The ins and outs of the litter box: A detailed ethogram of cat elimination behavior in two contrasting environments

Ragen T.S. McGowan⁎, Jacklyn J. Ellis, Miles K. Bensky, François Martin

Nestlé Purina Research, Saint Joseph, MO, 64503, USA

A R T I C L E   I N F O

Keywords:
Cat
Elimination behavior
Urrination
Defecation
Litter box
Wellbeing

A B S T R A C T

Few studies have sought to describe cat elimination behavior in detail and much of the information presently available focuses on factors that potentially cause cats to reject a litter box. Thus, the ethograms published in the current veterinary and scientific literature largely focus on macro behaviors (e.g., enter box, dig, squat, cover, and exit box) and lack the detail necessary to make distinctions between types of litter box experiences for cats. To facilitate our understanding of what positive and negative litter box experiences look like for cats, we observed cats eliminating in both an enriched (“positive”) and in a clinic-like (“restricted”) environment. Our results reveal that cat elimination behavior is complex and may include up to 39 different behaviors expressed during urination and defecation events. We further evaluated each event, examining the behaviors occurring pre-, during, and post-elimination as a means to better understand the behaviors associated with the appetitive, consummatory, and post-consummatory phases of the reward cycle around elimination. In doing so, we found clear differences in behavior at different stages of the elimination sequence between our two environments. In general, the elimination sequence was prolonged in the clinic-like environment compared to the enriched environment (P < 0.005) and most of the extra time was spent interacting with the box post-elimination (P < 0.005). In the clinic-like environment cats were hesitant to enter the box, spent a considerable amount of time pawing at surfaces other than the litter (P < 0.02) and spent a great deal of time sniffling eliminations post-elimination (P < 0.005). In addition, cats in the clinic-like environment had less frequent urination events and their events were longer in duration than when in the enriched environment (P < 0.0039). Thus, although seemingly counterintuitive, a relatively brief elimination sequence may be indicative of a more positive litter box experience. In addition, when given the opportunity cats will utilize a large amount of space during their elimination sequence. Despite popular perception that cats will immediately turn to out-of-box elimination if they are dissatisfied with their litter box environment, we discovered that cats will continue to use a box (and not eliminate outside the box) even when their behavior is indicative of frustration.

1. Introduction

The domestic cat is quickly becoming the most popular house pet in much of the Western world. It has been estimated that the pet cat population in the United States is approximately 74 million (Shepherd, 2012), in Canada is roughly 9 million (Canadian Animal Health Institute, 2016), and in Europe is nearly 98 million (FEDIAF, 2014). However, despite their popularity it is inevitable that problem behaviors will occasionally arise in these households, and threaten to weaken the bond between cats and their human caretakers. The most common behavioral reason cited by owners for relinquishing their cats to shelters is inappropriate elimination (Salman et al., 2000). Inappropriate elimination can often refer to two different problem behaviors: spraying, and toileting out-of-box (i.e., urinating or defecating). As a result, there is a wealth of resources available to concerned owners hoping to reduce the incidence of these behaviors in their homes. Many of these articles are prescriptive in nature and are written by licensed veterinarians or veterinary behaviorists, based on conventional wisdom (e.g., n + 1 for the number of litter boxes, Borchelt and Voith, 1996). Although in most cases, experts would agree that the recommendations given in these articles may result in a reduction in inappropriate elimination, many of the recommendations they give are not linked to actual randomized controlled trials (Olm and Houpt, 1988; Neilson, 2004).

In fact, there has been remarkably little scientific examination of inappropriate elimination. Spraying has received the bulk of the research, with most of these studies focusing on the efficacy of various treatments on the reduction of this behavior (summarized in Mills et al.,...
Toileting out-of-box has received significantly less scientific examination, with a few exceptions. If not medical in origin, this problem is generally attributed to a few different causes: 1) inter-cat issues, such as one cat guarding the litter box from another; 2) stress due to changes in the household, such as moving to a new home or the arrival of a new pet or family member; or 3) problems with the quality of the litterbox (Neilson, 2004). The recommendation for treating the first cause is often to increase the number of litter boxes available to the cats and to ensure these litter boxes are distributed in different locations around the house, to discourage resource guarding (Neilson, 2004). The second cause of inappropriate elimination is regularly attributed to stress or anxiety. Feliway is often recommended to treat anxiety related behavior problems (Herron, 2010), as it has been shown in several peer reviewed studies to reduce behaviors indicative of stress (e.g., Gaultier et al., 1998; Griffith et al., 2000; Pereira et al., 2015) and it is reasonable that this logic could easily be extended to problems with inappropriate elimination.

There are a handful of published studies investigating how different factors influence the cats’ perception of the quality of the litterbox environment, such as the type of substrate (Borchelt, 1991), the odor control abilities of the litter (Neilson, 2007, 2008a), and the size of the litter box (Neilson, 2008b; Guy et al., 2014). However, these studies evaluated the cat’s perception of the quality of the litterbox environment through the daily measurement of the frequency and location of urine and fecal deposits when presented with two competing environments. Although these data certainly communicate a great deal about cat preferences, they fail to consider the behaviors exhibited by the cat during the elimination sequence. It is likely that changes in these behaviors may be more sensitive to preferences, and may therefore communicate considerably more than the measurement of the frequency and location of elimination deposits alone.

Despite their probable importance, little is known about cat elimination behaviors. Sung (2001) developed a basic ethogram (cover, dig, paw, and sniff) and looked for relationships in these macro-behaviors (as well as some factors related to the cat and the litter box) between cats with or without known elimination behavior problems. Cottam and Dodman (2007) presented a list of seven micro-behaviors they classified as “dissatisfied” litter box behaviors (e.g., scratching at the side of the litter box, or raising a paw on the side of the litter box while eliminating). The classification of the behaviors in this list was based on evidence in peer reviewed experimental studies. However, this study does not present a complete picture of cat elimination behaviors, as it lacks positive or neutral behaviors. Spooner (1990) developed a detailed ethogram of feline urinary behavior. However, this ethogram lacks fine detail for some specific behaviors (e.g., whether the cat is scratching at the substrate or at the side of the box), and does not include the behaviors involved in defecation.

