



Flexibility and Use of a Novel Tool in Asian Small-Clawed Otters (*Aonyx cinerea*)

**Erin E. Frick¹, Leor Friedman², Jessica Peranteau², Kaitlyn Beacham³,
and Stan A. Kuczaj II¹**

¹*The University of Southern Mississippi, USA*

²*OdySea Aquarium, USA*

³*Six Flags Great Adventure, USA*

Asian small-clawed otters (*Aonyx cinerea*) demonstrate remarkable hand dexterity when gathering and consuming prey, but little is known about their ability to use objects as tools. The present study used a tool choice paradigm in which six Asian small-clawed otters were tested individually and presented with two identical hook-shaped tools. For each trial, only one tool was positioned such that pulling it allowed an otter to obtain food. Pulling the other hook resulted in the correct hook being moved out of reach, necessitating selection of the correct tool as its first choice. The two males performed above chance levels, but not significantly so. The females' poor overall performance may have reflected their initial inability to understand the tool choice task. In addition, some incorrect responses appeared to be due to the development of a side preference, rather than to the configuration of the apparatus. Four of the otters exhibited a significant side bias toward the left, but there were individual differences in how these preferences presented in each otter. For all otters, latency to approach and make a choice on the tool-use task decreased over time, regardless of success. Although otters do appear capable of learning which tool should be used in a forced choice comparison such as the one used here, other factors appear to influence the choices individual otters make.

Manipulating an object to alter another object or organism to purposely achieve a goal is considered evidence of tool use behavior in animals (Bentley-Condit & Smith, 2010; Mann & Patterson, 2013). Tool use was once considered unique to humans, but has since been observed in a variety of species (Alcock, 1972). For example, several instances of tool use in chimpanzees (*Pan troglodytes*) include using stones as a hammer/anvil to crack open nuts (Biro et al., 2003; Carvalho, Biro, McGrew, & Matsuzawa, 2009), grass for termite fishing (Goodall, 1964), sticks for digging (Seed & Bryne, 2010), and leaves to form compressed sponges to collect water (Sousa, Biro, & Matsuzawa, 2009). Other examples include Asian elephants (*Elephas maximus*) modifying branches for use as a switch to repel insects (Hart, Hart, McCoy, & Sarath, 2001). New Caledonian crows (*Corvus moneduloides*) manufacture and shape a hook from a stick to obtain food (Hunt, 1996; Weir, Chappell, & Kacelnik, 2002) and drop nuts from high heights onto rocks to open (Hunt, Sakuma, & Shibata, 2002). For aquatic species, bottlenose dolphins (*Tursiops truncatus*) are thought to use sponges as a tool to protect their rostrum (Smolker, Richards, Connor, Mann, & Berggren, 1997); and sea otters (*Enhydra lutris*) are known to rest rocks or stones on their stomach and bang mollusk shells on them until they break apart (Fisher, 1939; Hall & Schaller, 1964). The variety of tool use behaviors across such diverse taxa suggests that the learning—and transmission of—tool use may be dependent upon the purpose or goal driving this type of cognitive behavior.

Many of the aforementioned tool use examples were driven by the singular purpose of food extraction, which is considered one of the primary goals involved in tool use behavior (Alcock, 1972; Bentley-Condit & Smith, 2010; Hall, 1963; Parker & Gibson, 1977). Tool-use is often used as evidence of planning and other higher order cognitive abilities in animals due to its emphasis on purposeful or goal-directed behavior (Mann

& Patterson, 2013; Parker & Gibson, 1977). Demonstrating problem solving in a tool using species may rely on providing a novel tool in a situation unique to the animal, characterized by experimental testing where conditions warrant the manipulation of objects in the environment (e.g., use of a novel tool) to accomplish a task or solve a problem to achieve a goal (Boesch & Boesch, 1990; Mann & Patterson, 2013). For example, Auersperg, Von Bayern, Gajdon, Huber, and Kacelnik (2011) presented kea parrots (*Nestor notabilis*) and New Caledonian crows (*Corvus moneduloides*) with modified multi-access-box that allowed for four possible food extraction techniques, two of which required tool-use to solve the task. The results demonstrated individual differences between the two different avian species that were attributed to differences in boldness and types of behaviors used to manipulate the object. These findings further illustrate the need for increased research on cognitive tasks in different species of the same taxa, to illustrate the differences and similarities of the cognitive abilities within a given animal group.

