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Sniffing for fun: Evaluating the effect of olfactory enrichment on cats' toy preference and interaction

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ABSTRACT

Play is a critical natural behavior in domestic cats. Toys and olfactory enrichment are common methods used to encourage play; however, no research has previously evaluated how olfactory enrichment affects toy interaction in cats. We hypothesized that the addition of cats' preferred odor to a toy would increase toy interaction. Therefore, the objective of this study was to evaluate if adding cats' preferred odor to moving or stationary toys increased toy interaction. Pet cats (N = 31) participated in three, 5-minute free operant preference assessments where we first evaluated their preferred odor from a set of three different odors (i.e., catnip, silver vine, and Feliway®) and a control (i.e., unscented) and subsequently evaluated their interaction time with a moving or stationary toy with and without their preferred odor, independently. Cats' behavior during the different preference tests was video recorded and the amount of time they interacted with the testing stimulus was measured. Preference for an odor or a toy was defined as the stimulus that received the most interaction time. Cats interacted with catnip (85.24 s; 95 % CI [59.64, 110.85]) and silver vine (57.99 s; 95 % CI [35.32, 80.66]) more than with the control (3.36 s; 95 % CI [0.98, 5.75]) and Feliway® (8.11 s; 95 % CI [4.24, 11.97]). Although there was no statistical difference, more cats showed a preference for catnip (n = 19) than silver vine (n = 12). Subsequently, each cat's preferred odor (catnip or silver vine) was added to moving and stationary toys to evaluate the effect of olfactory enrichment on toy interaction. A linear mixed model was used to assess the effect of odor (scented vs unscented), toy type (stationary vs moving) and their interaction on the amount of time cats interacted with the toys. Cats interacted significantly more with moving toys, whether scented (59.04 s; 95 % CI [28.27, 122.14]) or unscented (58.24 s; 95 % CI [27.88, 120.50]), compared to unscented stationary toys (12.27 s; 95 % CI [5.47, 26.21]). Cats interacted statistically longer with scented stationary toys (38.01 s; 95 % CI [18.02, 79.02]) than with unscented stationary toys, but their interaction with scented stationary toys did not statistically differ from their interaction with scented or unscented moving toys. These results indicate that cats prefer moving and scented stationary toys compared to unscented stationary toys. Our results highlight that using olfactory enrichment is a simple method to encourage interaction with stationary toys and play behavior to support cat welfare.

1. Introduction

Recent estimates show that there are approximately 74 million domestic pet cats (*Felis catus*) in the United States (American Veterinary Medical Association, 2024). Despite their popularity, there is limited research regarding the implementation of and preference for enrichment to promote pet cats' welfare. Promoting natural behaviors, such as play, rooted in ancestral behaviors (e.g., predation and hunting), through enrichment is important because its frequency of occurrence has been associated with cats' welfare (Held and Špinka, 2011). For instance, playing leads to positive affective states, aids in cognitive development (Bekoff, 1995; Henning et al., 2023), and promotes positive health and welfare in adult cats (Rochlitz, 2005). The inability to perform play behaviors can lead to negative affective states (e.g., frustration, stress; Stella et al., 2013) as after periods of restricted play, owners have reported their cats showing behavioral signs (e.g., vocalizations and

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destructive behaviors) related to negative affective and welfare states (Henning et al., 2023). Additionally, it has been suggested that cat play is related to a decrease in potentially harmful behaviors, such as owner directed aggression (Strickler and Shull, 2014). Thus, encouraging natural behaviors, like play, through enrichment is a key approach to improving cat welfare.

Play behavior in domestic cats is commonly categorized as either social, locomotor, predatory, or object play (Delgado and Hecht, 2019). Between 18 and 21 weeks of age, the frequency of social play reduces, and object-oriented play behavior increases. Object play is the last play behavior to develop in domestic cats (Mendoza and Ramirez, 1987). Object play includes behaviors such as poking, batting, scooping, leaping, grasping, stalking, and biting different objects (Barrett and Bateson, 1978; West, 1977). Adding enrichment items to an animal's environment can promote natural behaviors. The use of toys is among the most common strategies used to promote play behavior in cats. Common toy-related factors that can affect toy interaction include odor and movement, perhaps due to their similarities with prey (Hall, 1995; Machado and Genaro, 2014).

The use of olfactory enrichment has been successful promoting interaction with scratchers in pet cats (Zhang and McGlone, 2020) and increasing exploratory behaviors in group-housed cats (Machado and Genaro, 2014). Bol (2017) found that cats tend to show a preference for catnip and silver vine when evaluating plant olfactory enrichment options. Furthermore, cats often display a repertoire of play behaviors when exposed to catnip called the "catnip response" which includes, sniffing, licking, rubbing, rolling, etc. (Bol et al., 2017; Hill et al., 1976; Tucker and Tucker, 1988). Hence, to promote play behavior, cat toy manufacturers often incorporate catnip or silver vine inside of their toys. The use of commercial, synthetic feline pheromones have been shown to decrease stress in cats (Pereira et al., 2023) by mimicking cats' interdigital chemical signals used for species-specific communication. Due to their calming effect, pheromones could be used as an alternative olfactory enrichment to promote play behavior. However, no previous research has evaluated its effect on play behavior or cats' olfactory preference between catnip, silver vine, and pheromones.

