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Authors

Siddik, Md. Abu Bokor
Mushtari, Bushra
Akter, Nadia

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A Case Report on an Investigation of Oddity Concept Learning in Humans (*Homo sapiens*) with Olfactory Stimuli

Md. Abu Bokor Siddik [1], Bushra Mushtari [1], & Mst. Nadia Akter [1]

[1]Department of Psychology, Government Azizul Haque College, Bogura, Bangladesh

The present study aimed to investigate whether children could acquire the oddity concept using olfactory stimuli. To this end, three children aged 3 to 6 years were concurrently trained on multiple odor oddity problems and tested with novel ones. The findings showed that the 6-year-old participant mastered the acquisition training and transferred this experience to the novel oddity problems in the transfer test, suggesting that the child had acquired a relational understanding of the difference between odd and identical odor stimuli. Factors influencing the acquisition of the oddity concept were discussed.

Keywords: concurrent presentation, oddity concept, odor stimuli, stimulus generalization

ヒトにおける嗅覚刺激を用いた異質概念学習の事例研究

本研究は、ヒトの幼児が嗅覚刺激を用いて異質概念を獲得できるのかを調べることを目的とした。この目的を達成するために、3 歳から 6 歳の 3 名の幼児を対象に、嗅覚を用いた複数の異質課題を同時に訓練し、新奇課題を用いてテストした。実験の結果、6 歳の被験者は獲得訓練を習得し、転移テストにおいてその学習経験を新たな異質課題に適用することができた。このことは、幼児が異質刺激・同一刺激の違いに基づく関係的理解を獲得できたことを示唆している。異質概念を獲得できた要因について議論した。

キーワード：同時提示、異質概念、嗅覚刺激、刺激般化

Un Informe de Caso Sobre una Investigación del Aprendizaje del Concepto de Rareza en Humanos (Homo sapiens) con Estímulos Olfativos

El objetivo del presente estudio fue evaluar si los niños podían adquirir el concepto de rareza a partir de estímulos olfativos. Para tal fin, tres niños de entre 3 y 6 años fueron entrenados concurrentemente en múltiples problemas de rareza olfativa y posteriormente evaluados mediante problemas novedosos. Los resultados indicaron que el participante de 6 años alcanzó el criterio de dominio durante la fase de adquisición y transfirió dicha experiencia a los problemas nuevos en la prueba de transferencia, lo que sugiere la adquisición de una comprensión relacional de la diferencia entre estímulos olfativos distintos e idénticos. Finalmente, se discuten factores que podrían influir en la adquisición del concepto de rareza.

Palabras clave: presentación concurrente, concepto de rareza, estímulos olfativos, generalización de estímulos.

The oddity concept has been studied for a long time. Most oddity studies involving humans (*Homo sapiens*) have used object stimuli (e.g., Bryant et al., 1988; Frijters, 1981; Krekling et al., 1989; Tyrrell, 1974), which might have specific features—such as visual, tactile, or pictorial cues—that could serve as discriminative stimuli and help participants solve the oddity tasks. Because object, tactile, and pictorial stimuli contain physical features, they may unintentionally assist in discrimination. To eliminate the possibility of relying on perceptual cues in oddity concept learning, studies using olfactory stimuli may be more appropriate, as odors lack obvious physical features. Although several studies (e.g., Chu, 2008; Gottfried et al., 2002) measuring learning-related performance in humans with a classical conditioning paradigm have used olfactory stimuli, there is little to no research investigating learning abilities in humans using an oddity learning paradigm with olfactory stimuli. Therefore, the present study aimed to explore this possibility in humans with olfactory stimuli.

Please send correspondence to Md. Abu Bokor Siddik, Department of Psychology, Government Azizul Haque College, Bogura, Bangladesh. Email: siddikbogra@yahoo.com

Oddity concept learning reflects the ability to consistently identify the stimulus that differs from others in a set and to transfer this learning to novel stimulus sets. For example, in a set with one green circle and two yellow squares, the green circle is the odd item. If a participant can discriminate the odd stimulus and transfer this ability to a new set (e.g., one triangle and two rectangles), it indicates that he/she has learned the relational property of the stimulus set. Transfer to novel items is considered evidence of oddity concept learning (Wright, 1991). The oddity concept is an important example of relative class concepts in the hierarchy of intellectual abilities (Thomas, 1980). It also enriches our understanding of cognitive abilities from a comparative perspective (e.g., Wasserman, 1993).

