Cross-modal transfer of oddity concept learning from visual to olfactory stimuli in a domestic cat (Felis catus)

Siddik Md. Abu Bokor[1,*], Akter Mst. Yeasmin[2]

Pet Behaviour Science
2026, Vol. 21, 50 - 61
doi:10.21071/pbs.vi21.18835

Siddik Md. Abu Bokor[1,*]
*Email: siddikbogra@yahoo.com

Akter Mst. Yeasmin[2]
[1]Professor, Department of Psychology, Government Azizul Haque College, Bogura, Bangladesh
[2]Graduates from the Government Azizul Haque College, Bogura, Bangladesh

Abstract: *The present study tested a domestic cat with novel odor stimuli sets (IIJ, JJI in odor test 1 and KKL & LLK in odor test 2) inserted after every four oddity training tasks, consisting of object stimuli. The findings showed that the cat demonstrated significantly above the chance transfer performance (90% for novel odor stimulus I and 100% for J in test 1; 95% for L and 100% for K in test 2) from object to odor modality, apparently indicated that the cat might have adopted a relational understanding to learn the oddity tasks. Nevertheless, the possibility of stimulus generalization, the sense of perceptual oddity or effect of oddity preference could not be excluded.*

Keywords: concurrent training; cross-modal transfer; oddity concept; stimulus generalization

HIGHLIGHTS

- The cat learned multiple oddity problems at acquisition phases.
- He transferred training experiences of object stimuli to odor sensory modality.
- These findings apparently indicated that a sign of relational understanding was affecting his cognitive behavior.

INTRODUCTION

Oddity concept learning refers to the ability to consistently pick the odd stimulus from two or more identical stimuli across changes in oddity problems (e.g., AAB, BBA, AAC, and CDC) and transfer this learning to novel problems (i.e., those never seen before) in a transfer test.

A handful of research studies on oddity concept learning in cats (e.g., Boyd & Warren, 1957; Warren, 1960; Strong & Hedges, 1966; Siddik & Yeasmin, 2025) have been conducted, in which cats were trained with object stimuli and tested with novel object stimuli. This process is called the intra-modal transfer tests of oddity concept learning. However, there is a concern that the transfer observed in such tests may reflect generalization from training stimuli to transfer stimuli, which may contribute to significant transfer

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Akter Mst. Yeasmin[2]

(Mackintosh, 2000). To address this concern, cross-modal transfer of learning can be considered a suitable approach.

Cross-modal transfer of learning has been examined in a range of animal species, such as rhesus monkeys (Cowey & Weiskrantz, 1975); dolphins (Schusterman, 1990); honeybees (Giurfa et al., 2001); rats (Winters & Reid, 2010); or electric fish (Schumacher et al., 2016). To the best of our knowledge, no study has yet attempted to demonstrate this higher-order cognitive ability with respect to cross-modalities in cats. Therefore, very little is known about this ability in cats. Hence, a question arises as to whether cats can transfer oddity learning from one sensory modality (e.g., visual) to a different modality (e.g., odor). In response, the present study aimed to explore cross-modal oddity learning abilities in a cat. To test whether there is similar neural mechanisms across various species during the higher-order learning task like the oddity learning may advance our understanding about comparative cognition.

METHODS

Subject

One adult male cat (N=1) aged 11-month-old, a household pet belonging to the Turkish Angora breed with unrestricted access to roam indoors was used as the subject of the present study.

Ethics

The present study received approval from the Department of Psychology of the Government Azizul Haque College, Bogura, Bangladesh during its 15th meeting held on November 14, 2024 (memorandum number: D.O.P.G.A.H.C.14.2024) and was conducted following the guidelines of the animals (Scientific Procedures) Act 1986 as well as EU directive 2010/63 for the protection of animals used for scientific purposes.

Apparatus and stimuli

A custom-made discrimination box, constructed from hard paper, was used in the experiment. The apparatus consisted of several components, including one entrance and three goal boxes, each with two doors to prevent food odors from escaping (Figure 1).