Tool-use behaviors in sea otters, the largest otter species in family *Lutrinae*, have been extensively recorded, and these behaviors are known to vary based upon the morphology of the prey type and its prevalence in that populations' ecological niche (Fujii, Ralls, & Tinker, 2015). Asian small-clawed otters, the smallest otter species, have not been the subject of tool-use research and observation, although there are reports which suggest this to be a highly intelligent species capable of higher order cognitive abilities. Individual otters are highly manually dexterous and capable of searching, hunting and capturing prey with their forepaws (Sivasothi & Burhanuddin, 1994). While Asian small-clawed otters have not been observed to exhibit the tool-use patterns for extracting food seen in sea otters, anecdotes detail observations that they are capable of parallel tool-use abilities. For example, Asian small-clawed otters have been observed to gather clams on a rock in the hot sun until the heat causes them to split open, even though the otters have the capability to break the shells apart on their own (Sivasothi & Burhanuddin, 1994). Experimental studies by Perdue, Snyder, Zhihe, Marr, and Maple (2011) and Perdue, Snyder, and Maple (2013) demonstrated that Asian small-clawed otters have spatial memory for a food-location task, and that this species has great potential for further cognitive testing.

Asian small-clawed otters are thus ideal subjects for experimental testing on a tool-use task due to their manual dexterity when locating food, exploratory nature, and collective results from Perdue et al. (2011, 2013), which described their cognitive abilities to solve a spatial memory task. The current study presented the otters with a tool-use apparatus modified from a previous environmental enrichment assessment in sea otters (Hanna, Frick, & Kuczaj, 2016). The current study required Asian small-clawed otters (6) to use a hook-shaped tool to obtain food that was otherwise out of reach. Completion of this task did not require any explicit training prior to trials. We predicted that Asian small-clawed otters would be able to use the novel hook objects as tools to successfully complete the task (i.e., subjects will be able to determine which tool-hook to interact with and pull to obtain a food reward). It was also predicted that all measures of performance would improve across test sessions for each subject.

Method

Subjects and Facility

The subjects used in this study included six Asian small-clawed otters, two males (coded as O1 and O2) and four females (O3, O4, O5, and O6), all approximately 2 years of age, from the same litter, and weighed approximately 9-12 lbs. Each otter regularly undergoes training sessions with animal care staff, but none have previously been involved in cognitive research. All otters have resided since their infancy at the SeaFari Theater facility at Six Flags Great Adventure in Jackson, New Jersey, USA.

Apparatus

The apparatus was modeled from a force-choice tool use task presented to sea otters as a form of environmental enrichment (Hanna et al., 2016). The base of the apparatus was a plastic cutting board (61 cm x 91 cm) with a PVC pipe pulley system attached to (2) hook-shaped tools. Each of the (2) hook-tools was the same size, shape, weight, and color. This apparatus presented the test subject with the choice between the (2) hook-tools that had food placed near them. Only one hook-tool was positioned such that pulling it allowed the otter to obtain food. Pulling the incorrect hook-tool caused the correct hook-tool to be moved out of reach, requiring the otter to choose the correct tool as the first choice (e.g., a forced choice tool use task). Each of the hook-tools had a blue line placed approximately 5 cm from the top of the tool. This was the point at which pulling the tool through the gated barrier removed the opposite tool as a choice option. Primary reinforcement for choosing correctly on the tool-use task was bite-sized pieces of capelin, which was in addition to the animals' normal daily diet. The otters were provided limited access to the apparatus to ensure that only one hook-tool could be chosen during a given trial. Therefore, the apparatus was presented via a gated wall that allowed the otters' paws to reach through to pull and interact with the apparatus..

