BBBA, BBBC, BBBD, BBBE, BBBF, CCCA, CCCB, CCCD, CCCE, CCCF, DDDA,



DDDB, DDDC, DDDE, DDDF, EEEA, EEEB, EEEC, EEED, EEEF, FFFA, FFFB, FFFC, FFFD, and FFFE) respectively. On other hand, 10 sessions, 168 sessions, 30 sessions, and 15 sessions required for Rat 4 to learn these tasks. It was observed that although both rats were required longer training to master the two oddity tasks (AAAB and BBBA), they were required considerably less training to learn the larger number of tasks (e.g., 12 oddity tasks, 30 oddity tasks). On the other hand, Rat 1 and Rat 3 were able to learn one odd task (AAAB) with 36 sessions but could not learn the AAAB and BBBA tasks even after receiving sufficient training. Therefore, the experiment was stopped for Rat 1 after he had received 172 sessions in AAAB and BBBA tasks. The training for Rat 3 was gradually extended on the possibility that larger number of stimuli might facilitate Rat 3 to improve his performances to the significant level. When novel item C was added (although AAAB and BBBA tasks were maintained), 0% transfer was observed to the novel item C across the whole period of training with AAAB, BBBA, AAAC, BBBC, CCCA, CCCB tasks . Addition of novel item D brought some improvement in rats' performances (40.01%). But it did not recover rather declined to 31.1% (on average with 30 oddity tasks consisted of item A, B, C, D, E, and F) despite providing longer training (368 sessions).

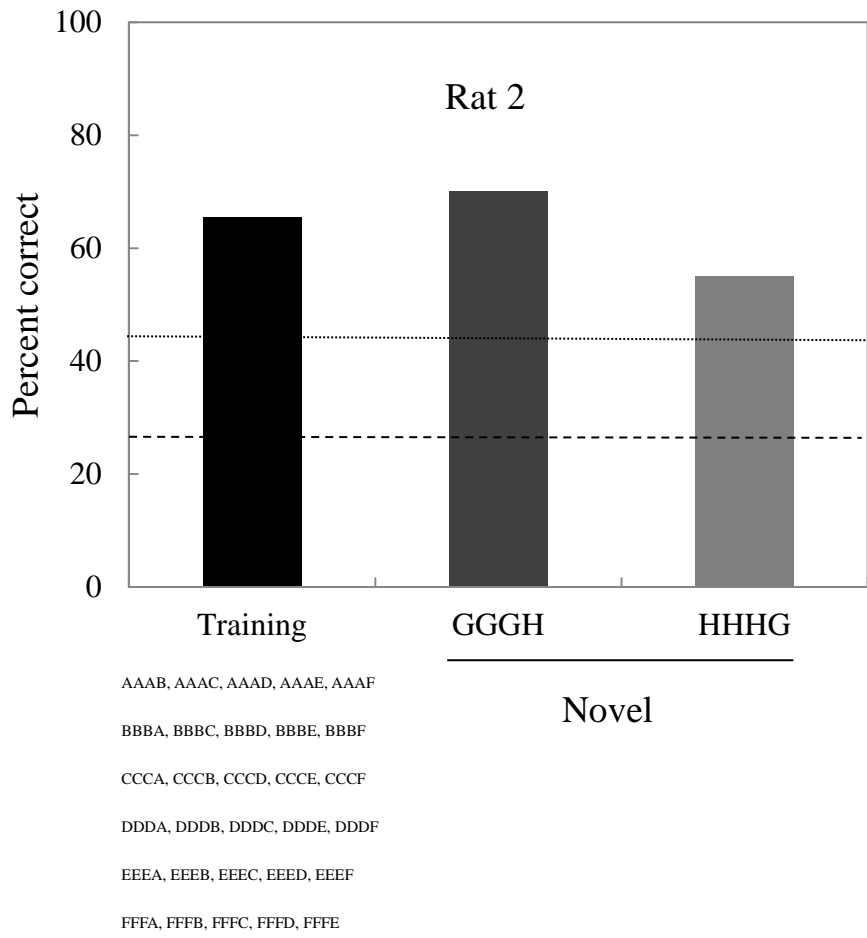


**Figure 14.** The transfer of learning in object transfer test 1 by Rat 2. Broken line represents a chance level (25%) and dotted line represents a statistically significant level (45% correct,  $p < .05$ ) in a session.

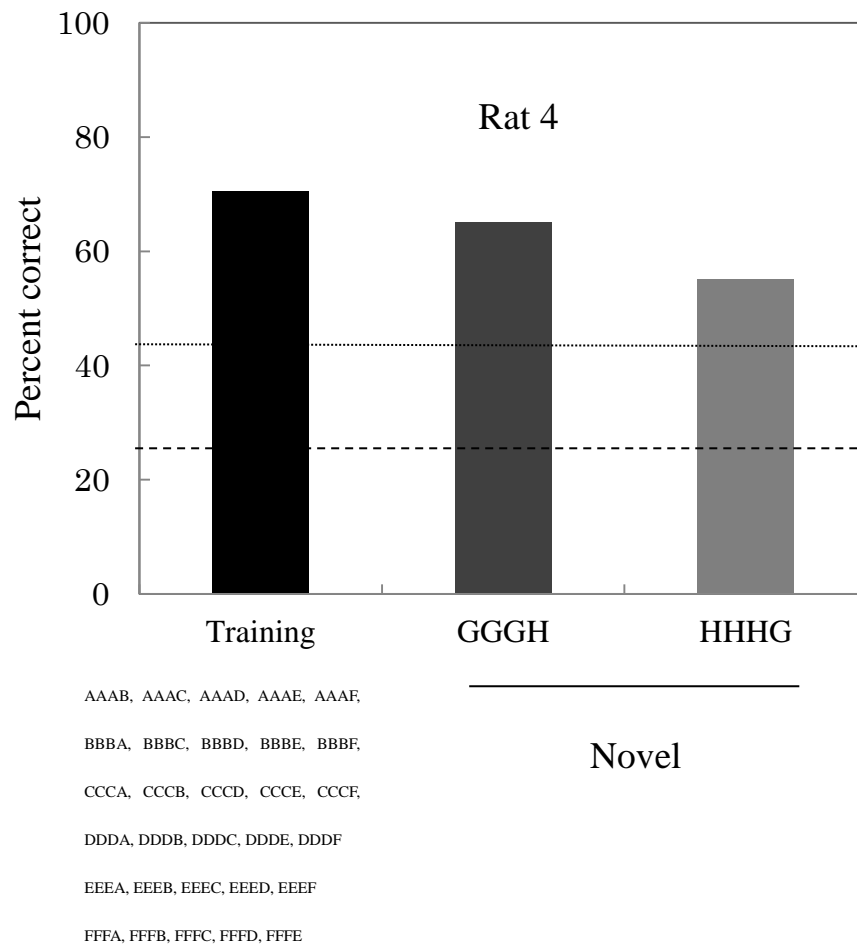


**Figure 15.** The transfer of learning in object transfer test 1 by Rat 4. Broken line represents a chance level (25%) and dotted line represents a statistically significant level (45% correct,  $p < .05$ ) in a session.

Results of object transfer test 2



**Figure 16.** The transfer of learning in object transfer test 2 by Rat 2. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $ps < .05$ ) in a session.



**Figure 17.** The transfer of learning in object transfer test 2 by Rat 4. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $ps < .05$ ) in a session.

### 3.1.2.2. Transfer

To confirm the acquisition of oddity discrimination learning, transfer test 1 with novel item E and F was administered (Figures 14 and 15). The percentage of correct responses for the novel tasks of EEEF and FFFE was 55 and 50, 35 and 60 made by Rat 2 and Rat 4 respectively. After transfer test 1, the novel items E and F were incorporated in to the main acquisition training resulting in 30 oddity tasks consisted of six objects (A, B, C, D, E, and F). Once both rats (Rat 2 and Rat 4) attained a learning criterion of 75% correct responses in five days, transfer test 2 was introduced with novel items G and H (Figures 16 and 17). 70% and 55% correct responses was made by Rat 2 and 65% and 55% correct responses was made by Rat 4 for the GGGH and HHHG tasks

respectively. However, these transfer performances except EEEF task (35%) made by Rat 4 reliably represent the significant transfer of learning ( $ps < .05$ , binomial test, one tailed) suggesting that they seemed to learn abstract relational property of the stimuli set after the concurrent acquisition of the multiple oddity tasks where single item feature could not be an effective discriminative cue. Learning during the transfer test 1 and 2 could not be interpreted in terms of additional learning to the odd stimuli in test trials. Because rats were reinforced non-differentially during testing trials meaning that when rat responded to item E in the novel stimuli set of EEEF, it got reward. By contrast, when rat responded to item F in the novel stimuli set of EEEF, it got reward. One more important point was that Rat 2 and Rat 4 yielded comparatively good performances with large number of tasks. For example, on completion of the acquisition tasks involving 12 oddity tasks, on average 52.5% (55% and 50% for EEEF and FFFE tasks) and 47.5% (35% and 60% for EEEF and FFFE tasks) transfer performances was made by Rat 2 and Rat 4 respectively in transfer test 1, whereas in transfer test 2 followed by an acquisition training involving 30 oddity tasks, on average 62.5% (70% and 55% for GGGH and HHHG tasks) and 60% (65% and 55% for GGGH and HHHG tasks) transfer performances was made by Rat 2 and Rat 4 respectively thus showing a clear improvement in rats' transfer performances.

### **3.1.3. Discussion**

The results from this experiment showed that rats (Rat 2 and Rat 4) could make significant transfer of learning ( $ps < .05$ , binomial test, one tailed) to the novel object stimuli suggesting an attainment of oddity discrimination learning. It was also observed that transfer of learning followed by 30 oddity tasks was more significant than that of 12 oddity tasks thus resulting in comparable performances over 12 oddity tasks.

These robust findings suggest that rats were not independently learning the different stimulus sets but were learning a relational strategy that can be applied to all sorts of stimuli set regardless of its physical features. These results reinforces the conclusion that tasks were learned relationally by rats and an each increase of relational learning facilitated the learning of all other set of stimuli encountered in the latter stages of Experiment 2. Although these findings of stable performances attest to the rats' ability to master the oddity discrimination tasks, one key issue of concern with newer observations was whether these transfer findings represented a true application of relational learning by the rats or might have instead been mediated by lower level mechanisms sensitive to item-specific learning (learning based on specific physical

features of stimuli). However, some explanations may clarify this concern. In the present study, three possible learning strategies could have been employed. Rats used in the present study may adopt a learning strategy based on such a hierarchy of learning process to the oddity discrimination tasks. The first possibility was to learn a single bit of information from the set of stimuli especially in the case of one odd task (AAAB). Because it is the simplest way to solve the tasks. In addition to, animals can solve the simple discrimination task (e.g., one odd task AAAB) by just remembering some specific physical features of the stimuli. This interpretation is supported by the results of the shift from Phase 1 (AAAB) to Phase 2 (AAAB, BBBA). In Phase 1, one odd task (AAAB) was rapidly learned by rats. But they seemed to master the AAAB task by approaching specific item B suggesting a responding tendency to item B and an avoiding tendency to item A.

An analysis of the initial performances of the rats on Phase 2 (AAAB, BBBA) showed very poor performances to item A and significant performances to item B. If rats learned the AAAB task based on relationship, they could transfer these experiences to the BBBA task by making correct responses to the odd item A. This is exactly what single feature learning based on existence of item B predicts. In one odd task (AAAB), it seemed that a single bit of information could be an effective discriminative cue for rats contributing to non conceptual solutions. For example, in all the trials of one odd task, item B was rewarded. Since item B was reinforced, rats could associate some specific features of item B with their responses or reinforcers. Therefore, one odd task might lead to non conceptual stimulus-specific feature learning. This suggests that rats were not responding to Phase 1 task on a conceptual basis.