An additional strategy to promote play behaviors is incorporating movement to toys, as cats engage in chase-like play (Delgado and Hecht, 2019) and prefer watching moving objects (Ellis and Wells, 2008). Cats also play more intensively with small (7x5x1 cm) rather than medium (12x7x2 cm), moving objects, which suggests that cats like to play with toys that mimic typical prey size and actions (Hall, 1995). Similarly, cats prefer to interact with toys with erratic movement (Vitale Shreve et al., 2017) and 80 % of surveyed cat owners reported their cats like to play with a moving laser (Kogan and Grigg, 2021). Although independent research has found that moving objects promote play behaviors and olfactory enrichment promotes positive behavior in cats, the possible synergistic effect of both strategies to promote play behavior has not been empirically evaluated.

The objective of the current study was to 1) evaluate cats' preference for three odor stimuli (catnip, silver vine, and a commercial feline pheromone) and 2) add cats' preferred odor to stationary and moving toys to determine if adding their preferred odor increases toy interaction. This study will bridge the existing gap in knowledge by utilizing free operant assessment tests to determine the effect of movement and olfactory enrichment on cat play behavior and toy interaction. The results of this study can be used to identify feasible and effective strategies to promote play behavior, thus supporting the expression of natural behaviors and improving overall cat welfare.

2. Materials and methods

2.1. Participants

Thirty-one pet cats were recruited from the city of Lubbock, Texas, USA via dissemination of a recruitment flyer shared on social media, the university's weekly email announcement system, hard copy flyers posted throughout the university campus, and local publicly accessed locations (e.g., stores, parks). Cat owners interested in participating were asked to complete an online questionnaire which informed them of the experimental purposes and asked basic demographic questions (e.g., age, location), as well as questions regarding their cat (e.g., age, sex, vaccination records, health, fear; see Supplemental Materials). Cat owners were able to register multiple cats within their household. Cats were eligible to participate in the study if they were 1–7 years of age, up to date on all vaccinations, and had no reported medical conditions. To protect the safety and welfare of all experimenters and cats, cats were ineligible if they were reported to display fearful or aggressive behaviors toward unfamiliar people, which was defined as "run, hide, or hiss upon approach of unfamiliar people". Participation in the study was voluntary and in appreciation of their participation the experimenters donated the toys used during testing to the owner.

2.2. Procedure

All testing procedures were approved by the Texas Tech University Institutional Animal Care and Use Committee (Protocol # 2024–1472). Research took place in the owners' house between 9:00 AM and 7:00 PM. The time of testing was based on owner availability. The majority of the testing (79 %) occurred after 4:00 PM, once owners returned from work. Within a testing session, cats participated in an odor preference assessment, followed by two toy preference assessments where we evaluated cats' preference for a scented or unscented, stationary or moving toy. The odor preference test was conducted first to determine their preferred odor to be used in the following tests, but the order of the stationary or moving toy preference test was counterbalanced. Each test lasted 5 minutes, and completing all three tests took approximately 20–25 minutes.

2.2.1. Testing setup

Upon arrival at the owner's house, experimenters explained the testing procedures and obtained written informed consent of participation before testing. The owner was asked to select a secluded and quiet area in their house without other pets to prevent their cat from being distracted and from other pets interacting with the testing stimuli. The rooms used in the study varied and included areas such as bedrooms, offices, living rooms, and kitchens. Once the owner identified a testing place, the experimenter marked the testing arena in the provided area.

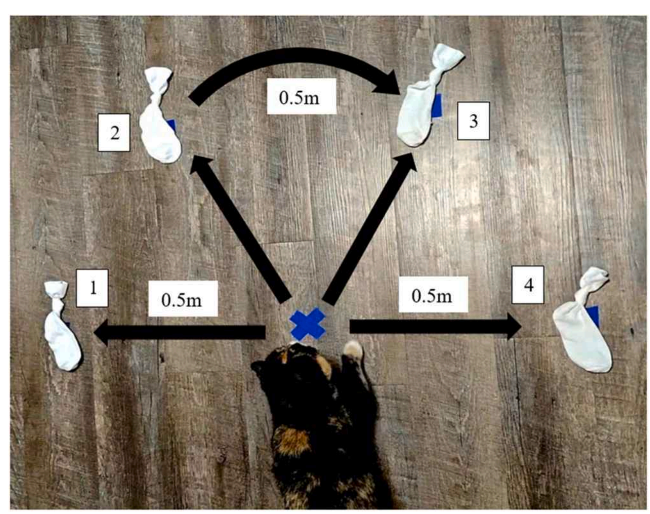

Fig. 1. Testing arena. The X shows the start location. Odors were placed on locations 1, 2, 3, and 4, while toys were placed on locations 2 and 3. All stimuli were 0.5 m from the starting location and the distance of the ark between each stimulus was 0.5 m.