The objective of this work was to describe the elimination behavior of domestic cats in two contrasting elimination environments. The first environment (“enriched”) was specifically designed to provide a positive elimination experience by including the preferred characteristics identified in the studies above (e.g., large space, moisture absorbing fine grained litter, odor coverage, ability to conceal eliminations). The characteristics of the second environment (“clinic-like”) were selected because they were counter to the preferred characteristics identified in the above studies (e.g., small space, no moisture absorbency or odor coverage, no ability to conceal eliminations) thus creating a relatively negative elimination experience. The second elimination environment was similar to that which a cat would experience at a veterinary clinic if urine or fecal samples were needed for analysis. Within the existing literature there has been little effort made to distinguish positive from negative litter box experiences. It was hypothesized that the cat’s behavior in the two environments would be different and that these differences would be reflective of the quality of the elimination experience. The goal of the study was to create an ethogram capturing the range of behaviors expressed in two extremes of litter box environments – not to investigate preference between the environments. In this regard, the behavioral information gained here could be employed as a useful tool in the subsequent assessment of litter box preferences in a wider range of environments or to assess the efficacy of clinical interventions.

2. Methods

2.1. Subjects

The elimination behavior of 12 domestic shorthair cats was observed (six neutered males and six spayed females). All cats were born and raised at the Nestlé Purina cattery in Missouri, USA and ranged in age from one to five years (mean = 1.7 years). These cats were well socialized with daily interaction with their caretakers and other cats. They lived in large, enriched, group rooms so that, as much as possible, they served as a good model for pet cats. All cats were healthy and none of them regularly expressed elimination behavior problems (i.e., “out-of-box elimination”).

2.2. Experimental design

The experiment was conducted according to the USDA guidelines for animal care and use. Furthermore, all aspects of the experimental design were approved by the Nestlé Purina Institutional Animal Care and Use Committee. The cats’ behavior was observed in two separate environments during three experimental phases.

2.2.1. Enriched environment – acclimation phase

This phase began at 08:00 h on experimental day 1 and ended at 08:00 h on experimental day 5. Cats were placed individually in a large room (3.65 × 4.26 m) with elevated resting boards, toys, and a sandbox-sized (89 × 89 × 17 cm) stainless steel litter box filled and maintained to at least 5 cm in depth with a commercially available loose sandy clay scooping litter (Fig. 1a). Cats were not videotaped during this phase.

Fig. 1. Depiction of the two environments: A) The enriched environment including a large (89 × 89 × 17 cm) stainless steel litter box filled with loose sandy clay scooping litter. B) The clinic-like environment including a small commercial (41 × 30 × 10 cm) litter box containing poly-propylene beads as litter substrate.
2. Measures and analyses

3.1. Video recording

Cats were video recorded with Mangold's VideoSyncPro software (Mangold International GmbH, Arnstorf, Germany) for 24 h on four consecutive days in both the enriched (ethogram development phase) and clinic-like environments. Four wireless video cameras (Bosch 540 TVL hi-performance day/night cameras, Bosch GmbH, Gerlingen, Germany, equipped with RF-Link 5.8 GHz SR wireless transmitter/receivers, RF-Link/Araneus USA, Inc., Corona, California, USA) were used to record the cats' behavior (cameras on three sides of the litter box and one camera on the ceiling looking down at the litter box).

3.1.1. Cat location

Using the video footage from the camera mounted above the litter box, cat location in the litter box was coded by the location of the cat's nose. The nose was tracked as an indicator of the cat's initial interaction (i.e., sniffing or touching the box while outside the box or jumping in the box) with the litter box before elimination until the cat exited the litter box after elimination. All events included a time buffer of 10 s before initially interacting with the litter box and 10 s after exiting the litter box.

3.1.2. Elimination information

Using the video footage, data for the time of day, type of elimination, and the location of each elimination were collected. The location of each elimination event was determined by noting where the cat's hind-end was positioned while eliminating using the same zoning grid as above.

3.1.3. Elimination sequence

Elimination events in the enriched environment and the clinic-like environment were coded and catalogued with Mangold's INTERACT 9 software (Mangold International GmbH, Arnstorf, Germany) by two coders. Elimination events were defined as the cat's initial interaction (i.e., sniffing or touching the box while outside the box or jumping in the box) with the litter box before elimination until the cat exited the litter box after elimination. All events included a time buffer of 10 s before initially interacting with the litter box.

3.2. Behavior coding

Urination and defecation combination events where less than one minute separated the excretion of urine and feces were made a separate category because it could not be determined which behaviors in the elimination sequence were associated with urination and which behaviors were associated with defecation. However, these events did not occur sufficiently often (nine events in total for both environments) to be analyzed statistically, and therefore are not included in the results.

Separate urination and defecation events were divided into three segments: pre-, during, and post-elimination. The 10 s buffer before elimination was included in the pre-elimination segment. The pre-elimination segment ended at the start of excretion. The “during” elimination segment included the time in which the cat was urinating or defecating. The post-elimination phase included the time from the completion of excretion until the end of the 10 s buffer after the cat exited the box.