Procedure

All data were collected from July-October of 2014 at Six Flags Great Adventure in Jackson, NJ. Trials were recorded using an Olympus SP-800UZ camera that recorded simultaneous audio and video, mounted on a tripod positioned 1 m from the ground. The subject's name, the time of day, and trial number were verbally recorded on video before the start of the trial. The researcher and all other personnel were positioned outside of the testing area during trials. Trials began once the otter entered the testing area, and concluded after 10 min had passed with no choice being made; or after the otter had made a choice on the tool-use task. Study otters did not have the ability to watch one another during trials, to minimize effects of observational learning. However, otters were always capable of acoustic contact during testing conditions. Testing areas were kept empty of all objects except for the presence of the trial apparatus.

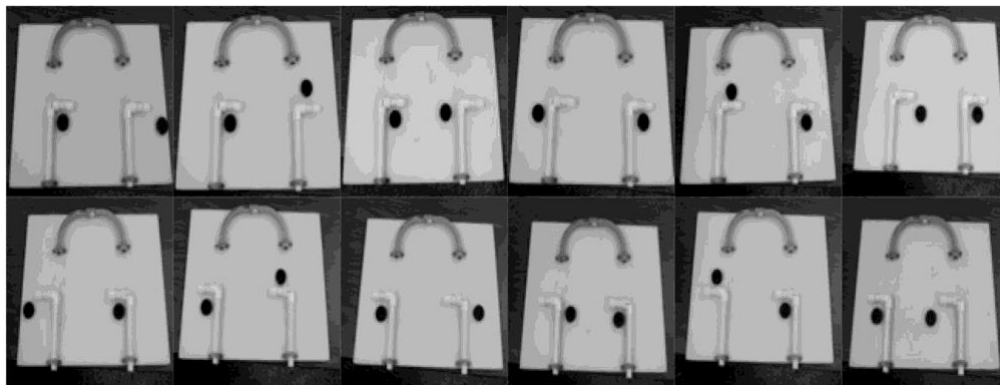


Figure 1. The forced choice tool use apparatus in the 12 possible configurations. The black circles indicate where food items would be placed on the apparatus for that particular configuration.

There were 12 configurations for the apparatus that accounted for all possible spatial locations of the hook-tool objects as well as placement of the food reward (Figure 1). Each otter was tested individually and exposed to all possible configurations five times, in a randomized order, to reduce the possibility of side bias toward the apparatus. Each subject received the same randomized order, totaling 60 trials per otter, or 360 trials total for data collection. Typically, trials were conducted 2-3 times a week, at 1-2 trials per day. Days in-between data collection varied; the average length was 2 days, with the longest gap noted at 7 days. The date and total number of trials run on a given day was dependent upon the schedule at SeaFari Theater and the animal care staff. Thus, trials could take place at any time of day, with the earliest trial in the dataset recorded at 9:00 a.m. and the latest trial occurring at 5:00 p.m. Data analysis focused on final outcome performance on the task, latency, and configuration of the apparatus as it related to task performance. Permission for this methodology was approved by the Institutional Animal Care and Use Committee at the University of Southern Mississippi in Hattiesburg, Mississippi, USA.

Results

Tool Use Performance

The two males, (O1-O2) completed the tool-choice task correctly above chance levels (> 50%), but one-sided binomial tests revealed neither male performed significantly above chance (O1: $p = 0.08$; O2: $p = 0.12$). Three of the females, (O4-O6) all performed correctly at below chance levels (< 50%) on the tool choice task (Figure 2). One female (O3) performed correctly exactly at chance levels (= 50%). None of the females' performance was significantly below chance levels. Examining overall sex differences, males ($M = 35$, $SD = 1.41$) chose correctly on the tool choice task significantly more than the females ($M = 27.25$, $SD = 1.89$), $t(4) = 5.01$, $p < 0.01$. Instances of no choice outcomes were infrequent. Comparisons of the proportion of correct responses in the first half of trials (1-30) to the second half (31-60) were assessed to ascertain any marked changes in performance over time (Figure 3). Performance decreased by 17% for O1, and 3% for O5. Subjects O2 and O3 both exhibited a small increase in performance, each choosing the correct tool 3% more often in the second half of the trials compared to the first. Subjects O4 and O6 exhibited a large increase in proportion of correct trials, while subject O4's performance improved by 20% and subject O6 improved by 17% from the first half to the second half of trials. All individual otter test results are presented in Table 1.