The findings of Phase 1 strongly suggest that Thomas and Noble's study (1988) might be interpreted in terms of single feature learning. They trained rats with serial presentation learning tasks (please see in detail in the study of Thomas & Noble, 1988). They gave the tasks to the rats regardless of their performances. Therefore, Thomas and Noble (1988) were failed to demonstrate the acquisition of rats' oddity concept. Hence, it is obvious that when non primate animals are used for training with small number of stimuli, it may not be difficult for them to learn and retain specific information in long-term memory even if they have the ability to form abstract conceptualization. Notably, long-term memory refers to the continuing storage of information where information can last for a matter of days to as long as many decades and from where it is easy to recall the information. The second possibility is to learn some configurations of specific item as discriminative cue. According to configuration learning, some possible configurations of specific items (e.g., AAAB, BBBA, AABA, BBAB, ABAB,

and BAAA) might be generated from the set of stimuli in the two oddity tasks (e.g., AAAB and BBBA tasks). Rats can solve these discrimination tasks by memorizing these possible configurations. If rats learn the given tasks based on configuration learning, their performances must deteriorate in the next phase involving new items (e.g., C) because the configurations of specific item will turn in to a new one when novel item (e.g., C) is added in the next phase (e.g., Phase 3). In such case, the possible configurations seem to be unfamiliar to rats thus contributing to rats' producing poor performances. This may be considered for the Phase 2 task of the present study. The Phase 2 (AAAB and BBBA tasks) produced some possible configurations of specific item (e.g., AAAB, BBBA, AABA, BABB, ABBA, and BAAA). For example, if AAAB task is given, responding to item B can lead to the solution. If BBBA task is given, responding to item A can lead to the solution. If rats adopt such responding strategy, it may result in configuration learning.

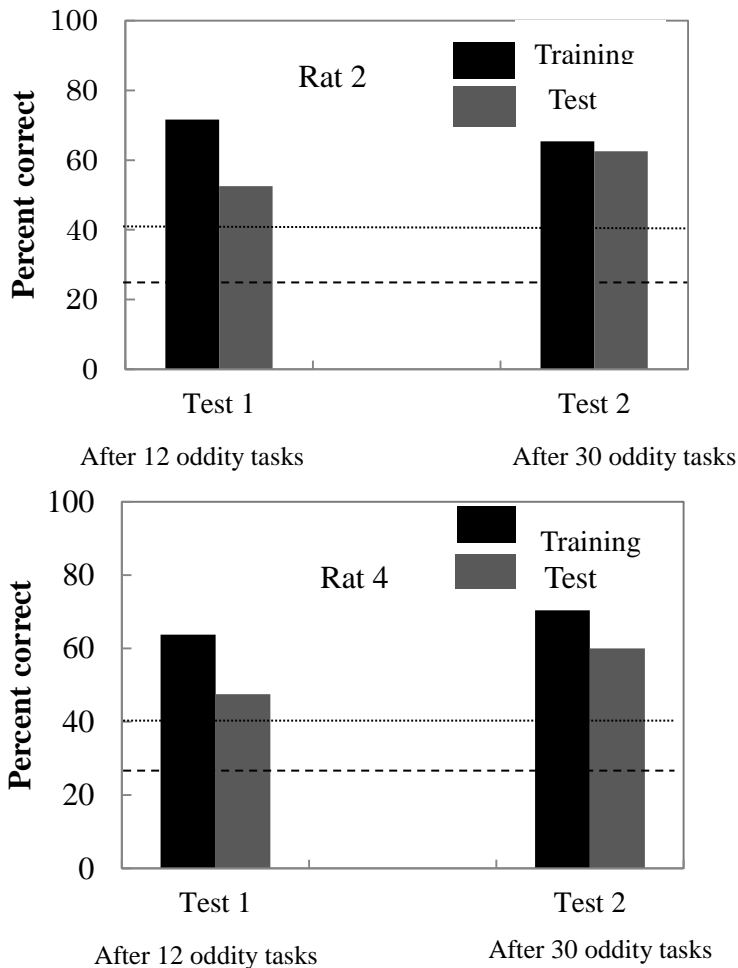
Although Rat 2 and Rat 4 showed very poor performances in the initial stages of Phase 2 tasks, they finally learned the two oddity tasks with learning criterion (17/24 correct responses for AAAB and BBBA tasks each in two days). But when item C was added in Phase 3 task (e.g., AAAB, BBBA, BBBC, and AAAC), their initial performances to the novel item C little deteriorated as compared to the average performances of A-odd (e.g., BBBA) and B-odd tasks (e.g., AAAB) suggesting that if rats learned an abstract rule in A-odd (e.g., BBBA) and B-odd tasks (e.g., AAAB), their performances would be stable or stronger with novel item C. In our study, it was observed that when item C was added, Rat 2 made 75%, 83.33%, and 58.33% correct responses in A-odd (e.g., BBBA), B-odd (e.g., AAAB), and C-odd (e.g., AAAC) tasks respectively in the first three days.

These findings showed that although Rat 2 made significant performances in A-odd task and B-odd tasks, he did relatively poor performances in C-odd task suggesting that he might have learned some configuration learning. Rat 4 also showed the same tendency in A-odd (e.g., BBBA), B-odd (e.g., AAAB), and C-odd (e.g., AAAC) tasks (70.83%, 87.50%, and 37.50% correct responses respectively). Concurrent training of two oddity tasks (e.g., AAAB and BBBA) could not be solved by single feature learning. It eliminates the possibility of single feature learning or relational learning. If rats learned an abstract rule in A-odd and B-odd tasks, he could have transferred it to the novel item C. Such findings also confirmed that small number of stimuli might produce item-specific learning (learning based on some specific physical features of the stimuli or combinations of specific items). Therefore, the results contingent with the shift from Phase 2 to Phase 3 seems to be in favor of configuration learning.



When animals don't learn single feature learning or configuration learning in the set of stimuli, they find abstract relational learning in which relationship among items rather than physical features of the stimuli become the discriminative cue. The third possibility might gain some support by the results of Phase 3 (e.g., AAAB, BBBA, BBBC, AAAC, CCCD, DDDC, AAAD, BBBB, DDDDB, DDDA, CCCA, CCCB, and so on) and transfer test (EEEE, FFFE, GGGH, and HHHG). For example, rats took comparatively little time to master the Phase 3 tasks as compared to Phase 2 tasks (AAAB and BBBA). Furthermore, significant transfer of learning (the percentage of correct responses was 55 and 50, 35 and 60 for novel EEEF and FFFE tasks made by Rat 2 and Rat 4 respectively) was observed in the transfer test 1 ( $p < .05$ , binomial test, one tailed). In transfer test 2, the percentage of correct responses was 70 and 55, 65 and 55 for GGGH and HHHG tasks made by Rat 2 and Rat 4 respectively suggesting that rats might not discriminate the stimuli in terms of single feature or configuration learning but in terms of a relational strategy. Hence, it can be confirmed that an oddity concept can control the behavior of rats in suitable situation in which single feature learning or configurations of specific patterns is not an effective discriminative cue. What caused these significant findings? Various theories have been proposed to answer to this question. The most notable suggestion is that concurrent training facilitated rats to use an abstract oddity rule in processing each of the stimuli set. The acceptance of this conclusion bears further implications that rats used in the study of Thomas and Noble (1988) might have learned some specific rules (single feature learning) or learning set for dealing with what looked like comparable tasks. Remarkably, Thomas and Noble (1988) devised an experimental procedure that used an odd item serially along with other identical stimuli (e.g., AAB, CCD, and EEF). Such procedure may contribute to rats' being more sensitive to the specific items that were changing in every task thus producing stimulus-specific discriminative cue. In contrast, my study used an odd item concurrently along with other identical stimuli in a stimuli set thus resulting in no stimulus-specific discriminative cue. For example, in the AAAB, BBBA, BBBC, AAAC, CCCD, DDDC, AAAD, BBBB, DDDDB, DDDA, CCCA, and CCCB tasks, item A may appear as odd one in a trial. Item B may appear as an odd one in the second trial. Item C and D may appear as the odd ones in other trials. In such manner, different trials may include different items as the odd ones thus producing many configurations (e.g., 12 oddity tasks involving four items A, B, C, and D) that were difficult for rats to memorize. In one-odd task, item-specific information is available for rats. But in concurrent training, stimulus-specific information is not effective. Therefore, rats may process the concurrent training tasks based on relationships among stimuli. The second

reason of rats' showing positive oddity evidences is that two identical and one odd stimulus are minimum requirements to constitute an oddity task. I used three identical stimuli and one odd stimulus that might contribute to the acquisition of oddity learning. Such constitution may make an odd stimulus more salient that might make the tasks easier for rats. Cook et al. (1997) trained pigeons to discriminate different display (e.g., five same stimuli vs. one odd stimulus) from same display (all stimuli were same). Pigeons could acquire the discrimination learning and transfer to the novel stimuli. Cook et al. (1997) explained that increasing number of identical stimuli might make the odd stimuli salient and facilitate pigeons to acquire the discrimination learning. We assumed that if such strategy (using many stimuli) was applied to rats' study, it might bring positive results. The third one is that the larger number of stimuli may facilitate rats to the acquisition of relational concept.



**Figure 18.** The level of transfer to the novel object stimuli according to the gradual increase in training stimuli. Broken line represents chance level performances (25%) and dotted line represents a statistically significant performance level (40% correct,  $p < .05$ ) in a session.

In my study, it is observed that when AAAB task was given to rats, they seemed to learn it item-specifically. When two oddity tasks (AAAB and BBBA) were given, they might have learned it based on configurations of specific items (e.g., AAAB, AABA, BAAA, BBBA, ABBB, and BBAB). But in Phase 3, when the number of tasks was increased to 12 different oddity tasks involving item A, B, C, and D, on average, 52.5% transfer of learning (55% and 50% for novel EEEF and FFFE tasks respectively) was observed in the case of Rat 2. In the case of Rat 4, on average, 47.5% transfer of learning (35% and 60% for EEEF and FFFE tasks respectively) was observed. When 30 different tasks were given to them, on average, 62.5% and 60% transfer of learning was made by Rat 2 and Rat 4 for the novel GGGH and HHHG tasks respectively.

These stable and significant performances suggest that the gradual increase in the training stimuli may facilitate the acquisition of relational concept (please see Figure 18). However, the transfer of learning made by Rat 2 and Rat 4 in Experiment 2 can be considered partial as it was significantly above the chance level and below the baseline performances (68.54% and 67.08% made by Rat 2 and Rat 4 respectively). If the transfer of learning were equivalent to baseline performances and above 80% correct, this should be considered full concept learning. There is empirical evidence (e.g., Wright & Katz, 2006) that a smaller set of training stimuli led to item-specific rote learning and larger set of training stimuli prompted an acquisition of abstract S/D concept learning.

Wright and Katz' study (2006) revealed that rhesus monkeys, capuchin monkeys, and pigeons showed chance level transfer performance of S/D discrimination of two colored pictures following acquisition training with eight stimuli. When the training set size was increased to 32 stimuli, monkeys showed evidence of partial S/D concept learning (a learning significantly above the chance and below the baseline performances) but pigeons showed no sign of transfer to the novel stimuli. Monkeys and pigeons showed full acquisition of abstract S/D concept learning (a learning equivalent to baseline performance with an accuracy of more than 80% correct) with the further expansion of the training set size to 128 and 256 items respectively. These findings suggest that if rats have an ability to learn abstract relationships between stimuli and if they are trained with larger number of stimuli, they may demonstrate evidence of transfer to novel pairs of stimuli. Lombardi et al. (1984) found similar findings with larger number of stimuli. They trained two groups of pigeons with few examples and many examples respectively using oddity-from-sample procedure and suggested that pigeons with many examples showed better transfer than the pigeons with few examples.