The testing arena consisted of a semicircle with a 0.5-meter radius (Fig. 1). The outline of the testing arena was created by marking the floor with small pieces of removable painter's tape. Five pieces of painter's tape were placed to mark the start point and four equidistant (0.5-meter arc) locations within the semicircle. The distance from the start point to each location was 0.5 m. After outlining the arena, the owner introduced the cat to the room. A 5-minute acclimation period was provided prior to testing. During this time, the owner and experimenters were with the cat in the testing arena. Owners and experimenters were allowed to pet and interact with their cat, and cats were also able to explore the testing arena freely. This was to ensure cats were acclimatized to the testing area prior to testing.

2.2.2. Odor preference Test

The first test comprised of a free operant preference test with three odor stimuli and a control. The odor preference assessment was conducted to identify cats' preferred odor out of three commercially available odors: catnip, silver vine, and a commercial pheromone (Feliway®). Cats' preferred odor was later added to toys in the following preference tests. By first evaluating cats' odor preference, we ensured that the odor added to the toys in the subsequent tests was pleasant and not aversive which allowed us to accurately assess the effect of olfactory enrichment in toy interaction.

Odors were prepared by placing scented cotton balls (2.5 cm) inside cotton socks (Falari®) as described in Bol et al. (2017) (Fig. 1). Cotton balls and socks were used directly out of the manufacturer's packaging and not reused for testing. The open end of the socks was tied with a knot to prevent the scented cotton balls from spilling outside of the socks. All socks were prepared and used within 12 hours after preparation. During odor preparation, precautions to prevent cross contamination were taken including changing gloves and cleaning the preparation area between odors. Each odor was stored and transported to owners' houses in separate bags (3.8 L mylar bags) within a separate plastic container (30.5 x 61 cm Sterilite®). Herein, we tested cats' preference for commercially available powdered catnip (Pet Craft®), powdered silver vine (Raw Paws®), sprayable feline pheromone (Feliway®), and a sock with no odor (control). Catnip and silver vine were selected for testing based on previous research that show cats have a strong preference for these odors (Bol et al., 2017) and that they promote positive behaviors (i.e., what behaviors?). The commercial, synthetic pheromone, Feliway®, was chosen to present cats with a species-specific odor. This commercial product is supposed to calm cats, but no study has compared cats' preference for a species-specific odor over plant attractants like catnip or silver vine. Thus, the pheromone was included in this test to explore cats' preference for a species-specific odor versus catnip and silver vine. Because both the pheromone and plant attractants, are readily used by cat owners to reduce stress and promote natural behaviors, comparing cats' preference for one over the other will be beneficial to identify the best stimulus to be used as an olfactory enrichment. The pheromone sock was prepared by spraying the pheromone solution onto the cotton ball one time (~ 0.1 mL). This amount was chosen to reduce the chances of an aversive response due to the strong odor of the solvent. Catnip and silver vine socks were prepared by adding 0.5 g of each powder to a sock with a cotton ball (Bol et al., 2017). Despite the low amount used, all testing odors were readily perceivable to the experimenters. An additional control sock with no odor was included in the test. This sock contained only a clean cotton ball. This was to ensure that cats were responding to the odor within the sock and not any unintentional odor or visual stimulus from the sock.

During testing, the cat owner and two experimenters were present in the room. While the owner kept their cat distracted by petting, playing, or giving them treats, one experimenter took each testing odor from their sealed bag, one at a time, and placed each sock in one of the four locations within the semicircle. The location of each odor was randomized within a session and counterbalanced between cats to ensure each odor was presented equally in each position. A session started once the owner placed the cat in the start position. Once the cat was in the start position, the five-minute timer and the video camera (Sony, Handycam, HDRCX405) were started by an experimenter which held the camera and maintained focus on the cat.

2.2.3. Interaction measurement

For the odor assessment test, the amount of time each cat interacted with each testing odor was live scored by an experimenter, sitting near the testing arena, using Countee, a commercially available mobile app (Hernández and Peić, 2016). This allowed us to determine cats preferred odor immediately and use this odor for the subsequent toy preference test. For the subsequent toy preference tests, live determination of the behavior was not necessary, therefore behavior coding was done using the video recordings.