Due to time constraints and the enormous amount of video footage recorded, not all elimination events were coded. One day (24 h) in the enriched environment and one day (24 h) in the clinic-like environment were coded for each cat. Within each environment, the day selected was based on: (1) whether there was both urination and defecation events that day; and (2) how many events occurred that day, with preference given to days with more events. A total of 91 events were coded in data collection/ethogram validation. All elimination events occurring during four days in the enriched environment and four days in the clinic-like environment were used to create a distribution depicting the time of day that both urination and defecation events occurred.

3.2.1. Ethogram

An ethogram was developed to include 39 different behaviors observed immediately prior to, during, or immediately following elimination events. A full description of these behaviors can be found in Table 1. All behaviors were coded as frequencies with measurable durations, with the exception of shake movements (very short duration) and elimination locations which were only coded as frequencies.

3.2.2. Inter-rater reliability

Thirteen of the total 91 (14%) elimination events coded in data collection/ethogram validation were randomly selected to check the inter-rater reliability of the two coders. The average Cohen's Kappa for all behavior classes coded was greater than 0.85, with the exception of "eye squint" which was at 0.70 concordance. Above 0.75 concordance between coders is generally characterized as excellent (Bakeman and Gottman, 1997).

3.3. Statistical analyses

Frequency and/or duration of each behavior are reported as means and standard errors to allow for quick reference in the interpretation of
comparisons made between the enriched and clinic-like environments. Inferential statistics were made using the Friedman Chi Squared test in SAS (SAS Statistical Software 9.3, SAS Institute Inc., Cary, NC, USA), as normality could not be assumed given the small sample size and uneven number of elimination events between cats. Data regarding potential differences in behavior between male and female cats are reported as percentages of elimination events where each behavior was observed. Inferential statistics between the sexes were made using the test for two proportions in Minitab (Minitab® Statistical Software 16.1.1, Minitab Inc., State College, PA, USA). However given the small sample size (six individuals from each sex) these comparisons should be interpreted with caution. With regards to the inferential statistics, only results statistically significant at the alpha 0.05 level are reported.

4. Results

Within the total of the 91 elimination events that contributed to the dataset there were 58 urinations (40 from the enriched and 18 from the clinic-like environment) and 24 defecations (14 from the enriched and 10 from the clinic-like environment). A complete report of the frequency and duration of each behavior occurring pre-, during, and post- elimination in each environment can be found in Appendices 1–6. Details regarding the percentage of events where male and female cats performed each behavior during urination and defecation in each environment can be found in Appendix 7.

4.1. Urination events

Cats urinated throughout the day with a peak in urinations occurring between 07:00 and 08:00 h in both environments (Fig. 4a). Cats took longer to complete their urination sequences when in the clinic-like environment (Mean ± SE: 434.31 ± 229.58 s) as compared to the enriched (150.91 ± 63.25 s) environment ($\chi^2 = 8.33, df = 1, P = 0.0039$; Fig. 4b).

4.1.1. Pre-urination segment

There was no difference in duration of the pre-urination segments of the elimination events in the clinic-like (Mean ± SE: 129.21 ± 116.53 s) environment as compared to the enriched (65.3 ± 50.64 s) environment (Fig. 4b). Of the 39 behaviors coded, all but “flex,” “whiskers bunched,” “over the shoulder,” “urination,” “defecation,” and “candy cane” were observed during the pre-urination segments (Appendix A).

In the clinic-like environment, cats stood more frequently ($\chi^2 = 5.44, df = 1, P = 0.0196$) and for longer durations ($\chi^2 = 5.44, df = 1, P = 0.0196$) in the clinic-like than in the enriched environment. In the clinic-like environment, female cats (78% of events, performed by 5/6 females; $z = 2.12, P = 0.0340$). While there was no difference in how often or for how long cats were walking when comparing the two environments, cats were observed to pivot more often ($\chi^2 = 8.33, df = 1$, $P = 0.0039$).
P = 0.0039) and for longer durations ($X^2 = 5.33, df = 1, P = 0.0209$) in the clinic-like environment as compared to the enriched environment.

Pre-urination tail posture was relatively similar between females and males in the enriched environment save for tail wagging which was observed more often for male cats (58% of events, performed by 5/6 males) than female cats (29% of events, performed by 4/6 females; $z = −1.95, P = 0.0491$). In considering the olfactory behavior of the cats, they sniffed objects other than the substrate or the elimination more often ($X^2 = 12.00, df = 1, P = 0.0005$) and for longer periods ($X^2 = 8.33, df = 1, P = 0.0039$) in the clinic-like environment than they did when housed in the enriched environment.

Cats pawed at surfaces other than the litter more often ($X^2 = 5.44, df = 1, P = 0.0196$) and for longer durations ($X^2 = 5.44, df = 1, P = 0.0196$) in the clinic-like environment than in the enriched environment. Although differences in the frequency or duration of digging between the two environments did not reach statistical significance, there were potential differences between males and females in the prevalence of this behavior. Male cats were observed digging pre-urination more often (95% of events, performed by 6/6 males) in the clinic-like environment than did when housed in the enriched environment.

When considering paw placement in and around the litter box, cats shifted their paw placement more often in the clinic-like environment as compared to the enriched environment. Cats had zero ($X^2 = 5.44, df = 1, P = 0.0196$), one ($X^2 = 7.36, df = 1, P = 0.0067$), two ($X^2 = 4.45, df = 1, P = 0.0348$), and three ($X^2 = 5.44, df = 1, P = 0.0196$) paws in the litter box more often in the clinic-like environment as compared to the enriched environment. In addition, when in the clinic-like environment cats maintained postures where only one ($X^2 = 5.33, df = 1, P = 0.0209$) or two ($X^2 = 5.33, df = 1, P = 0.0209$) paws were in the litter box for longer durations compared to when they were in the enriched environment. For the most part, cats utilized the entire box during their pre-urination activities in both the enriched (Fig. 2b) and clinic-like (Fig. 3b) environments. In the enriched environment specifically, male cats (95% of events, performed by 6/6 males) were observed in box zone 8 more often than female cats (71% of events, performed by 6/6 females) pre-urination ($z = −2.10, P = 0.0360$).