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Akter Mst. Yeasmin[2]

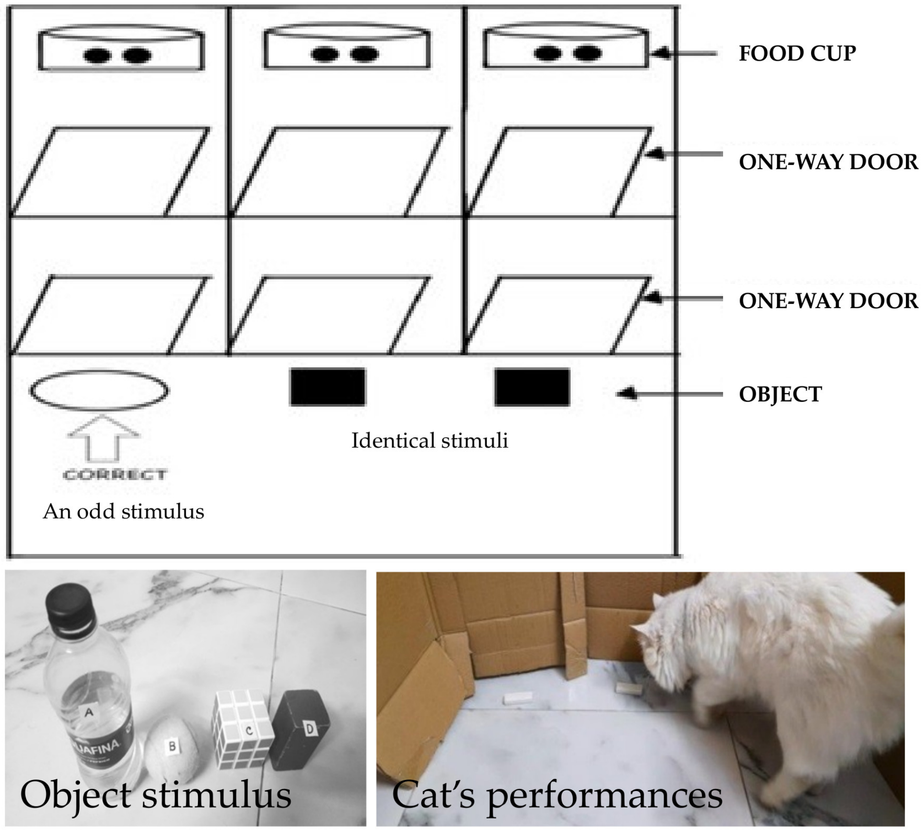

Figure 1. A diagram of apparatus (top), photos of training stimuli (middle) and an example of the cat's performances in the test phases (below) in which the cat was seen identifying a novel odd odor stimulus (I) from two other novel identical odor stimuli (JJ) in the cross-modal transfer test 1.

The overall dimensions of the apparatus were 46 inches in length, 20 inches in height, and 36 inches in width. Each goal box measured 22 inches in length and 13 inches in width. The cat could enter the goal boxes by pushing the doors open. One odd and two identical stimuli were placed in front of the doors of the goal boxes. A food cup filled with cat food named cat's enjoy made of fish and meat was placed at the back of each goal box, but the cat was allowed to get the food of only the correct goal box containing odd stimuli. The three goal boxes were positioned side by side, separated by partitions that were 1.2 cm wide. Four objects (a bottle, a tennis ball, a puzzle box and a wood block) and four odors (Davidoff Cool Water Wave perfume, a rose fragrance, a spicy scent, and a perfume oil roll) equally applied to four identical erasers were used as training and testing stimuli respectively. The size of the eraser we used for transfer test was .5.25 2.5 inches (width, depth, length). Throughout the study, the cat was treated with care, dignity, and respect, ensuring a setting free from discrimination, harassment, bullying, or retaliation.