### **3.2. Experiment 3**

**Odor test 1 : nondifferential reinforcement procedure**

**Odor test 2 : extinction procedure**

**Odor test 3 : extinction procedure**

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The acquisition and transfer performances of Rat 2 and Rat 4 in Experiment 2 suggested that their processing seemed to be relational but it seemed questionable whether rats' ability to learn relational concept was limited to the stimuli set within its context (limited to the features of training items) or was applicable to other sets of novel stimuli. If rats learn object oddity tasks based on abstract relational property of a stimuli set (e.g., object), then transfer of oddity discrimination is expected when stimuli sets consisting of different modalities (e.g., odor, sound) will be used. Because a relational learning can be applied to all pairs of stimuli. In an experimental report of cross-modal transfer test, Tyrrell (1974) trained four groups of third grade children. One half of the children were trained with visual modality. The remaining half received training with tactile modality. Following discrimination training, all children were given oddity problems in the alternate modalities. The study demonstrated significant cross-modal transfer of oddity learning in children. These findings strongly suggest that children could learn abstract oddity concept.

To examine abstractness of rats' oddity learning, Experiment 3 tested cross-modal transfer of oddity discrimination learning between object stimuli and odor ones. In addition, I examined intra-modal transfer of oddity discrimination between odor stimuli.

#### **3.2.1. Method**

##### **3.2.1.1. Subjects, apparatus, and stimuli**

The subject was one experimentally naïve rat (Rat 4 chosen from Experiment 2) maintained similar to the subjects in Experiment 2. The subject was trained in the same apparatus used in Experiment 2. Eight objects that he used in Experiment 2 and six odors (almond, lemon, vanilla, vinegar and two other odors made from different perfume) applied to identical erasers were used as training and testing stimuli. The size of the eraser I used for odor discrimination and transfer test was 52\*24\*11 mm (width, depth, and height). To make an odor stimulus, an odor substance was absorbed in cottons in a container. Four erasers were put in the container without touching directly with the cottons about for 20 h.

### **3.2.1.2. Procedure**

The acquisition training and the procedures of transfer testing (for example, two odor transfer test involving the novel tasks of 2221, 1112, 4443, and 3334 were carried on followed by acquisition training of 30 oddity tasks. In odor test 1, the novel tasks of 2221 and 1112 were inserted to the training of 30 oddity tasks. Two test trials for each task were administered daily. It continued for ten days. Similar procedures were followed in odor test 2 where the novel tasks of 4443 and 3334 were inserted to the training tasks) were the same as those of Experiment 2 except some changes in novel test procedures, acquisition training and stimuli. Two acquisition training were administered with concurrent procedures. The first one using 30 oddity tasks was the same as that of Experiment 2. To determine rats' ability to discriminate odor stimuli, the second acquisition training called "odor discrimination training" was carried on using 12 oddity tasks consisted of odor 2221, 1112, 4443, and 3334. Subsequently, odor transfer test 3 was administered using novel odor tasks 6665 and 5556 made from different perfume. Notably, the first odor transfer test followed nondifferential procedure where all responses were reinforced in the test trials. The rest two odor transfer tests (odor test 2 and 3) did extinction procedure where no response was reinforced in the test trials. 6 erasers containing the same color, shape, and appearance but different odors were used as stimuli in the odor discrimination training and odor transfer tests.

## **3.2.2. Results**

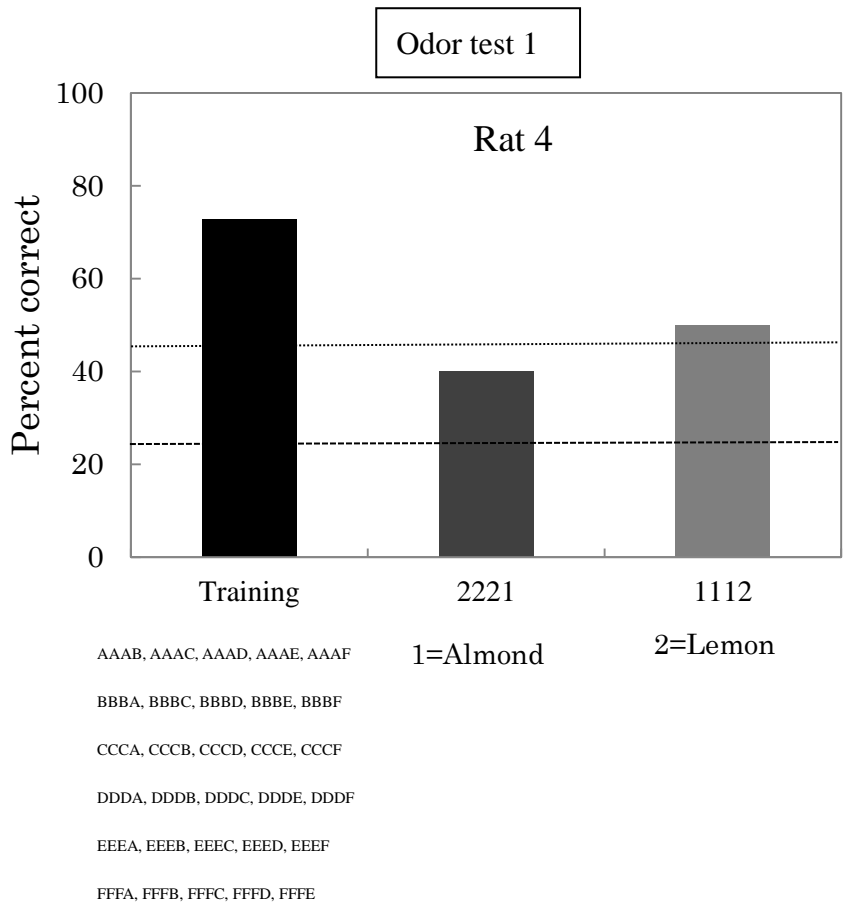
### **3.2.2.1. Acquisition**

As Rat 4 was familiar with the experimental apparatus from Experiment 2, he had no difficulty in learning the experimental procedure. Rat 4 could learn the object discrimination tasks much faster as these tasks were familiar to him from Experiment 2. Most notably was rat's rapidness to meet the learning criterion within two sessions (75% correct responses in two consecutive sessions). Learning a relational strategy of oddity concept is the only way that such acquisition functions could have been produced by Rat 4 with these large numbers of training stimuli.

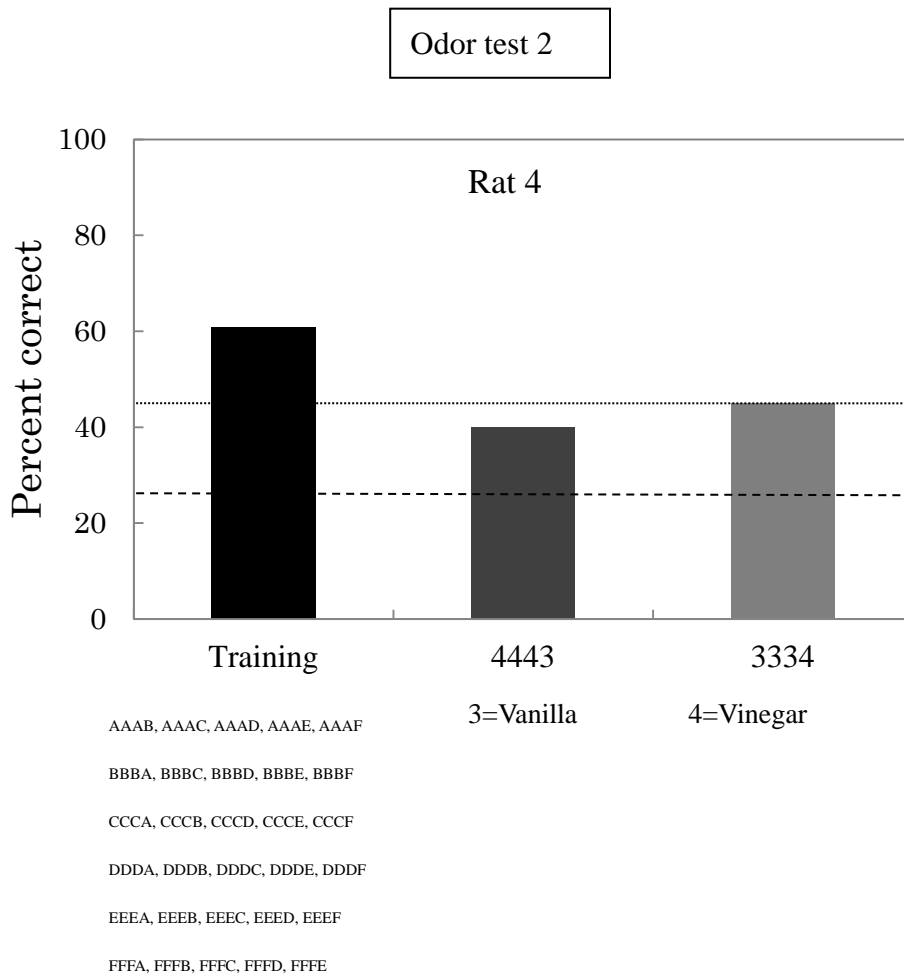
### **3.2.2.2. Transfer**

Transfer performances of odor test 1 and odor test 2 are shown in Figure 19 and

Figure 20. The percentage of correct responses was 40% and 50% for the novel odor tasks of 2221 and 1112 in the first odor transfer test. On the other hand, 40% and 45% was observed for the novel odor tasks of 4443 and 3334 in the second transfer test suggesting that Rat 4's discriminative behavior to the novel odor stimuli were not significant if test performances were analyzed individually ( $p < .05$ , binomial test, one tailed) but above the chance (25%).



**Figure 19.** The level of transfer in odor transfer test 1. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $p < .05$ ) in a session.



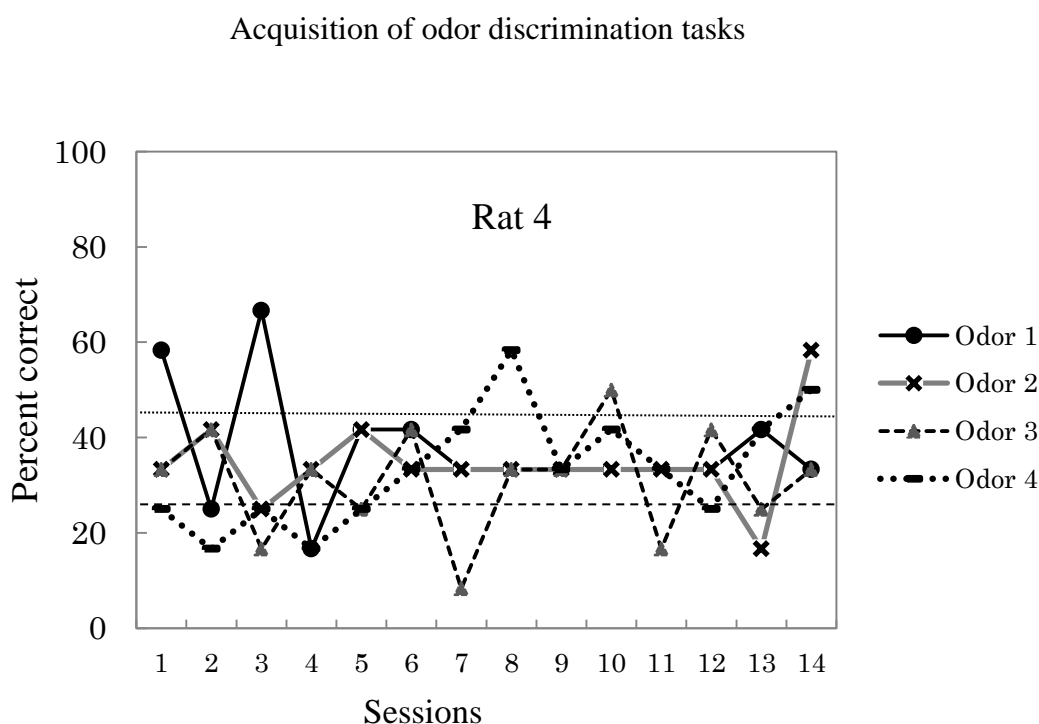
**Figure 20.** The level of transfer in odor transfer test 2. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $p < .05$ ) in a session.