A continuous sampling technique was used to determine the amount of time cats interacted with each odor. Only active interaction with the toy was recorded. The beginning of the interaction was defined as the moment when the cat initiated direct contact by manipulating the toy (e.g., biting, bating, pushing, etc.; Table 1). The end of interaction was defined as the moment when a cat started interacting with another toy or stopped manipulating a toy for more than 10 seconds. If a cat stopped manipulating a toy but was looking and sniffing toward the toy before reinitiating interaction within 10 seconds, we included this period of time as part of the interaction. This was included because proximity to a stimulus has been used to assess preference (Zajonc and Markus, 1982). Furthermore, previous research has also included sniffing a stimulus as a form of engagement with that stimulus (Vitale Shreve et al., 2017). The inclusion of looking and sniffing (i.e., focus on the toy) between direct manipulation bouts allowed for more continuous recording of the interaction rather than stopping and starting records between small gaps of physical touch (i.e., batting). This also helped simplify live coding of the interaction. If a cat was looking at one toy and interacting with another, interaction was recorded for the one receiving the physical interaction (e.g., biting). The preferred odor was defined as the odor with which the cat interacted the most within the testing session.

2.2.4. Toy Preference test

In Tests Two and Three we evaluated cats' preference for a scented or unscented toy when they were stationary or moving. Stationary and moving toys were tested separately because previous research showed that cats prefer to play with moving objects (Ellis and Wells, 2008; Hall, 1995; Kogan and Grigg, 2021; Vitale Shreve et al., 2017). Thus, we wanted to evaluate if adding an olfactory stimulus will have the same effect in stationary and moving toys. The testing order was counterbalanced between cats. The olfactory stimulus used for testing was based on the results from the previous test, thus it varied between cats. This was done to ensure that cats were attracted to the olfactory stimulus used for testing and that results are not affected by aversion or indifference to the odor. If a cat showed no preference for any of the testing odors in Test One, we used catnip toys for testing since this is a common odor used in commercially available cat toys.

Faux fur rattle mouse toys (10.4 cm, Chiwava®; Fig. 2) were the toys used in this experiment. Scented toys were prepared at least 12 hours prior to testing. The addition of the odor stimulus (impregnation process) consisted of placing the mouse toy in mesh bags before sealing

Table 1
Ethogram of interaction-related behaviors.

Behavior		Definition
Interaction		
	Manipulating Stimuli	Body is in physical contact and manipulating the stimulus (e.g., biting, batting with paw, kicking with hind legs)
	Sniffing/Looking	Head is oriented toward the stimulus with a still body; eyes/nose are within ~30 cm of the stimulus

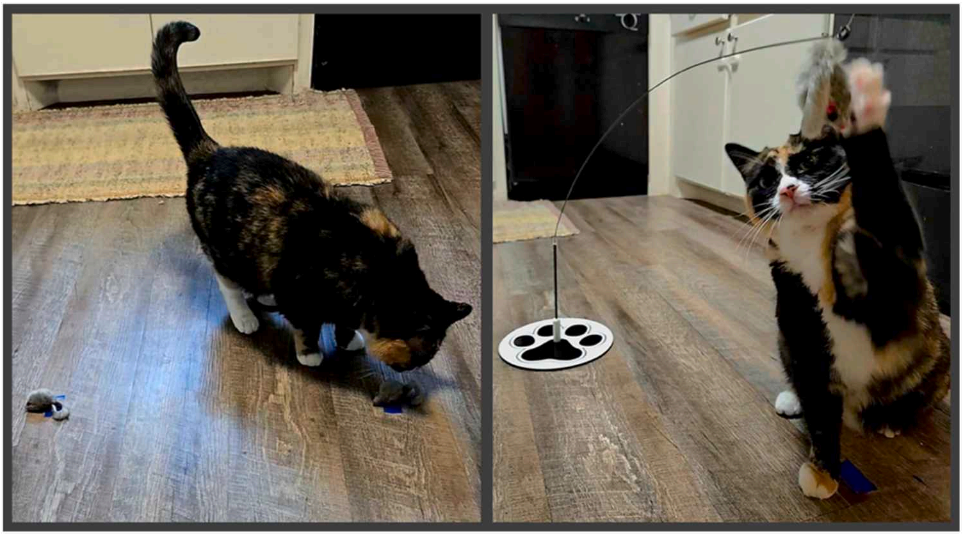

Fig. 2. Play preference tests. Left picture shows the stationary toy test where the toy mouse was placed on the floor. Right picture shows the moving toy test where the toy mouse is hanging on a wand.

them in a mylar bag containing the odor to allow for odor impregnation without covering the toy with powder in the case of catnip and silver vine. Scented and unscented materials were identical in form, shape, and color. The unscented toys were stored in mylar bags that did not contain any odor as a control. Mouse toys were never reused for testing and were given to owners in appreciation of their participation. For testing, cats were presented with a scented and unscented toy simultaneously. Therefore, just the two centermost locations of the testing arena were used (Fig. 1). The location of the scented and unscented toys was randomized and counterbalanced between cats.