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Procedure

A single-subject experimental design (N=1) was used with repeated measure time-series methodology in which behavioral performances were assessed as a time-series of trial-by-trial or session-by-session accuracy across repeated novel odor oddity discrimination tasks presented within the visual oddity training tasks. The design included within-subject measurement across time, baseline characterization and replication of effects across stimulus exemplars and experimental phases. The cat received preliminary and acquisition training in a visual oddity learning tasks (e.g., AAB, BBA, DDC and CCD) in Siddik and Yeasmin (2025). After the completion of the acquisition phases and the intra-modal transfer tests (object-novel object) reported in Siddik and Yeasmin (2025), the same subject was tested from visual to odor stimuli in the present study. As the data of the acquisition training were published in Siddik and Yeasmin (2025), we deleted these data in the present study. We presented only the data of the cross-modal transfer tests in the present study. We confirm that no data in the present submission have been previously published. The procedures of the preliminary and acquisition phases were mentioned in the following ways:

Preliminary training

For the first three days, the cat underwent daily handling for five minutes and was provided with 100 mg food pellets. On days 4–6, it was given 20 minutes to explore the apparatus, with three pieces of cat food placed inside each goal box and six near the entrance. The cat was allowed to consume the food during this exploration period, which continued until it entered the goal boxes without hesitation. On day 7, the shaping process began to train the cat to push open the one-way doors. During this phase, two of the three doors were blocked, allowing the cat to access only the open goal box. Each goal box was used equally for training. Gradually, the cat learned to enter a goal box with a fully closed door. The number of trials per day was progressively increased from four to twenty. By day 10, the cat consistently entered the goal boxes without hesitation.

Acquisition training and transfer testing

Once shaping was complete, the main training began with Phase 1, which introduced the AAB task. In this task, the cat was presented with two identical stimuli (AA) and an odd stimulus (B). Only responses to the odd stimulus were rewarded with three food pellets. The position of the odd stimulus was counterbalanced, and its placement in one of the three goal boxes was randomized (e.g., ABA, BAA, AAB) to minimize position and

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Akter Mst. Yeasmin[2]

sequence biases. The cat participated in daily sessions consisting of 20 trials, with a 1-minute inter-trial interval (ITI) between each trial. During the arrangement of the stimulus objects between trials, the cat was confined in a hard paper enclosure positioned behind the experimenter, preventing visual access to the stimulus setup process.

When the cat discriminated an odd stimulus from two identical stimuli in a stimulus set, the experimenter was behind the cat and refrained from providing auditory or visual cues during stimulus selection. Therefore, there was hardly any opportunity for the cat to get any cue from the experimenter that might help it solve the oddity problem.

A correction procedure was implemented during acquisition training. Following an incorrect response, the cat was allowed to make an additional choice within the same trial. If the cat subsequently entered the correct goal box, reinforcement was delivered. If the cat failed to enter the correct goal box, the trial was terminated without reinforcement. Only the cat's initial response on each trial was included in the accuracy analysis; responses made during correction trials were excluded from performance calculations.

To prevent odor cues from serving as distinguishing factors, multiple control measures were implemented. First, Objects used in the previous trials were wiped down during the inter-trial interval. Second, to minimize the possibility that odor cues could guide discrimination, the two identical objects and the odd object presented on each trial were randomly selected from a pool of four objects for each object type. Third, the assignment of identical objects to goal box positions was randomized. The learning criterion was set at 16 correct responses out of 20 (80%) across two consecutive sessions, at which point the cat advanced to Phase 2. In Phase 2, both AAB and BBA tasks were introduced and presented randomly within each session. The cat completed 10 trials of each task per day. Once it achieved 17 correct responses for each task over two consecutive sessions, it progressed to Phase 3. This phase introduced three oddity problems (AAB, BBA, and AAC) using stimuli A, B, and C. Each session contained seven trials for each problem type. The cat moved on to Phase 4 upon reaching a learning criterion of 16 correct responses out of 21 in a single session. Phase 4 expanded the complexity by introducing four oddity problems (AAB, BBA, DDC, and CCD) featuring stimuli A, B, C, and D. Each session consisted of five trials for each problem. In this study, item A corresponded to a bottle, item B to a tennis ball, item C to a Rubik's Cube, and item D to a wooden block (see Figure 1). When the cat met the learning criterion of 30 correct responses out of 40 across two days consecutively, it proceeded to the odor transfer test 1.