In 1969, Neimark and Horn investigated discrimination and oddity learning set in a two-year-old girl using card stimuli and found evidence of a learning set. Similarly, the present study investigated oddity learning ability in two three-year-old boys and a six-year-old girl using olfactory stimuli. These three human participants were trained using the concurrent presentation of multiple oddity tasks. Concurrent presentation means that an item (e.g., A) used as the odd item in one trial (e.g., BBA) may serve as a non-odd item in the next trial (e.g., AAB). In this procedure, participants must understand which item is different and which are identical within each stimulus set. Memorizing specific items is not useful in this context. Therefore, we hypothesized that the participants in this study would acquire the oddity concept.

Method

Ethics Statement

The present study was approved by the department of Psychology, Government Azizul Haque College, Bogura, Bangladesh and followed the APA ethical guidelines (https://www.apa.org/ethics/code2002.html) for the use and treatment of human participants in research.

Participants

Three children (two 3-year-old boys and one 6-year-old girl) participated. Informed consent was obtained from the children's parents. Participants were free to spend their time at home or school as they chose, except during the experimental sessions. They were also given the option to continue participating until a goal was reached or to withdraw at any time.

We selected two three-year-old boys to investigate whether the ability to learn the oddity concept emerged at that age using olfactory stimuli. Previous studies (e.g., Christie & Gentner, 2014) also used 2- to 5-year-old children to investigate relational matching-to-sample concept learning. A six-year-old girl was also included in the present study, as significant cognitive developments—such as concept formation—typically occur at this stage of human development (Piaget, 1936).

Apparatus and Stimuli

Four different odors (Lemon, Beli, Bullet wood, and Dark chocolate) were used to create multiple oddity tasks. Notably, the odor "Beli" spreads a smell similar to that of Arabian jasmine. For the transfer test, two novel odors (Spanish jasmine and Night-blooming jasmine) were used, which had not been presented during oddity training (see Procedures for details). All six odors (Lemon, Beli, Bullet wood, Dark chocolate, Spanish jasmine, and Night-blooming jasmine) were evenly applied to identical erasers used as stimuli. We used erasers because they were easier for the children to handle.

Each eraser measured 0.5 × 0.25 × 2.5 in. (width × depth × length). In each trial, three identical erasers with different odors were presented: one contained the odd odor, and the other two shared the same odor. The erasers were placed on a table measuring 30 × 20 in. (length × width). There was a 12-inch gap between each eraser so that odors could not spread from one eraser to another (see Figure 1).

Figure 1

A Photo of a Subject with Stimuli



Procedure

In an oddity discrimination task, a combination of one odd odor (e.g., Lemon) and two identical odor stimuli (e.g., Beli) arranged in a row was presented concurrently. In this arrangement, a specific stimulus served as the positive odd stimulus in one set and as a negative (non-odd) stimulus in another set. On every trial, the children (participants) were allowed to smell any of the three stimuli in the set according to their choices, with a time limit of three minutes.

In Phase 1, a one-odd task (AAB), where A indicated the odor Lemon and B indicated the odor Beli was presented. A response to the odd stimulus was reinforced with verbal rewards (e.g., "thanks," "marvelous," or "good"). In the case of incorrect responses, no reward was given. The position of the odd stimulus was counterbalanced. Participants were trained in daily sessions consisting of 24 trials in total. Each trial was separated by a one-minute inter-trial interval. The learning criterion (LC) for Phase 1 was set at 20/24 correct responses (more than 80%) across two consecutive sessions. Meeting this criterion allowed participants to progress to Phase 2, in which two oddity tasks (AAB and BBA) were presented concurrently. Twelve trials of each task (AAB/BBA) were conducted daily.

When participants achieved at least 75% accuracy (18/24 correct responses) across the AAB and BBA tasks together on two consecutive sessions, Phase 3 began. In this phase, three oddity tasks (AAB, BBA, and AAC) consisting of odors A, B, and C (C = Bullet wood) were presented. Reaching 75% correct responses across the three tasks on two consecutive sessions allowed participants to move to Phase 4, which comprised four oddity tasks (AAB, BBA, DDC, and CCD), where D indicated the odor Dark chocolate.