For the moving toy preference test, two commercially available flexible teaser-wands (80 cm tall with 0.5 kg bases of 19 cm in diameter; Gadgetsology®) were used to bounce the mouse toys (Fig. 2). The tails of the mouse toys were attached to the tips of the wands using a short strand of monofilament line (Ozark Trail®). The wands and stands were cleaned with odorless spray (Zero Odor®) in between cat participants. This product was selected because it removes cat odors, and its tracer odor disappears within 30 s. Thus, the wands were clean and odorless by the time another cat was tested. Prior to the test, the experimenter gently pushed the flexible toy wands to initiate toy movement. When scoring toy interaction behavior, all parts of the flexible-wand toy were considered. For the stationary toy preference test, the scented and unscented mouse were placed on the floor (Fig. 2). Similar to the procedure used for Test One, the cats were distracted by their owners while the experimenter prepared the testing arena. Once the scented and unscented toys were placed in their location, the owner placed their cat on the start location and the five-minute timer and video camera was initiated by an experimenter.

For all tests, the experimenters and owner remained silent but were permitted to briefly pet the cat if the cat initiated the contact. Petting was allowed since it can provide reassurance to cats when exposed to novel stimuli and people (Gourkow et al., 2014), while also simulating a natural play environment where owners anecdotally have reported to pet their cat while playing. If during testing the cat left the arena due to an apparent loss of interest or distraction, the owner was asked to regain its attention by calling them or returning them to the start location. Before returning the cat to the testing arena, the experimenter replaced the toys in their original locations if they were moved away from the testing arena and if applicable, reinitiated the teaser wand moving toys.

2.3. Data analysis

To determine real-time odor preference, interaction time in the odor preference tests were live scored. All videos of the odor preference tests were subsequently re-coded by the same experimenter to evaluate intra-observer reliability between the live scored interaction time and the video scored interaction times. Interaction time for the toy preference assessments were video coded by the same experimenter. Twenty percent of the toy preference assessments were also coded by a second observer to evaluate inter-observer reliability. All behavior coding was conducted using BORIS (Friard and Gamba, 2016). The intraclass correlation coefficient (ICC) was used to evaluate inter- and intra- observer reliability. ICC values greater than 0.90, between 0.75 and 0.90, and between 0.50 and 0.75 are indicative of excellent, good, and moderate reliability, respectively (Koo and Li, 2016).

For the odor preference test we used video coded toy interaction time for statistical analysis. Friedman's test was used to evaluate statistical differences in interaction time due to the lack of normality of the data. Subsequently, the Wilcoxon sign rank test with Bonferroni corrections was used for post-hoc pairwise comparisons between odors. Furthermore, the proportion of cats that showed a preference for each odor was calculated by summing the number of cats that showed a preference for an odor (e.g., greater interaction time) and dividing by the total number of cats.

A linear mixed model was used to assess the effect of odor (preferred odor vs unscented), toy type (stationary vs moving), and their statistical interaction on the amount of time cats interacted with the toys. The model included the toy and odor as a fixed effect and an interaction term between toy and odor, with cat included as a random effect. Tukey post-hoc test was used for multiple pairwise comparisons. Preliminary data assessment showed that the data did not meet parametric assumptions such as normal distribution of the error and homoscedasticity; thus, statistical analyses were conducted on the Log_{10} transformed data since the transformed data met parametric assumptions. Because interaction times of zero were not able to be log transformed, we added one second to all interaction times and calculated the Log_{10} of the measured interaction time plus the added one second. Least squares mean and 95 % confidence intervals from the model were back transformed to seconds and the back transformed data were used for data visualization. Because most of our participant cats were spayed females, the influence of sex was not explored due to the lack of variability. Additional exploratory analysis to evaluate the effect of other cat demographics such as age, breed, and activity level were not conducted due to lack of variability or because the information was not acquired in the questionnaire.

Cats' preference for the scented or unscented toys in the moving and stationary tests were categorized as either High, Low, or No Preference based on the magnitude of the difference in interaction time observed. For this we divided cats' interaction to the scented and unscented toy by the total interaction time (e.g., sum of both toys interaction). A cat was determined to have a High Preference for a toy if their interaction time with that toy was ≥ 60 % of their total interaction time (e.g., an increase in interaction of at least 10 % relative to the other stimulus). Low Preference was determined if their interaction time with a toy was between 55 % and 60 % (an increase in interaction between 5 % and 10 %) of the total interaction time. No Preference for any of the toys was determined if the difference in interaction time between scented and unscented toy was ≤ 5 %. Based on this, we calculated the proportion of cats that had High, Low, or No Preference for the scented and unscented toy within each test (stationary and moving). Cats' preference for stationary or moving toys regardless of odor was similarly categorized as High, Low, or No Preference using the same scale and procedure described above.

Statistical significance was declared when $p < 0.05$. All statistical analyses were conducted in RStudio (RStudio Team, 2015).