Note: Siddik and Yeasmin study (2025) set the learning criterion (LC) for each phase as follows:

• Phase 1: 80 % (16/20)

• Phase 2: 85 % (17/20)

• Phase 3: 76.2 % (16/21)

• Phase 4: 75 % (15/20)

LC was determined based on the complexity of the oddity problems. For example, in Phase 1, one oddity problem (AAB) was presented in 20 trials per session. This oddity problem was relatively easy to learn; therefore, an accuracy criterion of 80 % correct responses across two consecutive sessions was set as the LC for one oddity problem. In Phase 2, the criterion was set at 85 % correct responses (17/20) across two consecutive sessions for each oddity problem (AAB or BBA). This was because Phase 2 was the first stage that could form the foundation for mastering oddity problems concurrently and logically for the cat. If the cat learned the two oddity problems logically and consistently with high accuracy in Phase 2, relational understanding might be established. Consequently, oddity problems in the next phases, such as Phase 3 and Phase 4, might be easier for the cat to solve relationally. Therefore, the LC was set higher for the two oddity problems.

For Phase 3, the LC was set at 76.2 % %. If 15 correct responses out of 21 had been used, the LC would have been 71.42 %. Conversely, if 17 correct responses out of 21 had been used, the LC would have been 80.95 %. To align the LC with Phase 4, we set it at 76.2 %. For Phase 4, the LC was set at 75 %, as these multiple-oddity tasks were likely more difficult for the cat to solve. Therefore, we slightly lowered the LC for this phase.

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Odor Transfer Test 1

Two test trials for each novel odor oddity problems (e.g., IIJ or JJI) were inserted after every fourth training trials (e.g., one test trial-4 training trials-one test trial-four training trials and so forth).Each session included 16 training trials, consisting of object stimuli and four test trials. It continued for ten days. Note: Novel item I = Odor stimulus named Davidoff cool water wave [chemical properties are Alcohol Denat, Aqua (Water), Parfum (Fragrance oils), Linalool, Limonene] and Novel item J= odor stimulus named Rose [chemical properties are Geraniol, Nerol, Phenethyl alcohol].

Odor Transfer Test 2

Same procedures as those of Transfer Test 1 with an exception that Transfer Test 2 involved two novel odor oddity problems (KKL and LLK). Note:

Novel item L = spicy odor (chemical properties are yellow oily liquid, volatile, aldehyde group) and Novel item K= odor named perfume oil roll (chemical properties are Carrier Oil: Jojoba Oil, Fractionated Coconut Oil, Mineral Oil, Fragrance Compounds: Vanillin).

Note: One drop of each different odor was put on each eraser with a dropper that was used for a particular odor, meaning that four droppers were used for four odors (I, J and K, L). When the amount of odor decreased, the same procedure was repeated for each eraser that was kept separately between trials to prevent odor contaminations.

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doi:10.21071/pbs.vi21.18835
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RESULTS

Odor Transfer Test 1

The cat scored on the first trial (first-trial data) to the novel odor item I in the novel odor oddity task JJI when it, at first, appeared in the first session of 10 sessions of odor transfer test 1 (Table 1).

Sessions	Baseline performances (%)	Correct responses for Novel odor I (%)	Correct responses for novel odor J (%)
1	93.75	50	100
2	81.25	50	100
3	93.75	100	100
4	93.75	100	100
5	100	100	100
6	100	100	100
7	81.25	100	100
8	100	100	100
9	75	100	100
10	100	100	100
	91.87 (147/160)	90 (18/20)	100 (20/20)

Table 1. Cat's transfer of learning from object stimuli to odor stimuli session by session in Odor Transfer Test 1.