4.1.2. During urination segment

Cats urinated for longer durations in the clinic-like (Mean ± SE: 51.44 ± 33.75 s) as compared to the enriched (19.69 ± 6.1 s) environment ($X^2 = 8.33, df = 1, P = 0.0039$; Fig. 4b). Cats performed fewer behaviors during this segment (Appendix B). The following behaviors were not observed during urination in either environment: “interact with objects,” “eat/drink,” “groom,” “stand,” “sit,” “lying down,” “stretch,” “upright,” “defecation,” “incomplete elimination,” “head shake,” “body shake,” “sniff other,” “taste litter,” “pawing,” “digging,” “covering,” “1 paw,” “erect,” and “swish.” The occurrence and/or duration of only two behaviors were significantly different between the two environments. When urinating in the clinic-like environment, cats had three paws in the litter box more frequently ($X^2 = 7.00, df = 1, P = 0.0082$) and for longer durations ($X^2 = 7.00, df = 1, P = 0.0082$) than when urinating in the enriched environment. Cats also displayed the inverted U-tail
position for greater durations in the clinic-like environment ($X^2 = 8.33$, $df = 1, P = 0.0039$) than when in the enriched environment. Female cats looked over their shoulder more often (43% of events, performed by 3/6 females) than male cats (16% of events, performed by 2/6 males) while urinating in the enriched environment ($z = 1.98, P = 0.0480$). For the most part, cats used the entire box to make their urination deposits in both the enriched (Fig. 2c) and clinic-like (Fig. 3c) environments.

### 4.1.3. Post-urination segment

The mean duration of the post-urination segment was longer in the clinic-like (Mean ± SE; 253.65 ± 192.01 s) than the enriched environment (65.92 ± 54.92 s) environment ($X^2 = 8.33$, $df = 1, P = 0.0039$; Fig. 4b). Of the 39 behaviors coded, all but eight were observed during the post-urination segment (Appendix C): namely, “flex,” “eye squint,” “whiskers bunched,” “stretch,” “urination,” “defecation,” “incomplete elimination,” and “erect” tail posture.

Cats showed vigilance more frequently ($X^2 = 7.36$, $df = 1, P = 0.0067$) and for longer durations ($X^2 = 4.45$, $df = 1, P = 0.0348$) when housed in the clinic-like environment as compared to the enriched environment. Cats also groomed themselves more often ($X^2 = 4.00$, $df = 1, P = 0.0455$) and for longer durations ($X^2 = 4.00$, $df = 1, P = 0.0455$) in the clinic-like environment as compared to the enriched environment. In addition, when housed in the clinic-like environment cats wagged their tail for shorter durations ($X^2 = 4.00$, $df = 1, P = 0.0455$) than when in the enriched environment.

In the clinic-like environment, cats stood more often ($X^2 = 6.40$, $df = 1, P = 0.0114$), and for longer durations ($X^2 = 12.00$, $df = 1, P = 0.0005$), and also sat more often ($X^2 = 4.45$, $df = 1, P = 0.0348$) as compared to the enriched environment. Cats utilized the entire box in both the enriched (Fig. 2d) and clinic-like (Fig. 3d) environments, however when in the enriched environment male cats (74% of events, performed by 5/6 males) were observed in box zone 5 more often than female cats (29% of events, performed by 3/6 females) post-urination ($z = 3.20, P = 0.0010$). Especially for the clinic-like environment, cats frequently moved away the box. Cats had more frequent bouts of walking ($X^2 = 5.33$, $df = 1, P = 0.0209$) and pivoting ($X^2 = 7.36$, $df = 1, P = 0.0067$) as well as longer durations of pivoting ($X^2 = 5.33$, $df = 1, P = 0.0209$) in the clinic-like as compared to the enriched environment. While cats of both sexes were equally likely to be observed pivoting in the clinic-like environment, male cats were observed pivoting more often (100% of events, performed by 6/6 males) than female cats (71% of events, performed by 6/6 females) in the enriched environment ($z = -2.90, P = 0.0040$).

When considering their olfactory behavior, cats housed in the clinic-like environment sniffed the litter less frequently ($X^2 = 8.00$, $df = 1, P = 0.0047$) and for shorter durations ($X^2 = 8.00$, $df = 1, P = 0.0047$) compared to when they were housed in the enriched environment. By