3. Results

3.1. Descriptive data

Of the 33 pet cats recruited for participation, two were removed resulting in a total of 31 cat participants used for analysis (Supplemental Table 1). One cat was removed because they did not interact with any of the toys and the other because it was the only intact female (i.e., not spayed) in the group. Although there is no literature that suggests sex will influence toy interaction, we removed the intact female to keep a homogeneous group of cats (spayed and neutered) in the analysis. The age of the 31 participant cats (22 spayed females and 9 neutered males) ranged from 1 to 7 years of age, with a mean of 3.3 years ($SD = 1.9$). Eighteen participant cats were from a multi-cat household (e.g., 2–3) and thirteen cats were from single cat households.

3.2. Intra- and inter-observer reliability

Intraclass correlation coefficient showed strong intra-observer agreement between live scored and video coded data in the odor preference test (ICC =0.98). Similarly, high inter-observer agreement was found for the moving (ICC = 0.93) and stationary (ICC =0.84) toy preference tests.

3.3. Odor preference Test

Catnip was preferred by 61.3 % ($n = 19$) of the cats, and the remaining 38.7 % ($n = 12$) of the cats showed a preference for silver vine. None of the cats showed a preference for the commercial pheromone or the control sock. Fig. 3 illustrates the average interaction time for each testing odor. There was a statistically significant difference in the amount of time cats interacted with the different testing odors (χ^2= 51.5; df= 3; $p < 0.001$). Cats interacted significantly more with catnip (85.24 s; 95 % CI [59.64, 110.85]) and silver vine (57.99 s; 95 % CI [35.32, 80.66]) than with the pheromone (8.11 s; 95 % CI [4.24, 11.97]) and the control socks (3.36 s; 95 % CI [0.98, 5.75]). The interaction time for catnip and silver vine were not statistically different from each other, nor were the interaction times between the pheromone and control socks statistically different from each other.

3.4. Toy preference Test

In the moving toy test, 51.7 % ($n = 16$) of the cats had a preference for the unscented toy. Of these cats, most had a High Preference ($n = 14$), while the remaining had a Low Preference ($n = 2$). In contrast, 38.7 % ($n = 12$) of the cats preferred the scented toy, of which the majority ($n = 11$) had a High Preference, while only one cat had a Low Preference. No Preference for scented or unscented moving toys was observed in 9.7 % ($n = 3$) of the cats. As for the stationary toys, 71 % ($n = 22$) of the cats showed High Preference for the scented toy and only 25.8 % ($n = 8$) showed a High Preference for the unscented toy. Only one of the cats showed No Preference during the stationary toy test. Overall, 75.2 % ($n = 23$) of cats had a significant increase in interaction time (High Preference) for moving toys relative to stationary toys. In other words, only 6.5 % ($n = 2$) of cats showed High Preference for stationary toys compared to moving toys.

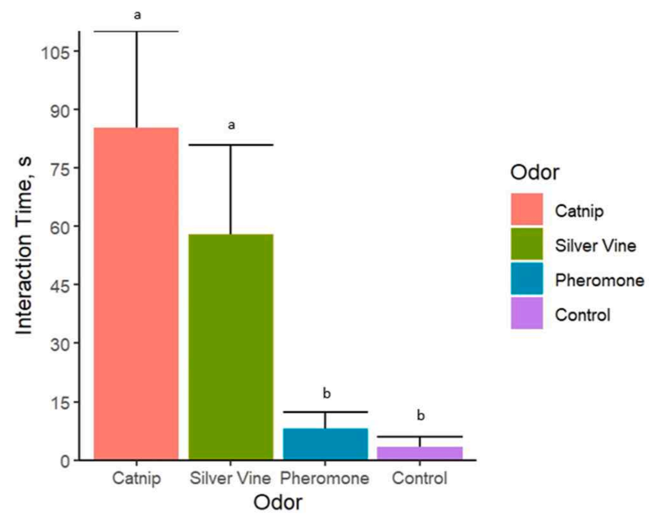

Fig. 3. Mean + 95 % upper confidence interval of cats (N = 31) interaction time (seconds) with each testing odor. The effect of odor was statistically significant (p < 0.001). Bars with different superscripts are statistically different from each other. Cats interacted more with catnip and silver vine than with pheromone or unscented socks.

The live scored interaction times between odors differed by a few seconds from the video scored interaction times for three cats, thus due to this discrepancy between the live and video recording data, these cats were tested with their second preferred odor. Despite this, all three cats still exhibited High Preference for the scented toy over the unscented toy. The main effect of odor ($F_{(1, 90)} = 6.57$, $p = 0.012$), toy (stationary or moving) ($F_{(1, 90)} = 20.45$, $p < 0.001$) and their interaction ($F_{(1,90)} = 6.25$, $p = 0.014$) were statistically significant. Post hoc multiple comparisons revealed cats interacted statistically more with scented (59.04 s; 95 % CI [28.27, 122.14]) and unscented (58.24 s; 95 % CI [27.88, 120.50]) moving toys and scented stationary toys (38.01 s; 95 % CI [18.02, 79.02]) than with the unscented stationary toys (12.27 s; 95 % CI [5.47, 26.21]) (Fig. 4). The interaction time between moving scented and unscented toys and the scented stationary toy were not statistically different from each other.