The transfer performance was 100% correct (one-tailed binomial test, $p < 0.01$) for the novel odor oddity item I in the JJI oddity task in all the test sessions except the first two sessions of 10 sessions. However, overall test

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performance in 10 test sessions for the JJI novel odor oddity task was 90% (18 correct responses out of 20 novel odor oddity tasks) correct (one-tailed binomial test, $p < 0.01$). Comparatively better test performance was observed for the other novel odor oddity item J in the IIJ oddity task. In detail, the cat correctly responded (100% correct or 20 correct responses out of 20 novel odor oddity tasks) to all the novel odor oddity tasks (IIJ) in 10 days' test sessions (one-tailed binomial test, $p < 0.01$). For both the novel odor oddity tasks (IIJ and JJI), transfer performances were significantly (one-tailed binomial test, $p < 0.01$) above the chance (33.33%) and consistent. The baseline performance (performances with training stimuli presented before or after the test trial with novel oddity problems in a test session) (91.87% correct, one-tailed binomial test, $p < 0.01$) was significantly above the chance (33.33%), steady and consistent across all the 10 day's sessions with a little deterioration in the session number nine (75% correct, one-tailed binomial test, $p < 0.01$) under the novel odor stimulus conditions.

Odor Transfer Test 2

The responding pattern of transfer test 1 was replicated in transfer test 2 showing consistently high accuracy across odor stimuli sets (Table 2).

Sessions	Baseline performances (%)	Correct responses for Novel odor I (%)	Correct responses for novel odor J (%)
1	100	100	100
2	100	100	100
3	100	100	100
4	93.75	100	100
5	100	50	100
6	100	100	100
7	93.75	100	100
8	93.75	100	100
9	93.75	100	100
10	93.75	100	100
	96.87 (155/160)	95 (19/20)	100 (20/20)

Table 2. Cat's transfer of learning from object stimuli to odor stimuli session by session in Odor Transfer Test 2.

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doi:10.21071/pbs.vi21.18835

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This pattern caused within-subject replication across stimulus conditions, a main criterion in single-case experimental methodology. In detail, the cat made correct response to the novel odor item L in the KKL novel odor oddity task on the first trial (first-trial data) of the first session of transfer test 2. In addition, he correctly responded to all novel odor oddity tasks [100% (2/2) for KKL & 100% (2/2) for LLK, one-tailed binomial test, $p < 0.01$)] in the first session of transfer test 2. The mode of his correct responding to all novel odor oddity tasks [95% (19/20) for KKL & 100% (20/20) for LLK, one-tailed binomial test, $p < 0.01$] continued across 10 day's test sessions except for the novel odor item L [50% correct (1/2)] in the fifth session of transfer test 2, suggesting a stable, consistent and significantly above the chance level transfer performances.

Baseline performances started with 100% correct from test session 1 to test session 6 with exception the test session 4 [93.75% correct (15/16), one-tailed binomial test, $p < 0.01$]. Although baseline performances declined to some extent from session no. 7 to session no. 10 [93.75% correct (15/16),] for each session], these ones were significantly above the chance (one-tailed binomial test, $p < 0.01$), suggesting a good ground of acquisition learning.

DISCUSSION

The cat demonstrated significant baseline performances and transfer of learning from object stimuli to odor stimuli in the cross-modal transfer tests with the first trial transfer data, apparently indicated that he understood the relationship between odd and identical stimuli in the training stimuli set that might have helped him spread this relational understanding over the novel odor stimulus modalities in the cross-modal transfer tests.

These results are consistent with those of Giurfa et al. (2001) who trained an individual group of bees across different modalities (from olfactory to visual) with Matching-to-sample (MTS) and Nonmatching-to-sample (NMTS) procedures and found that bees were able to transfer MTS and NMTS abilities to novel stimuli that shared no physical features of the stimuli specified in the training.