Table 1

<table>
<thead>
<tr>
<th>Type</th>
<th>Behavior</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Interact with objects</td>
<td>Cat bats, moves, or plays with toy, litter box, litter/beads, or other object</td>
</tr>
<tr>
<td>Vigilance</td>
<td></td>
<td>Cat suddenly becomes immobile, with body tense, eyes fixate away from litter environment</td>
</tr>
<tr>
<td>Eat/drink</td>
<td></td>
<td>Cat eats or drinks from food/water dishes</td>
</tr>
<tr>
<td>Groom</td>
<td></td>
<td>Cat cleans itself by licking its body or paws, or at scratches at self</td>
</tr>
<tr>
<td>Ear wings</td>
<td></td>
<td>During elimination, cat’s ears move out and to the side</td>
</tr>
<tr>
<td>Flex</td>
<td></td>
<td>During elimination, cat’s hips span in and out repeatedly</td>
</tr>
<tr>
<td>Eye squint</td>
<td></td>
<td>During elimination, cat slowly narrows eyelids</td>
</tr>
<tr>
<td>Whiskers bunched</td>
<td></td>
<td>Whiskers are held back against the face, close together</td>
</tr>
<tr>
<td>Over the shoulder</td>
<td></td>
<td>During elimination, cat turns head over one shoulder, cat looks back towards elimination spot</td>
</tr>
<tr>
<td>Balancing</td>
<td></td>
<td>Cat rests weight on sides of the litter box (minimum duration of 3 s to code this behavior)</td>
</tr>
<tr>
<td>Body postures</td>
<td>Stand</td>
<td>Cat is positioned with 3–4 paws in contact with the ground with legs straight</td>
</tr>
<tr>
<td></td>
<td>Sit</td>
<td>Cat rests fully on hind quarters with front legs straight, propping up chest and head</td>
</tr>
<tr>
<td></td>
<td>Lying down</td>
<td>Cat is positioned with ventral or lateral side and legs in contact with the ground, paws folded or unfolded</td>
</tr>
<tr>
<td></td>
<td>Stretch</td>
<td>Cat displays an extreme extension of either front or back paws and legs away from the body. May also include extreme arched back with legs fully extended.</td>
</tr>
<tr>
<td></td>
<td>Upright</td>
<td>Cat has both front paws pressed against a vertical surface</td>
</tr>
<tr>
<td></td>
<td>Urination</td>
<td>Cat lowers hind legs and pelvis into a squatting position and urinates</td>
</tr>
<tr>
<td></td>
<td>Defecation</td>
<td>Cat lowers hind legs and pelvis into a squatting position and defecates</td>
</tr>
<tr>
<td></td>
<td>Incomplete elimination</td>
<td>Cat lowers hind legs and pelvis into a squatting position but does not eliminate</td>
</tr>
<tr>
<td>Body movements</td>
<td>Walk</td>
<td>Cat locomotes forward in a relatively straight line taking at least three steps. Front paws count steps</td>
</tr>
<tr>
<td></td>
<td>Pivot</td>
<td>Cat rotates body 180° over a single focal point in a continuous motion. Interruptions greater than 1 s are considered a new behavior bout</td>
</tr>
<tr>
<td>Shake movements</td>
<td>Head shake</td>
<td>Cat rotates head to and fro in short, irregular, often jerky movements</td>
</tr>
<tr>
<td></td>
<td>Body shake</td>
<td>Cat rotates body to and fro in short, irregular, often jerky movements</td>
</tr>
<tr>
<td></td>
<td>Paw shake</td>
<td>Cat lifts and rapidly moves front or back paw(s) in short, irregular, often jerky movements</td>
</tr>
<tr>
<td>Sniff/taste behaviors</td>
<td>Sniff litter</td>
<td>Cat lowers head (nose) within two inches of the litter substrate</td>
</tr>
<tr>
<td></td>
<td>Sniff elimination</td>
<td>Cat lowers head (nose) within two inches of elimination site</td>
</tr>
<tr>
<td></td>
<td>Sniff other</td>
<td>Cat extends or lowers head (nose) within two inches of a surface other than litter or elimination</td>
</tr>
<tr>
<td></td>
<td>Taste litter</td>
<td>Cat places a small amount of litter in its mouth (may include elimination)</td>
</tr>
<tr>
<td>Paw motions</td>
<td>Pawing</td>
<td>Cat uses one or two front paws to repeatedly contact surface other than litter. Similar to scratching, but without nails extended</td>
</tr>
<tr>
<td></td>
<td>Digging</td>
<td>Cat uses one or two front paws to scratch at litter, appearing to be attempting to create a recess in the litter</td>
</tr>
<tr>
<td></td>
<td>Covering</td>
<td>Cat uses one or two front paws to move litter towards/over elimination site</td>
</tr>
<tr>
<td>Paw positions</td>
<td>0 paws</td>
<td>Cat outside of the litter box with no paws in the litter box</td>
</tr>
<tr>
<td></td>
<td>1 paw</td>
<td>Cat has one paw within the litter box</td>
</tr>
<tr>
<td></td>
<td>2 paws</td>
<td>Cat has two paws within the litter box</td>
</tr>
<tr>
<td></td>
<td>3 paws</td>
<td>Cat has three paws within the litter box</td>
</tr>
<tr>
<td></td>
<td>4 paws</td>
<td>Cat has four paws within the litter box</td>
</tr>
<tr>
<td>Tail positions</td>
<td>Inverted U-tail</td>
<td>Cat holds tail up and out from the body in a curved position resembling an upside down &quot;U&quot;</td>
</tr>
<tr>
<td></td>
<td>Erect</td>
<td>Cat hold tail straight up (perpendicular to back), no curve in the tail</td>
</tr>
<tr>
<td></td>
<td>Wagging</td>
<td>Cat holds tail out horizontally with the bottom half of the tail moving side to side</td>
</tr>
<tr>
<td></td>
<td>Swish</td>
<td>Cat holds tail out horizontally and full tail is lashing from side to side</td>
</tr>
<tr>
<td></td>
<td>Candy cane</td>
<td>Cat holds tail out horizontally with the end of the tail curved upwards</td>
</tr>
<tr>
<td></td>
<td>Twitch</td>
<td>Cat makes brief motions with the tip of the tail but does not consistently move tail side to side</td>
</tr>
</tbody>
</table>

contrast, cats in the clinic-like environment sniffed eliminations ($\chi^2 = 12.00, df = 1, P = 0.0005$) and other objects ($\chi^2 = 10.00, df = 1, P = 0.0016$) more frequently and for longer durations ($\chi^2 = 12.00, df = 1, P = 0.0005$ and $\chi^2 = 7.36, df = 1, P = 0.0067$, respectively) than when in the enriched environment. Male cats were more likely (100% of events, performed by 6/6 males) than female cats (67% of events, performed by 5/6 females) to be observed sniffing other objects in the clinic-like environment ($z = 2.12, P = 0.0340$).