Upon meeting the learning criterion (75% correct responses across AAB, BBA, DDC, and CCD on two consecutive sessions) in Phase 4, a transfer test was introduced. In this test, each novel oddity task consisting of novel odors (e.g., FFE or EEF) appeared twice after every four training tasks (AAB, BBA, DDC, and CCD) within a session. For example: one novel task (EEF), four training tasks; one novel task (FFE), four training tasks; one novel task (FEE), four training tasks. In this manner, four novel tasks were inserted into the training tasks each day, resulting in 24 trials per session (20 training tasks and 4 testing tasks). This procedure continued for ten days.

Note. The LC was set based on the complexity of the oddity tasks. Specifically, the easier the oddity task (e.g., AAB in Phase 1), the higher the LC. The more complex the oddity task (e.g., four oddity tasks in Phase 4), the lower the LC.

Data Analysis

The accuracy rate for each task across different sessions and phases was expressed as a percentage to facilitate comparisons with chance level and across individuals. A binomial test was conducted to determine whether the participants' performances were significantly above chance. We also used a one-tailed test because we expected the participants to perform better than chance (not worse). The chance-level performance was set at .33, since there were three stimuli in each set. Thus, the participants had an equal opportunity to respond to any of the three stimuli in a set, making the chance level 1/3 = .33. Performances during Phases 1, 2, 3, and 4 were considered **acquisition training performances**. Performances on the novel oddity tasks (e.g., EEF and FFE) in the transfer test were considered **transfer performances**. **Baseline performances** referred to the performances on Phase 4 oddity tasks that were presented immediately before and after the novel oddity tasks in the transfer test. Statistical analyses were performed using the Microsoft Excel 2010.

The Six-year-old

One-odd Task

The six-year-old girl made 87.5% (21/24) correct responses to the odd item **B** in the AAB task during the first session of Phase 1. Her performance on the AAB task improved in the second session (23/24 = 95.83%; one-tailed binomial test, $p < .01$), meeting the LC of (20/24 or more than 80%) correct responses across two consecutive sessions.

Phase 2 – Two Oddity Tasks

The subject made 58.33% (7/12) correct responses to odd item **A** in the BBA task (one-tailed binomial test, $p > .05$) and 91.67% (11/12) correct responses to odd item **B** in the AAB task (one-tailed binomial test, $p < .01$) in the first session of Phase 2. In the second session, she showed the same performance for odd item **A** (7/12 = 58.33%) and improved performance for odd item **B** (12/12 = 100%) in the BBA and AAB tasks, respectively. She attained the learning criterion (LC) of 75% correct responses across two consecutive sessions, scoring 77.08% (37/48) overall on the AAB and BBA tasks combined (one-tailed binomial test, $p < .001$).

Phase 3 – Three Oddity Tasks

The subject's performance on the BBA task improved to 87.5% (7/8) (one-tailed binomial test, $p < .01$) in the first session of Phase 3, compared to 58.33% (7/12) for the same task in Phase 2. In this phase, she demonstrated performance across all three oddity tasks (BBA, AAB, and AAC). Specifically, in the first session, she scored 87.5% (7/8) for odd item **A** in BBA, 75% (6/8) (one-tailed binomial test, $p < .01$) for odd item **B** in AAB, and 75% (6/8) (one-tailed binomial test, $p < .01$) for odd item **C** in AAC.

This performance consistency was maintained in the second session: 87.5% for **A**, 75% for **B**, and 87.5% for **C** in the BBA, AAB, and AAC tasks, respectively. Overall, she achieved 81.25% (39/48) correct responses across the three tasks over two consecutive sessions (one-tailed binomial test, $p < .01$), meeting the LC in Phase 3.

Phase 4 – Four Oddity Tasks

In the first session of Phase 4, the subject scored 66.67% (4/6) (one-tailed binomial test, $p > .05$) 83.33% (5/6) (one-tailed binomial test, $p < .01$), 50% (3/6) (one-tailed binomial test, $p > .05$), and 83.33% (5/6) (one-tailed binomial test, $p < .01$) for the BBA, AAB, DDC, and CCD tasks, respectively. In the final session, she scored 66.67% (4/6), 66.67% (4/6), 83.33% (5/6), and 100% (6/6) (one-tailed binomial test, $p < .01$) for the BBA, AAB, DDC, and CCD tasks, respectively. Across two consecutive sessions, she achieved an overall score of 75% (36/48) correct responses (one-tailed binomial test, $p < .01$) over all oddity problems, thereby attaining the LC.