Remarkably, these transfer of learning might not be attributed to the categorical identity shared between the training stimuli (object) and the transfer stimuli (novel odor). As a consequent, some differences between the transfer performances and the training performances were observed. Higher learning rate was observed in the training tasks (72.73% in the first transfer test and 60.83% in the second transfer test) as compared to transfer performances (on average, 45% for the novel odor tasks 2221 and 1112 in the first odor transfer test and 42.5% for the novel odor tasks 4443 and 3334 in the second transfer test). It is worth noticing that transfer performances during testing periods could not be attributed in terms of additional learning to the odd stimulus. Because rats were reinforced non-differentially during the testing trials of odor transfer test 1. It means that when rats responded to a non-odd item, for example, 2 in the stimuli set of 2221, they were reinforced. By contrast, when rats responded to an odd item 1 in the stimuli set of 2221, they were also reinforced. An extinction procedure was

followed for odor transfer test 2 and 3 meaning that responding to the odd and non-odd stimulus in the test trials was not reinforced.

### 3.2.2.3. Acquisition of odor discrimination tasks and transfer

Following odor transfer test 1 and 2, odor discrimination tasks involving odor tasks 2221, 1112, 4443, and 3334 were given to Rat 4 to determine his ability in discriminating stimuli of other modality (odor stimuli). Acquisition of odor discrimination tasks by Rat 4 is shown in Figure 21.

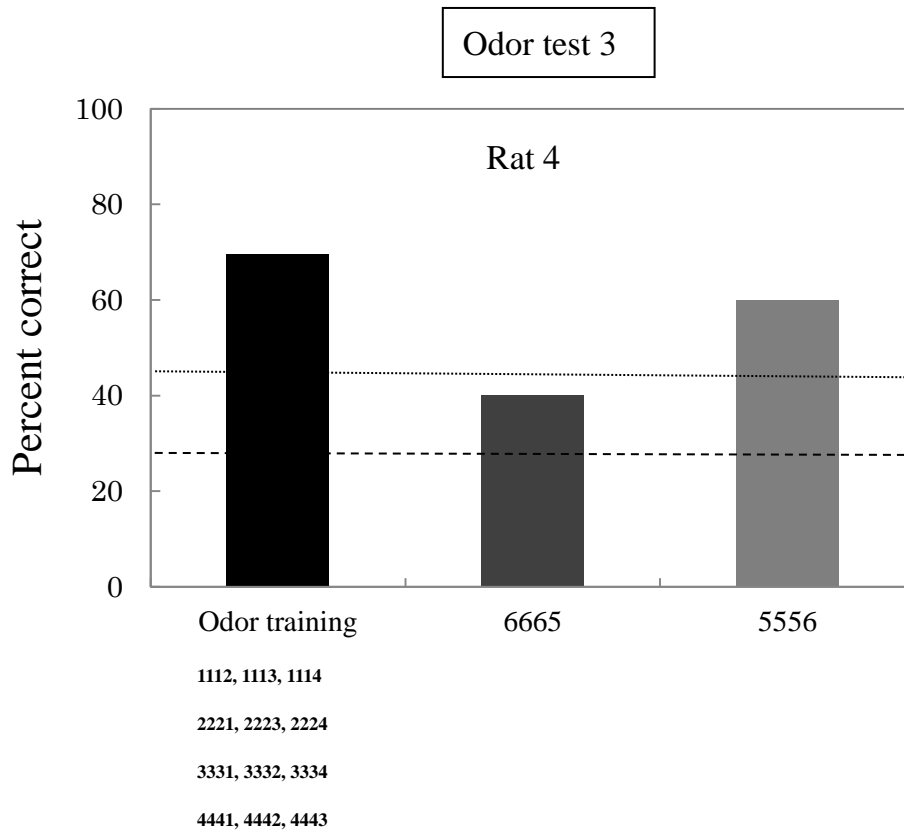


**Figure 21.** Percentage of correct responses in odor discrimination tasks. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45.83% correct,  $p < .05$ ) in a session.

The first session of odor discrimination training showed the robust performances (75% correct responses). The acquisition performances were almost constant and stable across the 14 training sessions within which Rat 4 met the learning criterion (75% correct responses in two days). It was observed that less training (14 sessions) required for the rat to master the odor discrimination tasks as compared to the basic training of object tasks (241 sessions) involving item A, B, C, and D. The transfer performances of



odor test 3 were shown in Figure 22.



**Figure 22.** The level of transfer in odor transfer test 3. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $p < .05$ ) in a session.

Odor test 3 showed that 40% transfer of learning to the novel odor task 6665 and 60% to novel odor task 5556 was observed in 10 days' testing phase. These transfers were poor than those of training stimuli (69.58%). A little improvement (60%) was observed for odor task 5556 compared to other odor tasks (2221, 1112, 4443, and 3334) observed in odor test 1 and 2. However, if the test performances to the novel odor tasks are calculated based on individual item (e.g., 40% transfer of learning to the novel odor task 2221), these results are not significant (but above the chance). By contrast, if these ones are calculated together (e.g., 40% for odor task 6665 and 60% for odor task 5556, on average, 50%), significant transfer of learning to the novel stimuli ( $ps < .05$ , binomial test, one tailed) was observed thus suggesting some cross-modal transfer of learning by Rat 4.

### 3.2.3. Discussion

Experiment 3 showed that rats were able to show some cross-modal transfer to other novel stimuli set (odor). These are important results because it shows that Rat 4's making relational judgment within a restricted-domain seemed to be able to expand their domain and to apply the same relational learning to stimulus sets of different modality (odor stimuli). Above the chance level performance to odor stimuli in cross-modal test suggests somewhat domain free relational learning. Conversely, these performances were poorer than that of intra-modal transfer test (object-object) that is, the performance in intra-modal test was 56.25% on average for the novel object tasks (EEEF, FFFE, GGGH, and HHHG), whereas 43.75% on average correct performance was observed for the novel odor tasks (2221, 1112, 4443, and 3334). Considering these results, rat's learning of oddity concept might be domain free in part but restricted-domain in part.

What caused the transfer of learning to odor stimuli. This is little mysterious. However, there are some indications. It is speculated that Rat 4 might encode the abstract relational property of the stimuli set in the basic training stimuli involving item A, B, C, and D that was reflected in the transfer test using novel object stimuli. In the case of cross-modal transfer test, he might generalize the same relational learning strategy over another novel stimuli set (odor stimuli) encompassing the entire domain. Another possibility is that rats are inherently more sensitive to the olfactory discriminanda (e.g., Lu, Slotnick, & Silberberg, 1993; Slotnick & Katz, 1974; Thomas & Noble, 1988). Such advantage might offer rats a congenial environment for making correct responding to the novel odor stimuli. One concern seems to be apparent decrease in test performances compared to that of training performances (e.g., 42.5% test performance was observed to the novel odor tasks of 4443 and 3334 whereas, 60.83% correct responding was observed to the training tasks). There are two compelling logical arguments. One speculates that such a decrease might be induced by the novelty of the new stimuli. For example, rat's performances to novel odor tasks 4443 and 3334 in the first transfer trial of odor test 2 was lower (0%) than those of training trials (58.33%) might argue for such a behavioral disruption. It was reported (D' Amato, Salmon, & Colombo, 1985) that animals are required some perceptual learning as to the novel stimuli before discriminating them. Such advantage may facilitate animals to make optimum use of their discrimination ability to the novel stimuli set. But the test performances to the first trial of object transfer test 1, where 100% and 50% transfer was observed to the novel task EEEF and FFFE respectively as compared to training

tasks (58.33%) does not support this explanation. The second one considers the contrast in familiarity between the novel transfer stimuli (novel odor stimuli) and the training stimuli (object stimuli) might have disrupted the rats. In the cross-modal transfer test, some novel odor tasks (e.g., 4443, 3334) were inserted to the training tasks consisted of object stimuli (e.g., A, B, C, D, E, and F). The features of object stimuli were completely different from those of odor stimuli. This contrast might have disrupted rats to make higher accuracy to the test odor stimuli as compared to training stimuli. The latter explanation deemed plausible for the case considered.

Although Rat 4 showed cross-modal transfer of learning to the novel odor stimuli, someone may ask of whether rats have ability in odor discrimination tasks. To defend such argument, Rat 4 was given the odor discrimination tasks (2221, 1112, 4443, and 3334) that was learned significantly (75% correct responses in two days). After the successful acquisition, odor test 3 involving two novel odor tasks 6665 and 5556 was administered in which 40% transfer for novel odor task 6665 and 60% for novel odor task 5556 was observed.

### **3.3. Experiment 4**

#### **Sound test 1: extinction procedure and nondifferential reinforcement procedure**

#### **Sound test 2: nondifferential reinforcement procedure**

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This experiment was conducted as the final replication of cross-modal transfer of learning to other novel stimuli “sound”. In Experiment 2, rats showed significant transfer of learning to the novel object stimuli. In Experiment 3, rats showed above the chance level transfer of learning to the novel odor stimuli. To confirm further generality of cross-modal transfer of learning, Experiment 4 was conducted. Our approach was that as rats significantly discriminated novel object stimuli and seemed to generalize it over novel odor stimuli to some extent, rats might perform correctly in novel sound stimuli too. Sound test was administered following acquisition of 30 oddity tasks. Two novel sounds (noise and tone) were played by either of four IC players in identical opaque containers in sound test 1 (Figure 23). A container with odd sound and three containers with identical sound were presented. In sound test 2, one noise pot with three silent pots was presented. This was done because the rat might not be able to discriminate two different sounds presented simultaneously in sound test 1. Rat’s performances were assessed with nondifferential reinforcement procedure or extinction procedure. More frequent responding to the container with odd sound was expected if the rat transferred oddity learning of object stimuli to sound stimuli.

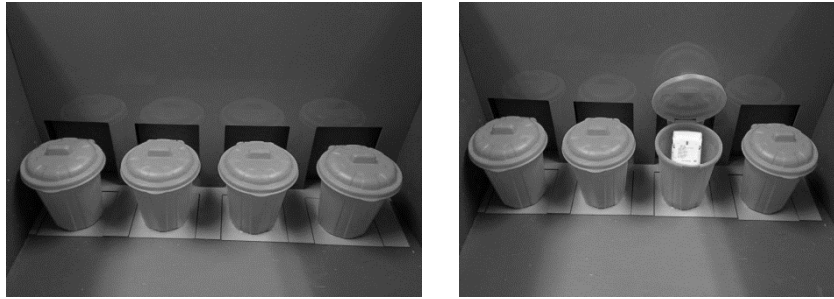
#### **3.3.1. Method**

##### **3.3.1.1. Subjects, apparatus, and stimuli**

One experimentally naïve Long Evans rat (Rat 4 who participated in Experiments 2 and 3) was trained in the same apparatus and maintained as those in Experiments 2 and 3. Novel sound items noise (X) and tone (Y) were used as stimuli.