4. Discussion

The present study is the first to utilize free operant preference assessments to examine the effects of olfactory enrichment in combination with different toy types on cats' toy interaction, thus revealing that cats have a preference for moving toys and scented stationary toys, with varying degrees of interest in catnip and silver vine.

In the current study, the odor preference assessments revealed that most cats preferred to interact with catnip and silver vine. Although not statistically significant, a majority of cats preferred catnip over silver vine. This lack of statistical significance could be due to the low sample size and therefore the preference for catnip could be biologically relevant. None of the cats showed a preference for the commercial pheromone or the control sock. The low interaction time with the control sock indicates that interaction with the testing socks was driven by the odor stimulus within the socks and not to the sock itself. Our results are

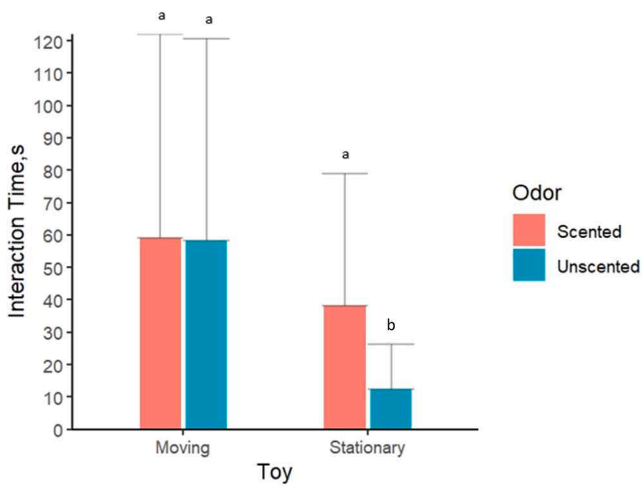

Fig. 4. Back transformed mean + 95 % upper confidence interval of cats (N = 31) interaction time (seconds) with scented and unscented toys during the moving and stationary toy preference test. Bars with different superscripts are statistically different from each other. The interaction effect between odor and toy was statistically significant (p = 0.014). Cats interacted with the scented stationary toy statistically more than with the unscented stationary toy. Cats' interaction with the scented and unscented moving toys was not statistically different from each other or the scented stationary toy.

consistent with previous research that also found that the majority of cats have a preference (e.g., displayed more behaviors like sniffing, licking, rolling on back, drooling) for catnip and silver vine (Bol et al., 2017; Zhang and McGlone, 2020). However, our results differ from one study that reported only 20 % of cats showed an active response to catnip (Espín-Iturbe et al., 2017), whereas our current study found that 61 % of the cats showed a High Preference for catnip. This discrepancy between research could be due to the way the different authors defined active behaviors, as the current study included all interaction with the stimulus as opposed to just rolling, vocalizations, and self-grooming. Furthermore, catnip and silver vine both contain nepetalactone, a well-known cat attractant. Differences in preference between catnip and silver vine could be due to differences in nepetalactone concentration between plants. Other factors which could impact cats' preference could include the presence of other volatiles present in the plants, and the state in which the plant is presented (e.g., dried, fresh). Future studies that evaluate the effect of nepetalactone concentration on cats' preferences and the possible synergistic effect of other volatiles and plant state are needed to better understand the underlying reason for cats' preferences of catnip and silver vine.

We did not find that cats showed a preference or even a significant interaction to the commercial pheromone. We impregnated cotton balls with only one spray of the pheromone as opposed to the eight sprays recommended by the manufacturer. This was to prevent over saturating the cotton ball and minimize the smell of the solvent and thus the chances of an aversive effect. Thus, this difference in volume could explain differences in results and the low interaction time observed. Furthermore, pheromones are commonly applied around the animal (spray on collar, room diffuser) to assist with their stress and encourage calm behaviors (Vitale, 2018). Although pheromones have shown to have a physiological and behavioral effect on animals (Contreras et al., 2018; Silva et al., 2017), they are not known to be cat attractants. Therefore, another possible explanation for the low interaction could be because of the calming effect Feliway® is intended to have on cats. It would be valuable to test these preferences in a more stressful environment such as a shelter to evaluate if cats have a better response to the pheromones in stressful environments. Zhang and McGlone (2020) found similar results as our current study. For instance, they found that both catnip and silver vine increased scratcher interaction but adding a pheromone to the scratcher did not increase scratcher interaction. Current results suggest that although pheromone therapies have been successful in reducing indicators of stress (Pereira et al., 2023), cats display preference for catnip and silver vine over the smell of the pheromone.