Transfer Test – Novel Oddity Tasks

The transfer test assessed performance on novel oddity tasks (EEF and FFE). The subject responded correctly on the first trial of novel odd item F in the EEF task. In subsequent trials, she showed consistent and reliable performance across both EEF and FFE tasks. Over ten sessions, she achieved 70% (14/20) accuracy on the FFE task and 90% (18/20) on the EEF task—both significantly above chance (one-tailed binomial test, $p < .01$). During the transfer test period, she also maintained high accuracy on the training tasks (BBA, AAB, DDC, and CCD), scoring 84% (168/200), which was also significantly above chance (one-tailed binomial test, $p < .01$).

The Three-year-old (1)

Phase 1-One-odd Task

The three-year-old boy scored 45.83% (11/24) on the first day of acquisition training with the AAB task in Phase 1. His discriminative performance then slightly improved to 50% in Session 2 and remained at that level in Sessions 3, 4, 5, and 6. However, his performance deteriorated to 37.50% in Session 7 and remained nearly the same over the next three sessions. Although he was able to slightly improve his performance on item B (50%) in Session 11, no further improvement was observed in the subsequent sessions.

The Three-year-old (2)

Phase 1-One-odd Task

The other three-year-old boy showed a similar pattern of performance in Phase 1. Therefore, neither of them met the learning criterion (LC) in the AAB task during Phase 1. Finding no further potential for improvement, they were removed from the experiment.

Discussion

The remarkable findings of the six-year-old girl include her correct response on the first trial of the novel oddity task (EEF) in the transfer test. In addition, she demonstrated significant transfer of learning to the novel oddity tasks across ten days of testing, suggesting that she had acquired an abstract relational understanding of the stimulus sets after concurrent acquisition of multiple oddity tasks—where the features of a single item could not serve as effective discriminative cues (see Table 1). Acquiring the oddity concept becomes easier when the task is solved by identifying the item that is odd in terms of a relationship (i.e., different from the other two). This relational understanding may have helped her solve the more complex tasks in later phases and generalize her training to novel stimuli in the transfer test.

Table 1

Transfer Performances to The Novel Odor Item E and F in Odor Transfer Test Trial by Trial

Odor Transfer Test					
Novel item E			Novel item F		
Test sessions	No. of trials in a session	Correct responses	Test sessions	No. of trials in a session	Correct responses
1	2	1	1	2	1 (first trial data) + 1
2	2	2	2	2	2
3	2	1	3	2	2
4	2	2	4	2	1
5	2	1	5	2	2
6	2	1	6	2	2
7	2	1	7	2	2
8	2	1	8	2	2
9	2	2	9	2	1
10	2	2	10	2	2
Total correct responses out of 20 trials		14	Total correct responses out of 20 trials		18

Note. Novel item E = Odor stimulus named Spanish jasmine and Novel item F = odor stimulus named Night blooming jesmine. 1 (first trial data) + 1 means that in this session, novel stimuli set (EEF), at first, appeared in the transfer test and the subject responded correctly to the novel item F in the EEF novel oddity task, showing the first trial data.

At the beginning of the experiment, the subject rapidly learned the AAB task in Phase 1. However, when items A and B were concurrently presented as odd ones (AAB and BBA) in Phase 2, she showed a lower accuracy rate for odd item A (although, still above chance level) and a higher accuracy rate for odd item B in both the first and last sessions of Phase 2. After completing the Phase 2 task, she performed significantly above chance level on all oddity problems (AAB, BBA, and AAC) in Phase 3. Although her performance sometimes deteriorated (e.g., in Phase 4), it recovered in the later phases. For example, her performance for odd item C deteriorated and was not significant compared to chance level [50% correct, chance = .33] in the first session of Phase 4, but it recovered and became significant (83.33% correct) in the last session of Phase 4. Similarly, her performance deteriorated in the first and last sessions of Phase 4 for odd item A (66.67% correct) and in the last session of Phase 4 for odd item B (66.67% correct), but it recovered and became significant (80% correct) compared to chance level in the baseline performances of the transfer test.

Attaining the learning criterion in Phase 2 marked a critical turning point in her development, as she encountered no further difficulty in mastering the tasks in Phases 3 and 4 with LC, or in the transfer test, despite the use of completely novel stimulus sets. This explanation gains further support from her significant and robust transfer performance in the transfer test, starting with the very first trial.