Noise: 900 ms while noise with 100 ms blank. This cycle was repeated throughout a testing trial.

Tone: 4000 Hz. The cycle of 100 ms tone and 100 ms blank was repeated throughout a testing trial. An IC recorder containing sound stimuli (noise and tone) was kept in the identical opaque containers (yellow pot) and placed it in the apparatus during the test.

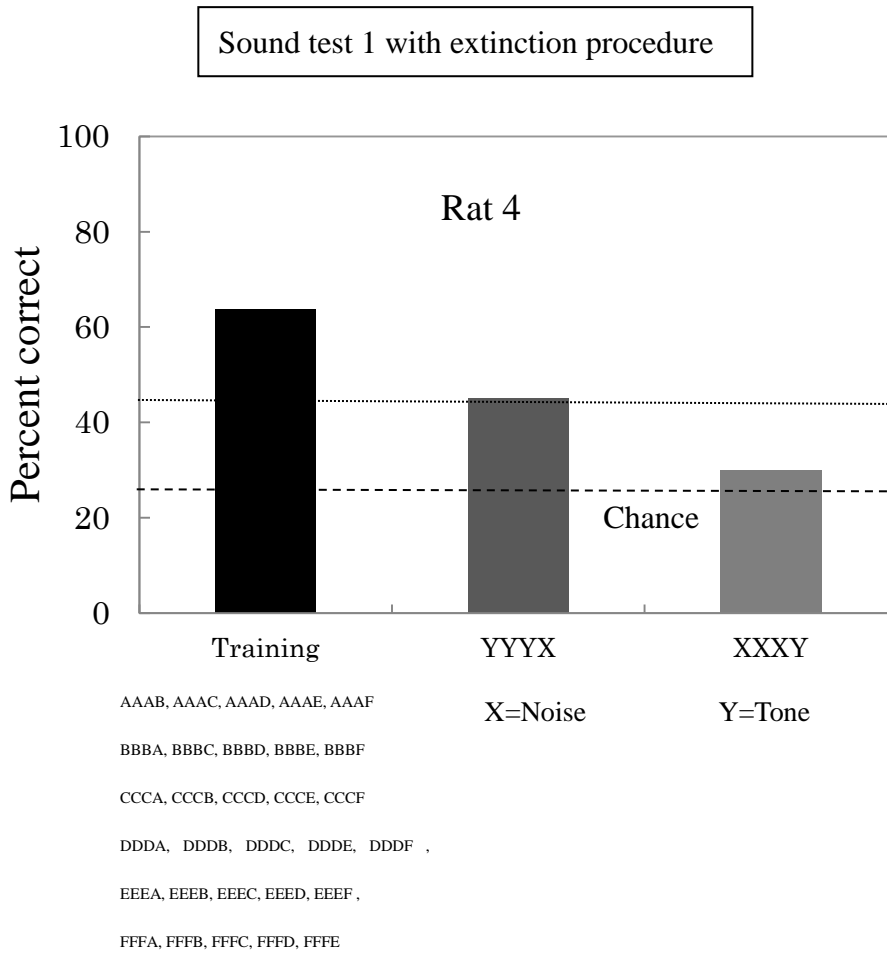


**Figure 23.** Containers with IC recorders used in sound transfer tests.

### **3.3.1.2. Procedure**

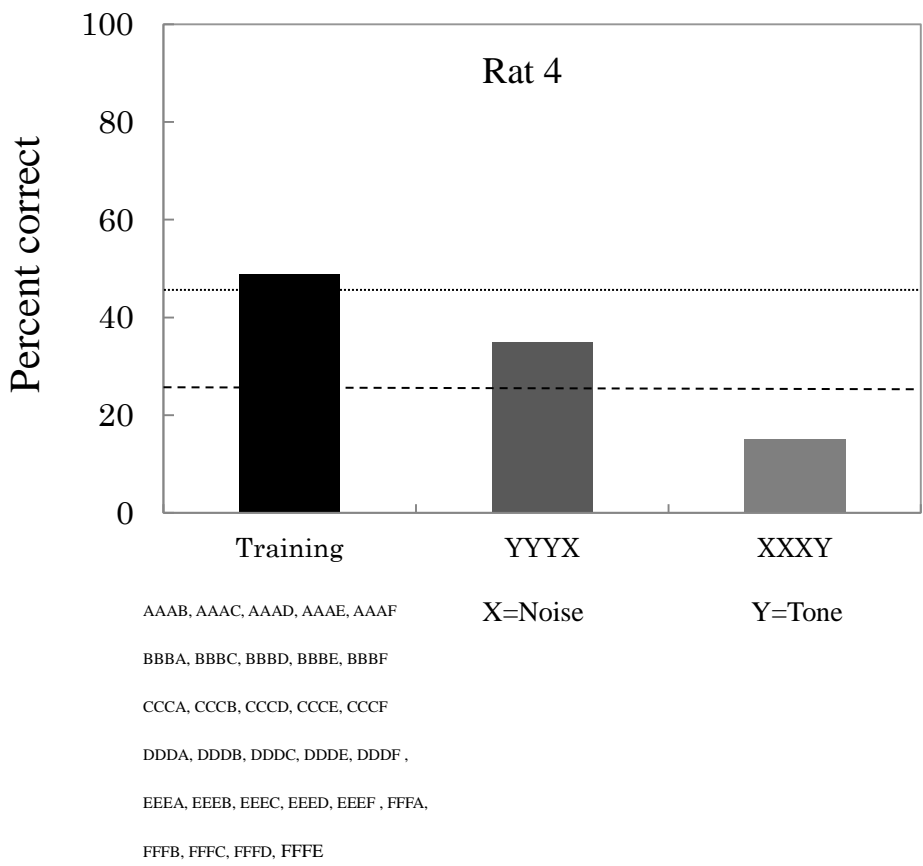
The acquisition training and the procedures of transfer testing (for example, sound transfer test 1 involving the novel sound tasks of  $YYYX$ ,  $XXX Y$  was carried on followed by the acquisition training of 30 oddity tasks. Each novel sound task was inserted twice to the daily training of 30 oddity tasks) were identical to previous experiments except that some changes in the domain of stimuli (sound). Sound transfer test 1 was administered twice: once with extinction procedure (10 days) and the next time with non differential procedure (10 days) using the same novel sound stimuli ( $X$ = noise and  $Y$ = tone). On the other hand, in sound transfer test 2, the novel sound tasks of  $*X**$ ,  $X***$ ,  $***X$ ,  $***X*$  were inserted to the training of 30 oddity tasks daily. It continued for five days. The sound stimulus “noise ( $X$ )” was repeated in the sound transfer test 2 along with three other silent stimuli (\*). All stimuli (noise and silent) were presented in the identical opaque containers (four yellow pots). During test trials, responses to odd and non-odd stimuli were reinforced (nondifferential procedure).

### 3.3.2. Results and Discussion



**Figure 24.** The level of transfer in sound test 1 with extinction procedure. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $p < .05$ ) in a session.

Sound test 1 with nondifferential procedure



**Figure 25.** The level of transfer in sound test 1 with nondifferential procedure. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $p < .05$ ) in a session.

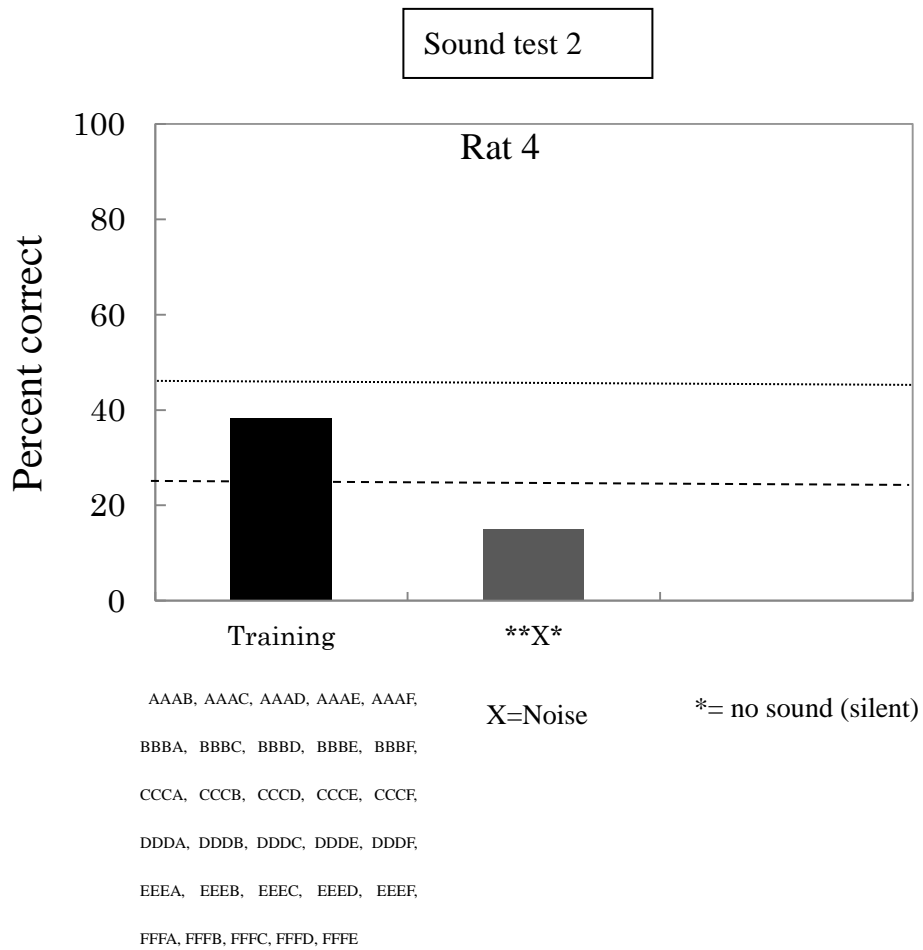
Experiment 4 showed above the chance level transfer of learning to the novel sound stimuli in the sound transfer test with extinction procedure (45% for the YYYX and 30% for the XXXY) maintaining an average performances of 63.75% accuracy in training stimuli (A, B, C, D, E, and F). Conversely, in the sound transfer test with nondifferential procedure, the rat showed above the chance level performance (35%) for the novel sound task of YYYX (noise) and below the chance level performance (15%) for the novel sound task of XXXY (tone) maintaining an average performances of 48.75% accuracy in training stimuli. Sound transfer test with extinction procedure suggest some cross-modal transfer to the novel sound stimuli. It apparently seemed that their transfer of learning was determined in terms of procedures. But actually it was observed that during the sound transfer test with extinction and non differential procedure, rat's performances started to decline to training stimuli ( 63.75% in the

sound transfer test with extinction procedure and 48.75% in the sound transfer test with nondifferential procedure), the experiences of which, were generally reflected to testing stimuli. If around chance level performances are found in the training performances, drastic fall will naturally be reflected in the transfer test. It is little complex to explain the drastic fall in Rat 4's performances. One possibility might be considered. Rat's performances may decline due to gradually becoming older even after receiving sufficient training. In our studies (in Experiment 2), since the completion of 166 sessions, Rat 2 began to show poor performances to the basic training stimuli (e.g., A, B, C, D, E, and F) and did not recover. Same was true for Rat 4 (although he could continue longer training efficiently as compared to Rat 2). After he had completed 361 sessions, he also began to show chance level performance and continued it to the end of the experiment without recovering.