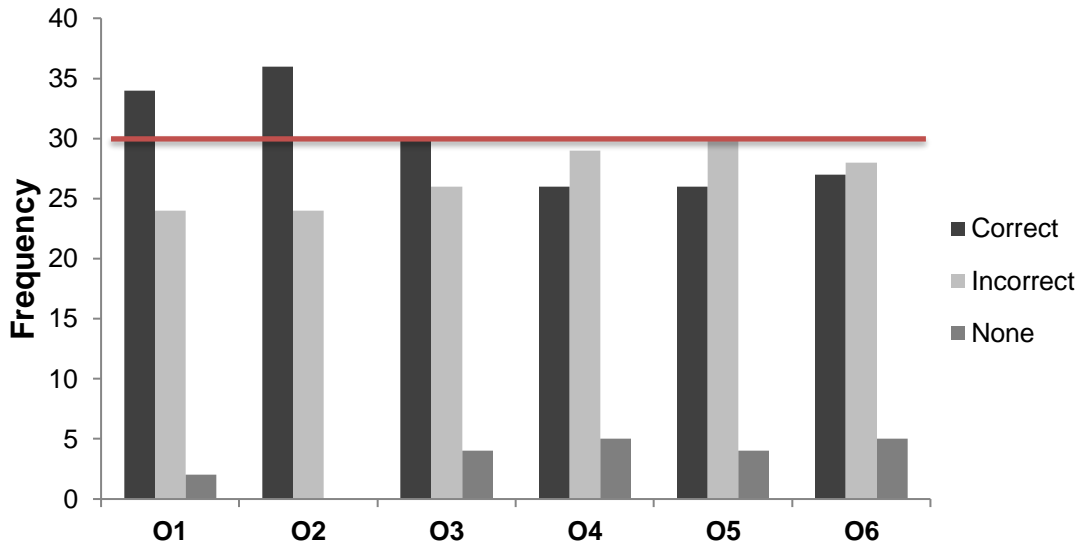


Figure 2. Frequency of using the correct tool on the forced choice tool-use task. The male otters performed above chance levels, but not significantly so. (O1: $n = 34$, 56%; O2: $n = 36$, 60%). All females performed correctly at or below chance levels (O3: $n = 30$, 50%; O4: $n = 26$, 43%; O5: $n = 26$, 43%; O6: $n = 27$, 46%). The red line indicates chance performance.

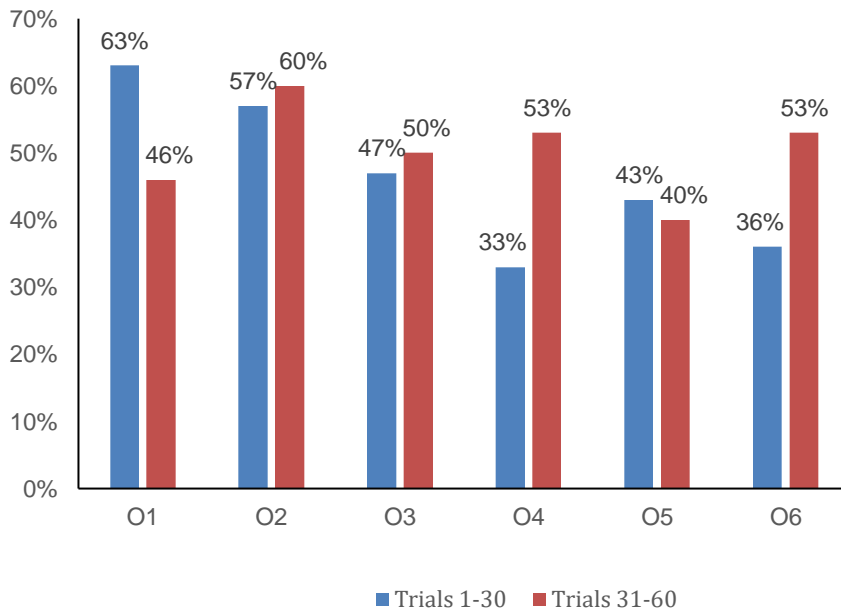


Figure 3. Percentage of correct responses in the first half of trials (1-30) and the second half of trials (31-60). O2 and O3 each showed a 3% improvement, whereas O4 and O6 showed 20% and 16% improvement respectively. O1 and O5 showed a 17% and 3% decrease in task performance between the first and second half of trials.