Cats in the clinic-like environment pawed surfaces other than the litter more often ($\chi^2 = 12.00, df = 1, P = 0.0005$) and for longer durations ($\chi^2 = 12.00, df = 1, P = 0.0005$) than when in the enriched environment. In the clinic-like environment, cats moved in and out of the litter box more often and shifted their posture more often as is demonstrated by the fact that they had zero ($\chi^2 = 12.00, df = 1, P = 0.0005$), one ($\chi^2 = 11.00, df = 1, P = 0.0009$), and two ($\chi^2 = 11.00, df = 1, P = 0.0009$) paws in the litter box more frequently than when in the enriched environment. Cats maintained body postures where they had zero ($\chi^2 = 12.00, df = 1, P = 0.0005$), one ($\chi^2 = 12.00, df = 1, P = 0.0005$), or two ($\chi^2 = 5.33, df = 1, P = 0.0209$) paws in the box for longer durations in the clinic-like environment as compared to the enriched environment and had all four paws in the litter box for shorter durations ($\chi^2 = 12.00, df = 1, P = 0.0005$) in the clinic-like environment when compared to the enriched environment.

### 4.2. Defecation events

Cats defecated throughout the day with a peak in defecations occurring between 07:00 h and 08:00 h in both environments (Fig. 5a). Twenty-four individual cat defecation events were coded (14 in the enriched environment [performed by 5 males and 5 females]) and 10 in the clinic-like environment (performed by 4 males and 5 females). Overall, cats took longer to complete defecation events in the clinic-like (475.17 ± 251.35 s) than in the enriched (234.92 ± 118.88 s) environment ($\chi^2 = 8.0, df = 1, P = 0.0047$; Fig. 5b).

#### 4.2.1. Pre-defecation segment

There was no difference in the duration of the pre-defecation segment between the enriched (132.13 ± 105.97 s) and clinic-like (189.17 ± 149.60 s) environments (Fig. 5b). All of the behaviors included in the ethogram were observed during the pre-defecation segment (Appendix D) save for “whiskers bunched,” “flex,” “over the shoulder,” “urination,” and “defecation,” which were not observed in either environment.

In considering body posture and movement there were three differences in cat behavior between the two environments. Cats displayed incomplete elimination postures less frequently ($\chi^2 = 6.00, df = 1, P = 0.0143$), pivoted more frequently ($\chi^2 = 6.00, df = 1, P = 0.0143$), and pivoted for longer durations ($\chi^2 = 4.50, df = 1, P = 0.0339$) in the clinic-like environment. Male cats, but not females, were observed stretching in the clinic-like environment (60% of events, performed by 3/4 males). Male cats were also more likely (80% of events, performed by 3/4 males) than female cats (20% of events, performed by 1/5 females) to be observed lying down in the clinic-like environment pre-defecation ($z = -2.37, P = 0.0180$). No such difference was apparent in the enriched environment.

Cats sniffed the litter less frequently ($\chi^2 = 4.50, df = 1, P = 0.0339$) and for shorter durations in the clinic-like environment ($\chi^2 = 8.00, df = 1, P = 0.0047$), but sniffed other objects for longer durations ($\chi^2 = 7.00, df = 1, P = 0.0082$) in this same environment. In the clinic-like environment, cats had zero ($\chi^2 = 4.50, df = 1, P = 0.0339$), one ($\chi^2 = 4.50, df = 1, P = 0.0339$), and two paws ($\chi^2 = 4.50, df = 1, P = 0.0339$) in the litter box for longer durations than when in the enriched environment.

Only male cats were ever observed to display an inverted U-tail (80% of events, performed by 3/4 males) in the clinic-like environment post-defecation. For the most part, cats utilized the entire litter box space pre-defecation in both the enriched (Fig. 6b) and clinic-like (Fig. 7b) environments.

#### 4.2.2. During defecation segment

The durations of the defecations did not differ between the enriched (Mean ± SE; 39.97 ± 19.62 s) and clinic-like (44.56 ± 24.81 s) environments (Fig. 5b). Fewer behaviors were observed during defecation (Appendix E) with “interact with objects,” “eat/drink,” “groom,” “stand,” “sit,” “lying down,” “stretch,” “upright,” “urination,” “incomplete elimination,” “body shake,” “sniff other,” “taste litter,” “pawing,” "
Fig. 5. Characteristics of defecation events: A) Time of day of all defecations for both environment types and B) mean duration of time spent in the three elimination sequence segments (pre-, during, and post-elimination) during the coded defecation events.

Fig. 6. Utilization of enriched litter box for defecation: A) Division of litter box space into nine defined zones with number of total defecation events in each zone; Mean frequency (F: Mean ± SE) cats entered and mean duration (D: Mean ± SE) of time cats spent in each zone of the enriched environment B) Pre, C) During and D) Post defecation.
and “0 paws,” not being observed in either environment.

The occurrence and/or duration for only five behaviors during defecation were significantly different between the two environments. Cats moved their ears into the ear wing position ($X^2 = 4.00, df = 1, P = 0.0455$) and squinted their eyes ($X^2 = 5.00, df = 1, P = 0.0253$) less often in the clinic-like environment when compared to the enriched environment. Cats had four paws in the litter box for shorter durations ($X^2 = 4.50, df = 1, P = 0.0339$) and balanced on the sides of the litter box in the clinic-like environment, a behavior that was not observed in the enriched environment.

When considering tail posture during defecation, cats had their tail in the inverted U-tail position more often in the clinic-like environment ($X^2 = 4.00, df = 1, P = 0.0455$) than when in the enriched environment. While cats of both sex were observed to hold their tails in the inverted U-tail position during 100% of the coded events in the clinic-like environment, females were observed displaying this tail position more often (83% of events, performed by 4/5 females) than males (13% of events, performed by 1/4 males) in the enriched environment. Male cats, on the other hand, were the only cats to display the candy cane tail ($X^2 = 4.50, df = 1, P = 0.0339$) in the enriched environment. For the most part, cats used the entire box during defecation in both the enriched (Fig. 6c) and clinic-like environments.