Despite poor performances to training stimuli, we continued training sessions for Rat 4 in the possibility that rat's performances might recover. Notably, previously Rat 4's performances deteriorated to the chance level in different stages of the experiments. But at every case, his performances were recovered and reached significant level. Therefore, becoming older remains a concern for the rats' study. To reduce such limitations in rats' study, future study should involve such a thoughtful experimental procedure in which rats can complete cross-modal transfer test (whether the findings are significant or insignificant) within short time. According to the Long-Evans rat longevity database (source: Doug Skrecky, October 10, 1997) that on average, the life span of a Long-Evans rat was 32.6 months thus creating an impediment for carrying on longitudinal studies by which many dimensions of rats' investigation may be explored. It was reported (Burke, Wallace, Hartzell, Nematollahi, Plange, & Barnes, 2011) that older rats faced more difficulty to perform discrimination tasks relative to young. Because an aged rat is more vulnerable to interference. Furthermore, during aging, functional changes occur within the perirhinal cortex-dependent pattern separation thus resulting in difficulty in the discrimination tasks.

Conversely, pigeons (about 8 years) and monkeys (e.g., *Macaca mulatta*: Rhesus Macaque, 29 years. Source: National Primate Research Center, University of Wisconsin-Madison) live more than rats. Such long span of life offers much advantage for animal investigators to make many discoveries in a study. However, in sound transfer test 2, 15% transfer of learning was observed to the noise stimulus (X) made by Rat 4.





**Figure 26.** The transfer performances of Rat 4 in sound test 2. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45% correct,  $ps < .05$ ) in a session.

## General discussion

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The main findings of the present studies revealed transfer of oddity learning to novel stimuli. In object transfer tests, both rats showed significant transfer of learning to the novel object stimuli. Rats' test performances improved from 12 oddity tasks to 30 oddity tasks suggesting that the larger number of training stimuli might facilitate acquisition of abstract oddity learning. This is the first evidence that rats can acquire oddity discrimination learning. Oddity learning of object stimuli to the novel stimuli of other modality (odor) observed in the present study has never been found in rats. These robust findings suggested a relational learning consisted of much broader range of stimuli called domain free relational learning to some extent. Previous oddity studies (e.g., Thomas & Noble, 1988) trained rats with oddity problems that could be solved by single feature learning, configuration learning, or win-stay/lose-shift strategy. Problems in training procedure might have prevented rats from acquiring oddity concept learning in those previous studies. However, the rest two (Rat 1 and Rat 3) out of four rats in Experiment 2 could learn AAAB task but could not learn two oddity tasks (AAAB and BBBA).

### 4.1. Individual differences

Four rats (Rat 1, Rat 2, Rat 3, and Rat 4) went through the same experimental procedure in the present study. But Rat 1 and Rat 3 could virtually not learn the AAAB and BBBA concurrent tasks. Conversely, Rat 2 and Rat 4 could learn two oddity tasks. In addition, the transfer performances of Rat 2 (55% for EEEF and 50% for FFFE in transfer test 1 and 70% for GGGH and 55% for HHHG in transfer test 2) was more significant than those of Rat 4 (35% for EEEF and 60% for FFFE in transfer test 1 and 65% for GGGH and 55% for HHHG in transfer test 2). What caused this difference? The most plausible explanation was that an application of the relational learning to the stimuli considerably depends on the sensitivity employed by the subjects during solving the oddity tasks. More specifically, some rats might be sensitive to the physical features of the stimuli or to the combinations of specific pattern (configuration), whereas some rats might be more sensitive to the abstract relational property of the stimuli set that might led them to learn the discrimination tasks based on relational concept. Elmore et al. (2009) observed such individual differences in their studies. They trained three pigeons in a three-item simultaneous S/D discrimination task of two pictures. The results showed that two pigeons could acquire restricted-domain relational learning and the rest one could learn the tasks item-specifically.

#### **4.2. How does large number of stimuli facilitate the acquisition of relational concept?**

In the present study, it was observed that in one odd task (AAAB), a particular item B was used as an odd one in all the trials in a session. Single feature learning (memorizing the features of item B as positive stimulus) was sufficient for rats to solve the task. In Phase 2, when BBBA task was added, single feature learning became ineffective, because both of items A and B were used as positive and negative stimulus. But these two odd tasks could be solved by configurations of specific items. That is, item B was positive if there are many A in a stimuli set, and item A is positive if there are many B in the set. Therefore, rats can master the two oddity tasks (AAAB and BBBA) by memorizing some possible configurations of specific items. But this memorizing strategy would fail, or at least very difficult when rats faced with a large number of discrimination tasks. In the case of 30 oddity tasks, it should be far difficult to memorize all of the configurations of so many stimuli. Therefore, the larger number of tasks might make memorizing the number of tasks more difficult (Cook, Levison, Gillett, & Blaisdell, in press) and contribute to make memory load for memorizing strategy high. This difficulty might have forced rats to give up on the memorizing strategy and switch to a more conceptual based strategy (the application of an abstract rule that can contribute to reducing the increased memory load. (see also Santiago and Wright, 1984). Wright and Katz (2006) revealed that rhesus monkeys, capuchin monkeys, and pigeons were trained with 8-item set and 16-item set, they could not relationally learn these tasks. When the training set size was increased to 32 stimuli, monkeys showed evidence of partial S/D concept learning (a learning significantly above the chance and below the baseline performances) but pigeons showed no sign of transfer to the novel stimuli. Monkeys and pigeons showed full acquisition of abstract S/D concept learning (a learning equivalent to baseline performance with an accuracy of more than 80% correct) with the further expansion of the training set size to 128 and 256 items respectively. These findings suggest that larger number of stimuli might make the memory load for memorizing stimulus-specific cues high and facilitate animals to start acquiring relational learning. This memory load hypothesis explains why two rats in the present study showed transfer of oddity discrimination to novel stimuli after concurrent training with multiple tasks and their test performances improved from 12 oddity tasks to 30 oddity tasks.

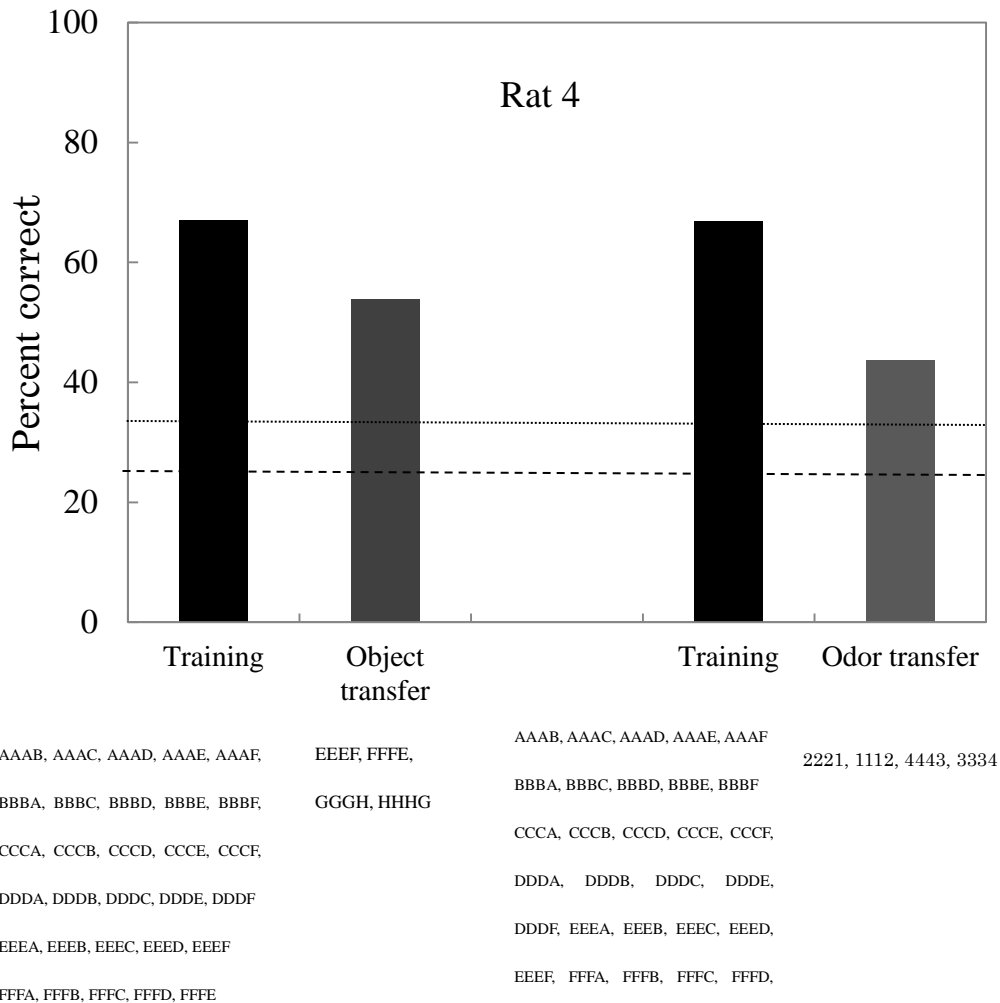
### **4.3.Facilitated relational learning is not only the possible explanation for improved test performances made by the larger number of stimuli**

Significant transfer may somewhat reflect generalization from training stimuli to transfer stimuli. Because larger number of stimuli may potentially increase the similarity between training and testing stimuli and such similarity contribute to significant transfer. Therefore, it becomes difficult to rule out the possibility that transfer may be based on some common physical features shared between the novel stimuli and some of the stimuli used in training (Mackintosh, 2000, p.132 cited from Wright & Katz, 2006). Wright and Katz (2006) observed such phenomenon in their studies. They mentioned that larger number of stimuli may contribute to stimulus generalization process resulting in good transfer. Human conceptual behavior showed that it is exemplar (Brooks, 1978; Hintzman, 1988; Nosofsky, 1986; Tarr & Bulthoff, 1998 cited from Blaisdell & Cook, 2005) and is determined based specifically on generalization from past experiences. I acknowledge that this theoretical possibility might be true for rats too and that both rats and humans might not engage in concept formation, but rather depend on similarity to past experiences to guide behavior.

In the present study, the acquisition training of Experiment 2 involved object stimuli. Test performance was improved in the transfer test 2 following training with six object stimuli than in the transfer test 1 following training with four objects. Hence, it might be possible that transfer performances might be the product of generalization from training stimuli to transfer stimuli thus posing a remaining concern for Experiment 2.

But comparative results of the object and odor transfer test might provide further explanations over this issue (Figure 27). It showed that when object transfer test was followed by object discrimination training, the transfer performances to the novel objects (EEEF, FFFE, GGGH, and HHHG) were on average 53.75%, whereas when odor transfer test was followed by object discrimination tasks, transfer to the novel odor tasks (2221, 1112, 4443, and 3334) were on average 43.75%. Better performance in object-object transfer than in object-odor transfer might be explained in terms of stimulus generalization. However, test performance was also significant in cross-modal odor test. Such significant cross-modal test performance is difficult to explain in terms of stimulus generalization from object stimuli to odor stimuli because, generally speaking, it is hard to find any similar physical features between object and odor stimuli (for cross-modal tests on oddity concept learning in children, see Tyrrell, 1974). The present study does not deny the possibility of stimulus generalization. But the results of the cross-modal test showed that rats, at least, partly learned relational property of the

oddy discriminative stimuli.



**Figure 27.** Comparative results of cross-modal transfer test. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (33.75% correct,  $p < .05$ ) in a session.