Now a question arises what facilitated the cat to make the significant transfer of learning from object modality to odor modality in the cross-modal transfer tests. The precise cognitive processes remained unknown. However, it can be assumed that concurrent training of multiple oddity tasks might contribute to the cat's significant transfer of learning in the cross-modal transfer tests. According to the concurrent training, a stimulus (e.g., A in the BBA stimulus set, in which stimulus A is an odd stimulus) that

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is correct in a trial turns into incorrect in another trial (e.g., AAB stimulus set, in which stimulus A is an identical stimulus). Such a presentation of stimuli helps the subject understand that responding to a particular stimulus will not solve the oddity problem. Rather unearthing a relationship (which is an odd stimulus and which are the identical ones) between or among the stimuli is the main way to solve the tasks thus propelling the subject to adopt relational strategy to work out the discrimination tasks.

Multiple oddity tasks involve many stimuli as odd stimuli in the oddity learning tasks. In the present study, we used four oddity problems (one oddity problem with AAB oddity task; two oddity problems with AAB and BBA tasks; three oddity problems with AAB, BBA and AAC tasks; four oddity problems with AAB, BBA, DDC and CCD tasks).

It is reported (Cook, Levison, Gillett & Blaisdell, 2005) that when many stimuli were used in the training tasks, a large number of configurations of stimuli produced that might make memorizing the number of tasks more difficult and make the subject's memory load high. This difficulty might pave the way for the subject to give up the memorizing strategy and switch to a more conceptual based strategy (an abstract rule that can contribute to reducing the increased memory load) (see also Santiago & Wright, 1984). Recent oddity studies with cat (e.g., Siddik & Yeasmin, 2025) and rats (e.g., Lazarowski et al., 2019) demonstrated evidence of oddity concept learning employing concurrent presentation of multiple oddity tasks.

There were some concerns in the present study. First, the present study used only one cat. Based on the findings of only one cat, it was difficult to generalize these findings over the cat species. To overcome this limitation, future oddity study should be conducted with more number of cats.

Second, significant transfer may somewhat reflect generalization from training stimuli to transfer stimuli. We know that every object may have a specific odor that may share the same with the novel odor stimuli. Such similarity between the odor of the object stimuli and the novel odor stimuli may contribute to significant transfer. To overcome this limitation, a critical test involving the sound stimuli might be considered in the future study.

Third, the present study did not conduct the olfactory baseline discrimination tasks prior to the transfer test with an aim to verify the possibility whether the cat could perceptually discriminate the specific odors used. Without this baseline discrimination tasks, significantly above the chance level transfer performance cannot unambiguously be regarded

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Akter Mst. Yeasmin[2]

as the concept formation, because the cat might have pre-existing olfactory sensitivities to the odor used in the present study.

Fourth, novelty preference effect might facilitate the cat to show the significant transfer to the novel odor stimuli in the cross-modal transfer tests. Zola et al., (2000) gave monkeys opportunities to see a particular picture for a sufficient time and later to see the same picture and a novel picture. They found that monkeys spent more time for the novel picture rather than the familiar picture. To reduce such concern, relational nonmatching-to-sample concept learning (RNMTS) tasks (e.g., AA vs. BB & CD) might be considered in the future study.

Finally, it can be said that due to having some concerns, it is difficult to conclude that the cat could apply the relational strategy to acquire higher-order learning. But his higher accuracy in baseline performance and transfer tests apparently indicated that something (a sign of relational understanding) was affecting his cognitive behavior in relation to the odd stimuli of different modalities.

ACKNOWLEDGMENT

We would like to give our sincerest thanks to Md. Muhib Raihan who helped conducting experiments of the present study.

FUNDS

The present study received no funds.

CONFLICT OF INTEREST

The authors declares no conflicts of interest

AUTHOR CONTRIBUTIONS

Md. Abu Bokor Siddik: Conceptualization, Data curation, Supervision, Validation, Formal analysis, Visualization, Writing - original draft, review & editing.

Mst. Yeasmin Akter: Investigation, Visualization, Record of data, Formal analysis

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the author(s) used ChatGPT in order to improve readability and language of the present manuscript. After using this tool/service, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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2026, Vol. 21, 50 - 61
doi:10.21071/pbs.vi21.18835

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Siddik Md. Abu Bokor[1,*]

Akter Mst. Yeasmin[2]