Table 1

Summary of Individual Subjects Test Results

Subjects	Overall task performance	Performance over time	Side preferences
O1	57% overall correct response ($p = 0.12$)	Trials 1-30: 63% correct response Trials 31-60: 46% correct response 17% decrease in performance	83% of tool use was the left-side tool ($*p < 0.05$)
O2	60% overall correct response ($p = 0.08$)	Trials 1-30: 57% correct response Trials 31-60: 60% correct response 3% increase in performance	Tool use side preferences non-significant ($p = 0.13$)
O3	50% overall correct response ($p = 0.35$)	Trials 1-30: 47% correct response Trials 31-60: 50% correct response 3% increase in performance	Tool use side preferences non-significant ($p = 0.22$)
O4	43% overall correct response ($p = 0.39$)	Trials 1-30: 33% correct response Trials 31-60: 53% correct response 20% increase in performance	75% of overall tool use was the left-side tool ($*p < 0.05$)
O5	43% overall correct response ($p = 0.35$)	Trials 1-30: 43% correct response Trials 31-60: 40% correct response 3% decrease in performance	71% of overall tool use was the left-side tool ($*p < 0.05$)
O6	46% overall correct response ($p = 0.45$)	Trials 1-30: 36% correct response Trials 31-60: 53% correct response 17% increase in performance	86% of overall tool use was the left-side tool ($*p < 0.05$)

Trials were broken down into thirds to assess trends in mean latency over time when making a choice on the tool-use task (Figure 4). These segments were characterized as (1) early (trials 1-20), (2) middle (trials 21-40), and (3) late (trials 41-60). A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean latency differed significantly as trials progressed from the beginning to end of trials, $F(1.51, 7.64) = 15.55, p < 0.05$. Post hoc tests using the Bonferroni correction revealed that latency to make a choice on the tool use task was significantly different between early trials and middle trials ($p = 0.01$) and late trials ($p = 0.04$), but there was no significant difference in mean latency between middle trials and late trials ($p = 0.85$).

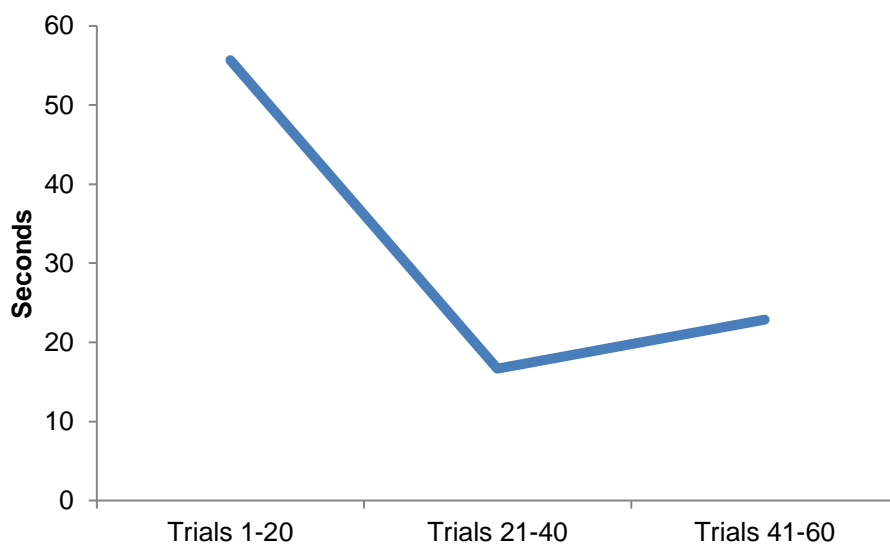


Figure 4. Overall mean latency across trials. Otters approached and made a choice on the tool-use task significantly faster as trials progressed.