4.2.3. Post-defecation segment

The post-defecation segment lasted longer in the clinic-like (241.44 ± 194.07 s) compared to the enriched (62.82 ± 29.48 s) environment ($X^2 = 8.00, df = 1, P = 0.0047$; Fig. 5b). All 39 behaviors included in the ethogram were observed during the post-defecation segment (Appendix F) save for “ear wings,” “flex,” “eye squint,” “whiskers bunched,” “over the shoulder,” “stretch,” “urination,” and “defecation,” which were not observed in either environment.

While cats groomed themselves post-defecation in the clinic-like environment, this behavior was never observed post-defecation in the enriched environment. Interestingly, only female cats were ever observed to groom post-defecation (80% of events, performed by 4/5 females) in the clinic-like environment. In the clinic-like environment, cats stood for longer durations ($X^2 = 8.00, df = 1, P = 0.0047$), sniffed eliminations more often ($X^2 = 4.50, df = 1, P = 0.0339$) and for longer durations ($X^2 = 8.00, df = 1, P = 0.0047$), sniffed surfaces other than the litter or elimination more often ($X^2 = 4.50, df = 1, P = 0.0339$) and for longer durations ($X^2 = 4.50, df = 1, P = 0.0339$) as compared to the enriched environment. In the clinic-like environment, cats pawed more frequently ($X^2 = 7.00, df = 1, P = 0.0082$) and for longer durations ($X^2 = 7.00, df = 1, P = 0.0082$) than in the enriched environment.

In the clinic-like environment, cats moved in and out of the litter box more often and shifted their posture more often as is demonstrated by the fact that they had zero ($X^2 = 6.00, df = 1, P = 0.0143$), one ($X^2 = 6.00, df = 1, P = 0.0143$), or two ($X^2 = 5.00, df = 1, P = 0.0253$) paws in the box more frequently, and one ($X^2 = 8.00, df = 1, P = 0.0047$) or four ($X^2 = 4.50, df = 1, P = 0.0339$) paws in the litter box for longer durations as compared to when they were housed in the enriched environment. For the most part, cats used the entire box post-defecation in both the enriched (Fig. 6d) and clinic-like environments.
(Fig. 7d) environments. However, male cats were more likely (63% of events, performed by 4/4 males) than females (17% of events, performed by 1/5 females) to be in zone 7 post-defecation in the enriched environment \( z = -2.00, P = 0.0450 \).

4.3. Out-of-box elimination

During the eight days cats were housed in the enriched environment, no out-of-box urinations or defecations were recorded. During the four days cats were housed in the clinic-like environment, four out-of-box urinations and five out-of-box defecations were recorded. Cats of both sexes were equally likely to eliminate out-of-box (females: two urinations and two defecations, males: two urinations and three defecations).

5. Discussion

Prior to the efforts described within this paper, very little was known about the typical elimination behavior of domestic cats. The sum of the previous literature in this area includes only a handful of reports describing the sequence of macro behaviors exhibited around an elimination event. The results from the present study suggest that cat elimination sequences are actually much more complex than previously thought, including as many as 39 different behaviors ranging from gross macro-behaviors (e.g., posture, body movement) to more subtle micro-behaviors (e.g., ear placement, tail position). The present work contributes much to the limited previous body of knowledge. However, the number of urination events observed greatly exceeded the number of defecation events, and thus it is important to be cognizant of this limitation when interpreting the detailed behavioral analysis around defecation.

To better understand the ‘reward cycle’ around litter box use, elimination events were divided into three phases, pre-, during, and post-elimination. In this way, it was possible to quantify the cats’ appetitive (pre), consummatory (during), and post-consummatory (post) behavior around each litter box event. Typically, the appetitive phase of a behavior sequence is linked to states such as excitement and anticipation, the consummatory phase is linked to liking and pleasure, and the post-consummatory phase linked to satisfaction and relaxation (Keeling et al., 2008; Burman et al., 2011; Seehuus et al., 2013). Disruption of any part of this cycle by blocking or not providing the resources necessary for an animal to successfully carryout its motivated behavior can potentially lead to frustration or other negative affective states (Seehuus et al., 2013). The present study involved a detailed investigation of the elimination behavior of 12 cats in both an enriched environment presuming that these environments represented a positive and a negative elimination experience, respectively. While observation of elimination behavior in an outdoor naturalistic setting was outside of the scope of the present work, every attempt was made to consider some outdoor features in the design of the enriched space. For example, the cats had access to an entire open room and a large sandbox sized box filled with sand-like litter substrate. This provided ample space for the cats to express their pre-, during, and post-elimination behavior. While it is important to consider that different behaviors and/or frequencies or durations of behavior might be observed in a more natural setting, the environments presented within the current work represented two extremes in elimination environments. For the majority of pet cats in home, the features of their elimination environment would fall somewhere between these two extremes. Thus, using the resulting data it is possible to make inferences about what behaviors are associated with a positive elimination experience and those that may be associated with frustration in a less than ideal elimination environment.

For instance, in the enriched (“positive”) environment cats readily entered and exited the litter box before and after eliminations, while, by contrast, in the clinic-like (“restricted”) environment cats were more hesitant to enter the litter box to eliminate. Cats instead would waffle in an out of the litter box and it was more common for them to keep one paw out of the box while eliminating. This is in agreement with the behaviors previously described by Cottam and Dodman (2007) who noted that cats may approach a litter box, hesitate to enter and walk away or jump in and immediately jump out if they were somehow dissatisfied with the litter box. Thus, although seemingly counter-intuitive, a relatively brief elimination sequence may be indicative of a more positive litter box experience.