Previous research has found that olfactory enrichment promotes positive behaviors (Ellis and Wells, 2010; Machado and Genaro, 2014; Zhang and McGlone, 2020) and that toy movement increases play behaviors (Hall, 1995; Vitale Shreve et al., 2017); however,the possible synergistic effect of movement and olfactory enrichment on toy interaction had not previously been evaluated. Our results show that cats spend more time interacting with moving than stationary toys, which is consistent with previous research (Ellis and Wells, 2008; Hall, 1995; Kogan and Grigg, 2021; Vitale Shreve et al., 2017). Although the cats in our study showed significantly higher interactions to moving toys, they did not show any preference between a scented and unscented moving toy; however, a preference for the scented toy was observed when toys were stationary. This aligns with previous research that suggests odor may not be a strong enough enrichment stimulus on its own as cats allocate only a small portion of their time interacting with different odors (Ellis and Wells, 2010; Vitale Shreve et al., 2017). We hypothesize that movement is such a strong stimulus for encouraging cat play behavior that adding an odor to a moving toy has no effect increasing toy interaction.

Although interaction with the scented stationary toy was slightly lower than interaction with moving toys, the addition of cats' preferred odor to a stationary toy significantly increased interaction time with a stationary toy. This is consistent with previous research that shows the addition of odor can increase interaction with enrichment items (Cozzi et al., 2013; Zhang and McGlone, 2020). Similar findings have been reported in other species and settings. For instance, shelter dogs have also shown preference for scented stationary toys compared to unscented ones (Howard et al., 2024; Murtagh et al., 2020). Notably, dogs were tested on different scents than cats, with their most preferred being hotdog and duck scents. Future research could benefit from testing toy interaction behaviors with the same odors across species or by using biologically relevant odors (e.g., food odors). Our results suggest that toy movement promotes toy interaction more than the addition of scent and that the use of olfactory enrichment may promote toy interaction or play behaviors with a stationary toy. These results can be used to enhance play behaviors of pet cats, thus encouraging natural behaviors and promoting positive welfare.

Although moving toys are more engaging and can strengthen human-animal bonds when used together (Ahloy-Dallaire et al., 2018; Johnson et al., 2021), the ability to stimulate the use of stationary toys with odor additives can aid in continuing cat physical activity, mental simulation, and natural play behavior when automatic moving toys or owners are unavailable.

It is important to consider that we only tested cats' preference once, at the owner's convenience, and each test was conducted consecutively. These preference tests therefore only captured a snapshot of their choice within the specific time, environmental context, and affective and physiological state, as opposed to capturing their long-term, consistent preference. However, this was done to encourage cat owner participation, and to reduce cat stress, arousal, and chance of habituation to toys by limiting overall testing time. Future research should verify that cats' preferences remain the same throughout repeated sessions. Moreover, re-testing can highlight when habituation occurs and the influence of habituation on toy and odor preference. Also, preference for moving toys could have been impacted by the tracer scent in the Zero Odor® spray; however, this is unlikely as it should have dissipated within 30 seconds of application. Furthermore, cats' previous experiences with similar toys and odor should also be considered in future work to distinguish between a stable preference and a possible novelty induced preference. Herein we did not test cats' preference for stationary and moving toys simultaneously. Thus, further studies that make a simultaneous comparison between scented and unscented moving and stationary toys are needed to further confirm our findings. In this study, we only recorded active interaction with toys and odor stimulus. Future research should consider other, more passive forms of interaction, such as laying on top of or near the toys, for a more in-depth look at the types of interaction that each odor might elicit. This was not done in our current study because our focus was towards non-passive forms of interactions with the toys such as play. Future research should also assess if the same preference is observed in different cat populations (e.g., shelter and lab cats), within the context of social play, and to explore the effectiveness of using cats' preferred toys to redirect problem behavior (i.e., play with inappropriate objects).

5. Conclusion

Our results show that all cats preferred either catnip or silver vine, with a majority preferring catnip, and that cats interacted more with moving than stationary toys. Adding cats' preferred odor to stationary toys increased their interaction time but this effect was not observed in moving toys, likely due to movement itself being a strong enough stimulus to promote play behavior. Altogether our data suggest that movement increases toy interaction more than olfactory enrichment but, in the case of stationary toys, olfactory enrichment might be a simple way for owners to increase toy interaction with stationary toys. These results can be applied to encourage play behaviors and promote positive welfare in pet cats.

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Zhang Lingna: Writing – review & editing. **Stellato Anastasia C.:** Writing – review & editing, Methodology, Conceptualization. **Webberson Emily:** Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Aviles-Rosa Edgar O.:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Formal analysis. **O'Hanley Kristina A.:** Writing – review & editing, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Declaration of Generative AI and AI-assisted technologies in the writing process

No AI technology was used to prepare or edit the manuscript.

Supporting information

All data associated with this article can be found in the supplementary materials.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2025.106592.

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