#### 4.4. How may many identical stimuli in a set make an odd stimulus salient?

In the present study, one odd and three identical stimuli are used. It is known that a one odd and two identical stimuli are the minimum requirements to construct an oddity task. Using one odd and three identical stimuli in the present study, we expected two different effects. One is increasing salience of an odd stimulus and another one is decreasing chance level. The first effect shows that the presentation of two or more identical stimuli along with an odd one in a trial induces a perception (the process of

recognizing and interpreting sensory stimuli) of sameness among identical ones that makes an odd stimulus contrast. Furthermore, such perception of sameness enhances the perception of difference among identical stimuli and odd stimulus in a set (Cook et al., 1997). Cook et al. (1997) reported successful discrimination of existence of an odd stimulus in pigeons using an odd and five identical stimuli.

The second effect shows that larger number of stimuli (e.g., ABBB) in an oddity task decreases the possibility of random responding because random responding might be less frequently rewarded in large number of oddity stimuli set. When random choice fails to attain sufficient reinforcement, animals may learn a relevant cue. There is no formal scientific report on this phenomenon but our laboratory has preliminary results (Okajima, 2010, unpublished data, personal communication with Tohru Taniuchi).

#### **4.5. Domain free vs. restricted-domain relational learning**

Experiment 3 was directed at clarifying whether rats' ability to learn abstract relational concept is limited to the stimuli set within which they were trained (object) or to be applicable to other novel stimuli set such as a set of odor stimuli. If rats are able to apply their relational learning to other novel stimuli set, it is considered the domain free relational learning. To acquire such learning, rats' making relational judgment within a restricted domain will need to expand their domain and apply the same relational judgment to other novel stimuli set. In contrast, if rats cannot apply relational learning of one modality to another novel stimuli set, it is considered the restricted-domain relational learning. It can be assumed that when the set size of the training stimuli becomes sufficiently large, the training and the testing stimuli may share some common properties of the stimuli (e.g., size, shape, color). Animals sometimes may keep such common properties in their memory and transfer to the novel stimuli on the basis of such similarity (stimulus generalization) rather than making concept formation. If animals constantly respond to the testing stimuli following such rule, their learning would be in a restricted domain.

It was reported (Nakamura et al., 2009) that learning might be relational but in a restricted domain. Humans had initially learned some relational tasks with a restricted domain that later in development gave way to relational factors (e.g., Chen & Mo, 2004). In the present study, although performances in odor transfer test were poorer than that of object transfer test, rats could show some cross-modal transfer of learning. These findings suggest that the domain of relational learning might be broader in the object stimuli dimension rather than the other dimensions (e.g., odor) in the oddity

discrimination tasks. The most important point was that Rat 4 was able to broaden his domain. This is very important result because it suggests somewhat domain free relational learning.

Rat 4 showed good transfer (53.75%) to the intra-modal transfer tests (e.g., in object transfer test involving EEEF, FFFE, GGGH, and HHHG tasks, whereas 43.75% in odor transfer test involving 2221, 1112, 4443, and 3334 tasks. Notably, test performances in odor novel tasks are significant if these ones are analyzed in total). But if the performances of object transfer test are compared with that of odor test, performances of object test are better than those of odor test. These object-to-odor test performances might be explained in terms of restricted-domain relational learning. Wright and Lickteig (2010) observed restricted-domain relational learning in their studies. They found that when novel-novel test (when both comparison stimuli were novel) was conducted, pigeons showed modest transfer to the test stimuli. By contrast, when novel-familiar test (when one of two comparison stimuli on transfer trials was one of the training stimuli) was conducted, pigeons showed no transfer to the test stimuli.

When an oddity task involves one modality, animals need to learn the tasks within the modality. They don't need to expand their domain. Restricted-domain relational learning was sufficient for solving these tasks and domain free relational learning was not needed. In this sense, restricted-domain learning is cost saving strategy. On the other hand, if animals are provided training involving various domains, they may learn somewhat domain free relational learning because restricted-domain learning is not sufficient for solving the tasks.

But how rats in the present study showed domain free relational learning is still unknown. It is reported (Elmore et al., 2009) that the transition of restricted-domain to learning with broader domain possibly occurs by turns. In the first stage, the subjects learn to compare the relationship among training and transfer stimuli in order to make a judgment of an abstract concept, but only in the cases in which both stimuli have an advantage to share some common features thus falling within the restricted-domain. In the second stage, when the number of stimuli is expanded resulting in broadening the domain, subjects learn to use relational processing to solve the tasks with a much broader range of items. Similar findings were found in the development of abstract thinking and analogical reasoning in children. According to Dumas, Hummel, and Sandhofer (2008) cited from Elmore et al. (2009), children's restricted-domain relational shift may transition from a domain based on its characteristics features to a domain based on its characteristic relational too. In the relational tasks, the subjects may initially learn the same/different aspects of the training stimuli and associate these

aspects with some responses that are reinforced. In the case of new exemplars, they may apply this rule more generally once they are able to grasp a full understanding of the relationship among stimuli. What may the physiological basis of such explanation be? One potential answer is that overcoming the restricted-domain requires a degree of cognitive flexibility (Elmore et al., 2009). It is reported (Watanabe, 2006 cited from Elmore et al., 2009) that a flexible system requires high costs than that of a fixed system (p. 632). Tasks consisted of small number of stimuli have few benefits of operating outside of the domain. Therefore, the subjects do not need to be cognitively flexible to solve the tasks. Conversely, tasks consisted of large number of stimuli increases the costs of a fixed system and decreases the costs of flexible system thus facilitating the latter one to win out that ultimately make possible an application of abstract concept to broader domain.

In the present study, gradual increase in training set-size might cause an expansion of domain along the stimulus dimension. If the process (novel-stimulus transfer and restricted-domain relational learning) expands and completely covers more diverse stimuli (an important features of concept learning that makes it unique- the range of an abstract rule develops rapidly than anything that might accrue from simple generalization) than would be understandable by any simple generalization process (Wright & Katz, 2007), it may turn in to a general application of relational concept. Perhaps, this process was somewhat in operation in the case of Rat 4 thus making him possible to generalize the relational strategy over the domain of stimuli of different modalities.

In object transfer test, transfer performances to the novel stimuli were above the chance level but below the baseline performances suggesting an acquisition of partial relational learning. Test performances which are above the chance and below the training performances imply that rat might use a complex learning strategy combining some relational treatment (to discriminate stimuli based on relationships) with an item-specific learning (Wright et al., 1984). Thus, multiple learning processes with cues in different levels (stimulus-specific cue, restricted-domain relational cue, domain free relational cue) might be involved in the oddity discrimination task in rats.

#### **4.6. Non differential reinforcement procedure and extinction procedure**

In nondifferential reinforcement procedure, every stimulus is reinforced during testing trials (please see in detail in chapter-III). It is worth noticing that if rats have no tendency to respond to an odd stimulus, their responses are expected to be the same to



all the stimuli, whereas if they have any tendency to respond to an odd item, they will get more reinforcement that can make the results a little bit biased in this treatment. However, nondifferential reinforcement procedure is widely used in animal research (e.g., Young et al., 1997. Please see in detail in introduction chapter).

According to extinction theory (please see in detail in chapter-III), if rats have any responding tendency to the odd items, this one may gradually decrease due to getting negative feedback more frequently for responding to the odd items. Therefore, extinction test procedure is considered more conservative testing procedure rather than nondifferential reinforcement procedure (Davis, 1992). Therefore, we adopted this procedure in some tests to examine rats' transfer performances.

#### **4.7. Effects of perceptual modalities in rats**

In the object discrimination tasks, rats moved here and there, touched and smelled the objects to distinguish these ones. In the cross-modal transfer test especially in odor discrimination tasks, they did not touch but sniffed. In recognizing stimuli of different modalities, rats seemed to employ all senses they had. For the adaptations to the demands of the environment, most species highly depends on only a few sensory modalities. Primates mostly depends on vision, hearing and tactile sensitivity to maintain their daily life (Slotnick, Hanford, & Hodos, 2000). For nocturnal rodents such as rats, vision, tactile plays a minor role in comparison with olfaction. Slotnick et al. (2000) trained rats on multiple two-odor discrimination tasks and tested them on novel two-odor tasks. Rats could acquire the odor-learning set very quickly suggesting that rapid acquisition of odor-learning set demonstrated rats' critical dependence on olfactory cues. There are further evidences on this issue where Brushfield, Luu, Challahan, and Gilbert (2008) trained 40 male rats to discriminate olfactory and visual tasks using two-choice discrimination and found that rats could learn olfactory tasks more readily than visual tasks. There is physiological basis of odor functions in rats. Previous studies (e.g., Johnson & Leon, 2000 cited from Slotnick & Bodyak, 2002) showed that odors produced a complex pattern of activity across the olfactory bulb and these patterns differ as a function of odor species. More specifically, sensory input to the olfactory bulb is arranged odotopically (Slotnick & Bodyak, 2002). Odor quality coding employs a combinatorial mechanism where each odor makes a pattern of activity across some set of bulbar glomeruli. Differences in these patterns together with synaptic interactions among bulbar neurons (Yokoi, Mori, & Nakanishi, 1995 cited from Slotnick & Bodyak, 2002) allow discrimination among odors. The individual pattern

represents the neural code for specific odors (Xu, Greer, & Shepherd, 2000 cited from Slotnick & Bodyak, 2002). As compared to odor sensitivity, rats have poorer visual acuity relative to humans. Rats can see 1 m as we can see 10 m (see <http://www.ratbehavior.org/RatVision.htm>). Furthermore, it was reported (Kurylo, Van Nest, & Knepper, 1997 cited from Minini & Jeffery, 2006) that relative to humans, rats had lack in using proximity (objects near each other tend to be grouped together) and alignment cues for perceptual grouping. Kurylo et al. (1997) trained rats to discriminate horizontal from vertical solid luminance-defined lines. But rats could not transfer to the similar arrays of stimuli consisted of disjoint elements (dots) varying in proximity and alignment suggesting a diminished ability to use proximity and alignment cues for perceptual grouping and it might be one of the possible candidate for poorer object recognition in this species. To provide evidence on visual discrimination tasks with rats, Minini and Jeffery (2006) trained five rats to discriminate between squares and rectangles or triangles (shape discrimination tasks). The shapes of squares and rectangles were varied in absolute size, relative size, luminance, and so forth. After acquisition training, five probe tests were administered using different shapes (e.g., kanizsa shapes formed from illusory contours, outline shapes, contrast shapes of squares and triangles). Their studies showed that rats could not use “squareness” or “triangleness” to solve the discrimination tasks rather responded based on the luminance in the lower position of the visual field suggesting a limited visual capacity to process the discrimination tasks.

It is difficult to specify what kind of perceptual modality played a principal role in recognizing oddity stimuli. However, considering rats’ perceptual ability and its influence on their performance described above (e.g., Slotnick et al., 2000), using olfactory modality in the cross-modal transfer test might contribute to transfer of learning to the cross-modal test stimuli in the present study.

#### **4.8. Why did different species (e.g., monkeys, pigeons, rats) show relational learning with different number of training stimuli?**

In the present study, rats showed significant transfer to the novel test stimuli after receiving training with four or six items. In Wright and Katz’s study (2006), it was observed that monkeys and pigeons could not show transfer to the novel stimuli with 8-items. Monkeys showed evidence of transfer of S/D discrimination to novel stimulus only after training with 32-items. Other experiments (e.g., Katz et al., 2002) also showed that monkeys could acquire full abstract concept learning with 128-items. Why

rats showed evidence of oddity learning with smaller number of stimuli in comparison with monkeys and pigeons? There are two possibilities. One is that rats might be more sensitive to relational cue than monkeys and pigeons. But it is unlikely considering previous negative results reported in relational learning studies in rats. Second is that less memory capacity in rats than monkeys and pigeons. Rats might have limited capacity to memorize multiple item-specific cues. When rats are given various tasks concurrently, they might abandon memorizing all item-specific cues because of their limited capacity and start to learn relational cue. Further investigation would be needed about the relationship between capacity for memorizing item-specific cue and sensitivity to relational cue.