The biggest difference observed when comparing the behavior of the cats during elimination between the two environments was the duration of urination. Cats in the clinic-like environment appeared to be holding their urine. They urinated less often and for longer durations than when they were in the enriched environment (urine stream lasting on average 52 s compared to 20 s). This difference is also reflected in the duration of time the cats spent with their tail in an inverted U posture (a tail position that usually coincides with the elimination stance), as cats in the clinic-like environment maintained this tail position for longer durations than when in the enriched environment. Interestingly, regardless of size, all mammals take approximately 20 s to empty their bladders (Yang et al., 2013), thus 52 s is an unusually long duration. This finding may have important implications for cat urinary tract health as, at least for humans, holding urine for longer durations can make people more susceptible to urinary tract infections (Adatto et al., 1979). It is plausible that the same may hold true for cats.

Generally, cats eliminating in the clinic-like environment appeared more restless. In the clinic-like environment cats pivoted their bodies, walked around, shifted their paw posture and balanced on the side of the box more often before and after elimination than when eliminating in the enriched environment. This warrants speculation that the cats were frustrated by the elimination experience in the clinic-like environment. Perhaps the constraints of the clinic-like environment prevented them from fully completing the pre (appetitive) or post (postconsummatory) phases of the elimination sequences to their satisfaction. Of note is the fact that, even in the enriched environment, cats utilized the entire litter box space available to them. This provides grounds for speculation that larger litterboxes may allow more opportunity for cats to complete a greater repertoire of elimination behavior. Many litter boxes currently on the market are designed with human convenience in mind to fit nicely into corners or closets. Perhaps size should be considered more strongly when designing litter boxes, taking into account the cat’s perspective (Neilson et al., 2008b; Guy et al., 2014 Guy et al., 2014).

The most pronounced differences in behavior between the two litter box environments occurred in the post-elimination segment. Both the post-defecation and post-urination segments were significantly longer when the cats were in the clinic-like environment. One of the most striking behavioral differences observed between environments was the incessant pawing at all surfaces around the litter box following an elimination event by cats in the clinic-like but not enriched environment. On average cats in the clinic-like environment spent nearly two minutes post-urination and over one minute post-defecation pawing at surfaces around the litter box. Interestingly, while little pawing at surfaces around the litter box post-urination was observed in either environment, cats spent on average 21 s performing this behavior pre-defecation in the clinic-like environment but never performed this behavior pre-defecation in the enriched environment. Thus, it seems that in the clinic-like environment, where cats did not have sufficient litter substrate to either prepare a location for elimination or to cover their waste post-elimination, they redirected their pawing behavior to any surface available. These observations also align with criteria that Cottam and Dodman (2007) defined for cats being dissatisfied with their litter box environment: namely, that cats would scratch the sides of their litter box or the floor or wall near their litter box. Anecdotally, cat owners who use hooded litter boxes often complain about “box banging” behavior where their cats repeatedly paw at the side of the
found that pre-urination males scratched during 76% of occasions compared to females who scratched during 47% of events. While this author did not distinguish between scratching at the litter, the ground, or the side of the box, these numbers are consistent with the present findings for digging in the litter substrate pre-urination in the enriched environment (most comparable situation to Spooner 1990) where males dug significantly more than females. Rates of digging in general were higher than those described by Spooner (1990) with females observed digging during 62% and males during 95% of the pre-urination events in the enriched environment. However, if we consider the number of occasions where cats were observed digging with two paws specifically, males dug during 79% of events and females during 43% of events; levels almost identical to those found by Spooner (1990). As very little pawing at surfaces other than the litter pre-urination was observed in the enriched environment in the present study, it is reasonable to suspect that the scratching Spooner (1990) reports was directed toward the litter. Taken together the results from these two studies point toward sex differences in the appetitive pre-urination phase of the elimination sequence.

Spooner (1990) also noted that pre-urination females turned 50% of the time compared to males who turned 40% of the time. A similar difference in pivoting behavior during the pre-urination segment was apparent in the present study where, in the enriched environment, females pivoted during 43% of events and males during 32% of events. Spooner (1990) also noted tail wagging by males during 95% and females during 76% of urination events. The author defined wagging as a side to side tail movement thus may be comparable to what we deemed “wagging” or “swishing.” In the present study, while urinating in the enriched environment, males wagged their tails during 58% and females during 29% of events. Cats were much more likely to be observed holding their tails in an inverted U position while urinating (90% and 100% of events for males and females, respectively) than wagging while urinating (79% and 52% of events for males and females, respectively) in the current study, while Spooner (1990) does not report the prevalence of this tail position. More data is necessary to determine if these represent true sex difference in urination behavior, however the similarities are worth mentioning.

Despite popular perception that cats will immediately turn to out-of-box elimination if they are dissatisfied with their litter box environment, the present study revealed that cats will continue to use a box (and not eliminate outside the box) even when their behavior is indicative of frustration. In fact, only four out-of-box urinations and five out-of-box defecations were produced by all twelve cats over four days in the clinic-like environment (no out-of-box eliminations in the enriched environment). Thus, out-of-box elimination alone may not provide a sufficient indicator of whether the cat finds the litter box experience acceptable.

6. Conclusion

Cat elimination behavior is much more complex than previously thought. Here we described cat elimination behavior with a level of granularity never before reported. We have documented 39 behaviors associated with positive and negative litter box experiences and highlight the importance of the provision of a suitable litter box environment to promote not only optimal wellbeing, but also possibly urinary tract health in cats.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.applanim.2017.05.009.

References

Adatto, K., Doebele, K.G., Galland, L., Granowetter, L., 1979. Behavioral factors and