The findings of the present study are somewhat similar to same/different discrimination learning studies, particularly relational matching-to-sample (RMTS) concept learning conducted by Christie and Gentner (2014), who reported that subjects under four years of age could not match the standard with one of the two alternatives that matched it. However, when children aged 5–6 acquired symbolic–linguistic experiences, they were able to process the RMTS tasks relationally.

The present study raises several important questions. First, what enabled the subject to acquire an understanding of the logical relationship between odd and identical stimuli? One possible factor is the concurrent presentation of stimuli, where an item (e.g., A), used as the odd item in one stimulus set (e.g., BBA), serves as a non-odd item in another set (e.g., AAB). Such a procedure may help the subject understand that the correct response does not depend on the specific features of a particular item. Rather, it depends on relational properties (same/different), leaving no room to rely on physical features. In Phase 1, odd item B was reinforced in every trial of the AAB task. In Phase 2, both items A and B served as odd items in different trials of the AAB and BBA tasks, respectively. This dual usage provided an ideal opportunity for the subject to understand the relationship between odd and identical items. Previous studies (e.g., Taniuchi et al., 2017) have also shown that concurrent stimulus presentation can support oddity concept learning.

Another potential factor is training with multiple oddity tasks. A single oddity task (e.g., AAB) can often be solved by memorizing the specific features of the odd item (e.g., item B), as such memorization is relatively easy (see Koronakos & Arnold, 1957). However, in two oddity tasks (e.g., AAB and BBA), the same item (e.g., A) may be odd in one trial and non-odd in another. In such cases, memorizing the features of a specific item is insufficient. Instead, remembering the configurations (e.g., respond to B in AAB, respond to A in BBA) can suffice for solving two-task problems (see Wodinsky & Bitterman, 1953).

But when multiple oddity tasks are introduced (e.g., Taniuchi et al., 2017), subjects cannot rely on either item-specific or configural cues, as many possible configurations emerge from multiple items (e.g., A, B, C, and D). For example, in 12 different oddity problems (AAB, AAC, AAD, BBA, BBC, BBD, CCA, CCB, CCD, DDA, DDB, and DDC), it becomes extremely difficult to memorize all combinations. This may force the subject to abandon memorization strategies in favor of applying an abstract rule, thus reducing memory load (Santiago & Wright, 1984).

Although the present study provides evidence of oddity concept learning in a six-year-old girl, the other subjects—two three-year-old boys—were unable to learn the tasks. This raises a second important question: Why? In response, we refer to a study by Premack (1983), which reported that children under four years old were unable to solve tasks involving same (XX–AA) and different (XY–CD) relationships. Children aged 4.5 years could solve the XX–AA task but still struggled with the XY–CD task. Both tasks could only be solved reliably by age six.

In the context of the present study, it would be difficult to conclude that age alone is the determining factor in acquiring the oddity relational concept, because out of three subjects, the two three-year-old boys could not master the oddity learning tasks. This higher-order learning ability might be found in other three-year-old boys if a larger number of subjects were tested. The present study had only a small sample size. Thus, individual differences, along with age, might be factors in acquiring oddity concept learning.

In the present study, a third question arises: Did her significant and robust transfer performance reflect genuine generalization, or was it influenced by the similarity between training and test stimuli within the same modality (olfaction)? It is possible that a large number of stimuli increased the perceived similarity between training and test items, thereby facilitating transfer (e.g., Wright & Katz, 2006). Thus, we cannot completely rule out the possibility that the subject's performance was influenced by stimulus generalization.

To address this concern, future studies should explore cross-modal transfer, where training is conducted with olfactory stimuli and transfer tests are conducted using a different modality, such as auditory stimuli. Since olfactory and auditory stimuli do not share physical features, successful transfer in this context would be difficult to explain by generalization alone (e.g., Tyrrell, 1974, with humans). Another concern is that only one six-year-old girl in this study demonstrated the oddity concept. Although Triana and Pasnak (1981) suggested that if one member of a species consistently shows evidence of concept learning, this ability likely exists in others, future research should replicate the present study with a larger number of human subjects.

To our knowledge, this is the first study to demonstrate oddity concept learning in humans using olfactory stimuli. We believe these findings offer valuable insight into the mechanisms of human intelligence.

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