#### **4.9. Differences between the experimental procedures of the present study and previous rats' study**

One key difference between the procedures of the present study and those in prior attempts may be the use of concurrent training of multiple oddity tasks. The present study trained rats with 30 oddity tasks concurrently. In concurrent procedure, positive stimuli are exchanged with negative ones among tasks. Therefore, no stimulus-specific cue is effective. Only relationship among stimuli is the most effective cue. Only when there is no simple and effective stimulus-specific cue, animals may employ relational strategy to solve the discrimination tasks (e.g., Lombardi et al., 1984; Wright et al., 1998). Concurrent training and use of larger number of training stimuli were markedly different from the training sets employed in prior studies. Koronakos and Arnold (1957) used only eight problems. Rats were trained with each problem (one-odd task) until they reached learning criterion. Following acquisition of learning criterion, rats were given second problem. In one-odd task, the same three discriminanda (e.g., ABB) are used in a stimuli set. Single feature learning seemed to be sufficient for solving one-odd task. In Wodinsky and Bitterman's study (1953), two-odd tasks were used. Rats were, at first, trained to choose an odd stimulus (black card) from among two non-odd identical stimuli (white cards). Following acquisition, the task was reversed (white card was made an odd stimulus and black cards were made non-odd identical stimuli). Then the second problem (white rectangle on black ground was made an odd stimulus and two black circles on white ground was made non-odd identical stimuli) was presented in the same manner as that of the first problem. In the two-odd tasks, memorizing some combinations of specific items (that is configurations) was sufficient for solving the discrimination tasks. Although Thomas and Noble (1988) used 300 problems, their

serial presentation training could not be effective for rats to acquire oddity concept. They showed improved performances on the second trial but not on the first trials. Such learning set could be explained by win-stay/lose-shift strategy but not oddity concept. Earlier I discussed that animals may, at first, try to employ the simplest way to solve the tasks. Only when they cannot find any simple way in the discrimination tasks, they may start to solve the tasks by applying relational learning strategy. As concurrent training bears no item-specific cue, such structure of stimuli set may lead rats to the relational learning.

#### **4.10. Do the research findings of the present study indicate the real concept?**

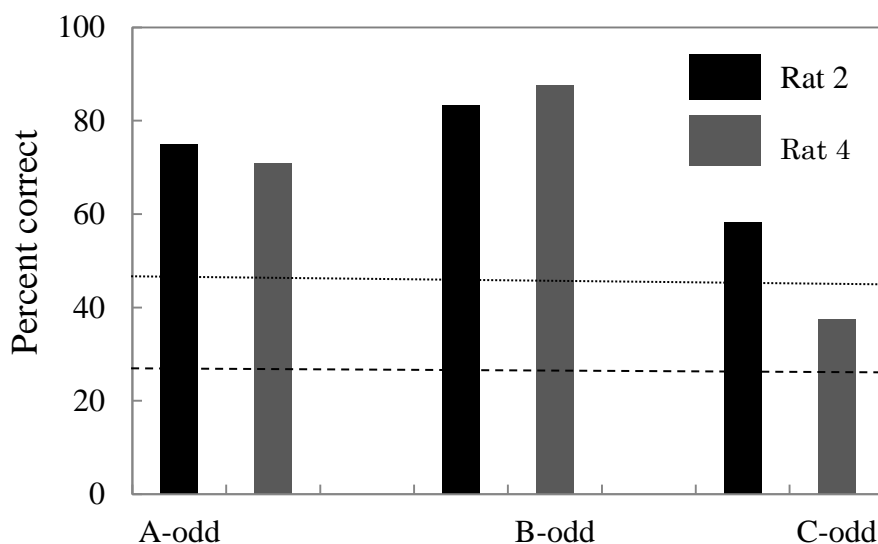
There could be some possible alternative explanations for successful learning of multiple oddity tasks and transfer of learning to novel stimuli. First, animals may sometimes make correct responses on the basis of perceptual oddity given by the arrays of stimuli. Forwood, Bartko, Saksida, and Bussey (2007) reported that rats explored an odd stimulus longer than two identical stimuli presented simultaneously although those oddity stimulus sets were presented first time to the subjects. In this study, both of the oddity and identical stimuli were completely novel to the subjects. Longer exploration of the odd stimulus might represent that the rats perceived perceptual oddity but not conceptual oddity in the stimulus sets. If rats learned to respond to stimulus that gave perceptual oddity, such learning could be applied to novel stimulus sets. At present, we might not be able to distinguish between perceptual oddity and conceptual oddity. This problem is not unique to the present study and relevant to other previous successful reports of oddity concept learning with other species (e.g., Hille et al., 2006; Lombardi et al., 1984). Obviously, further examination is needed regarding this matter.

Another possible candidate is that different objects might possibly have different odor. In this case, cross-modal transfer of oddity learning was, at least partially, intra-modal odor-odor transfer. Using pictorial stimuli in LCD monitor might be an effective way to eliminate this possibility, because such stimuli cannot have its own odor.

The third possibility is that all the stimuli (object, odor, and sound stimuli) were treated as object features. For example, some erasers containing different odor were used as odor stimuli. Similarly, an IC recorder representing as sound stimuli were kept in the yellow container that was used as sound stimuli. Rats' responding might be based on the features of different objects that might yield an object-to-object transfer. This does not mean that the results of our cross-modal transfer tests between object and odor

stimuli were not adequate. However, it might be important that these stimuli of different modalities were presented as features of objects to enhance cross-modal transfer.

The fourth possibility is that rats might learn an oddity task regardless of the physical features of the stimuli thus applying relational strategy.



**Figure 28.** The performances of the first 24 trials of each task after the introduction of item C. Broken line represents a chance level (25%) and dotted line represents a statistically significant performance level (45.83% correct,  $p < .05$ ) in a session.

One potential interpretation for the first perceptual oddity view and the fourth true relational learning view was that in our study, it was observed that when item C was added (Figure 28), Rat 2 made 75%, 83.33%, and 58.33% correct responses in A-odd task (e.g., BBBA), B-odd task (e.g., AAAB), and C-odd task (e.g., AAAC) respectively in the first three days. These findings showed that although Rat 2 made significant performances in A-odd and B-odd tasks, he did relatively poor performances in C-odd task suggesting that he might have learned some configuration learning. Rat 4 also showed the same tendency in A-odd, B-odd, and C-odd tasks (70.83%, 87.50%, and 37.50% correct responses respectively). If rats learned an abstract rule in A-odd and B-odd tasks, they could have transferred it to the novel item C. On the contrary, if they learned the tasks on the basis of perceptual oddity, their performances would be better to the novel item C because novel item C should have given more odd impression to rats than familiar items A and B. In this regard, configuration learning might be the suitable term for learning the AAAB and BBBA tasks. In the case of cross-modal

transfer test, different domain of stimuli (e.g., odor), the features of which, were completely different from those of object stimuli, were used. If rats responded based on perceptual oddity of the objects, their performances would be poorer.

For the second possibility, the rat might show significant transfer of oddity discrimination learning because the transfer task was actually between familiar odors and novel odors. In this case, our findings can be interpreted in terms of restricted-domain relational learning. We should admit the possible odor cue and it might be a reason for good transfer in odor-odor tasks, to a certain extent, because possibility that rats used odor of objects “partially” (they used both of visual and odor of objects) could not be ruled out by our explanation. In this regard, sound test may be a critical test (not in the present study but in a future study) that can rule out the possibility of different odor cues for objects. To eliminate odor cue in object discrimination, cross-modal transfer of oddity discrimination learning should be examined in a situation in which common physical properties do not exist. For example, visual oddity discrimination using LCD display and subsequent transfer to odor stimuli might be effective to test cross-modal transfer of oddity discrimination because visual stimuli in LCD display cannot have its own odors.

However, as there are no clear evidences of oddity concept with rodents, in this stage, the successful findings of the present study may be accepted widely. But a question still remains as a concern whether these findings indicate the real concept. Actually, distinguishing conceptual from perceptual dimensions seems to be a far more difficult. Many other studies (e.g., Wright & Katz, 2006; Lombardi et al., 1984) have also shown successful findings with monkeys and pigeons that are also questionable. I suggest transfer paradigm from oddity discrimination to S/D discrimination (or vice versa) to distinguish relational learning and perceptual similarities. According to the plan, the experimental group should be trained with 12 oddity tasks involving item A, B, C, and D and then a transfer test will be conducted following the Wright and Katz’s (2006) S/D two-item discrimination procedure. On the other hand, the control group would be trained with AAAB and BBBA tasks and then receive a transfer test involving the same procedures as that of experimental group. If rats learn the oddity task based on perceptual oddity, no effect of the number of training tasks on transfer performance is expected. On the other hand, if rats learn the oddity task in terms of relational properties of the stimulus sets, then considerable positive transfer effect in learning the S/D discrimination task is expected. Specifically, learning of the S/D discrimination task is expected to be faster in experimental group than control group. Such an experiment may be a part of the future research.

Another future task of the present study is to determine the effect of number of identical stimuli in the oddity discrimination tasks. As mentioned earlier, I assumed that larger number of identical stimuli might make a positive effect in decreasing chance level and increasing saliency of the odd stimulus. However, we have no objective data over this issue. One of the possible ways to examine the effect may be that two groups of subjects will be trained following the same procedure as used in the present study: One with smaller stimuli set (e.g., AAB) and another one with larger stimuli set (e.g., AAAAAB). If substantial differences in acquisition rate and transfer effect between two groups are observed, an effect of number of identical stimuli in the oddity discrimination would be demonstrated directly.

#### **4.11. Implications of the findings in general**

In sum, the present study provides some of the strongest evidences yet collected for the existence of the ability in rats to learn the oddity discrimination tasks on a conceptual basis. The empirical evidences of the present study will be helpful to discover animal intelligence indicating their potentialities and to identify the phylogenetic origin of abstract concept learning. In addition, this study may advance our thinking towards understanding human behavior indirectly by educational learning of mechanisms of abstract concept of animals. Notably, human brain contains 100 billion cells (Pearce, 2008, p. 19). It's still an issue of curiosity of how such a huge collection of neurons and synapses control our thoughts, actions, experiences and so on. The intelligence of humans share some features with those of animals. In this regard, an understanding of animal intelligence may provide an insight in to the mechanisms of human intelligence.

#### **4.12. Conclusion**

In the present study, several experiments were carried on to demonstrate an empirical evidence of relational concepts in rats. In Experiment 1, conditional place discrimination tasks (e.g., AA/BB vs. AB/BA) were given to rats in which an acquisition of item-specific learning was observed.

In Experiment 2, concurrent training of multiple oddity tasks was given to rats that provided convincing evidence of relational concepts in rats. One possibility remains concern that significant transfer to novel stimuli observed in Experiment 2 might be the product of stimulus generalization. In Experiment 3, cross-modal transfer test using the same procedures as those of Experiment 2 were administered and significant cross-modal transfer to the stimuli of different modalities was observed. These findings suggest that rat's learning was not mediated by the features of training stimuli. It is rather applicable to the stimuli of broader domain.

These robust findings may eliminate the possibility of item-specific learning in rats observed in Thomas and Noble's study (1988) and show first evidence of oddity concept learning in rats. Nevertheless, further examination is needed on several issues. First, determinants of individual differences should be examined. Second, present findings were observed in limited number of subjects. Obviously, further study should involve more number of rats in order to confirm inter-subject generality. Finally, some artifacts should be eliminated in the present results of cross-modal transfer of oddity discrimination. To prove real relational concept learning in rats, further studies with sophisticated procedures should be administered.



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