A paired t -test was conducted to compare the frequency of the otters to choose to use the hook-shaped tool on the right versus the tool on the left side of the apparatus. There was a significant difference in the overall number of times the otters choose the left ($M = 43.00, SD = 7.72$) compared to the right ($M = 13.33, SD = 9.71$), $t(5) = -4.22, p < 0.01$ (Figure 5). Binomial tests revealed that four of the subjects chose the left side tool significantly more than chance (O1: $p < 0.01$; O4: $p < 0.01$; O5: $p < 0.01$; and O6: $p < 0.01$), whereas the other two subjects did not show a significant side preference (O2: $p = 0.12$; O3: $p = 0.22$). Each otters' individual test results for side preference are additionally displayed in Table 1.

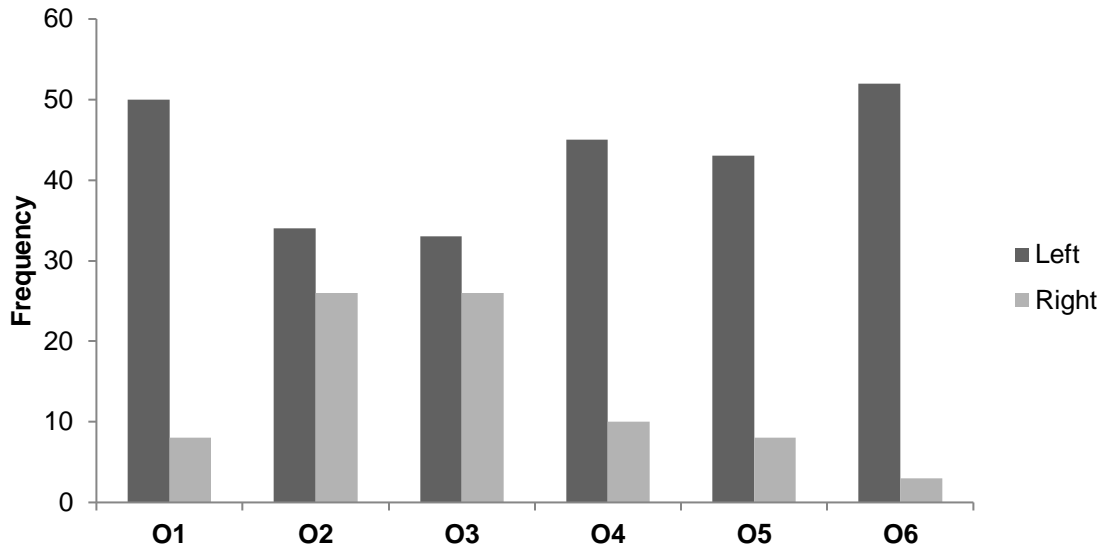


Figure 5. Frequency of choosing the tool on the left versus the right. Several otters showed a significant preference for choosing the left-side tool (O1: $n = 50$, 83%; O4: $n = 45$, 75%; O5: $n = 43$, 71%; O6: $n = 52$, 86%) while subjects O2 and O3 showed no significant side preference.

Discussion

Although otters appear capable of learning which tool should be used in a forced choice comparison, the non-significant findings related to subjects' performance suggests that other factors seem to influence the choices individual otters make. Efficacy of a cognitive task to promote interaction and motivate the animal to solve the task can vary between individuals (Kuczaj, Lacinak, Otto, Trone, & Solangi, 2002). Individual differences in motivation and learning may contribute to the current non-significant findings.

Comparisons of proportion of correct responses in the first half of trials (1-30) to the second half (31-60) were assessed to ascertain changes in performance possibly attributed to differences in learning across subjects. Individual differences were present in performance as trials progressed from start to finish. In particular, subjects O2 and O3 both showed minor improvement (3%), whereas O4 and O6 showed a 17% and 20% performance increase respectively. The present study controlled for variables that promoted social learning, (i.e., learning that was influenced by the observation or interaction with another animal; Galef, 1988; Heyes, 1994). Additionally, no training took place prior to the first exposure to the apparatus and subjects underwent trials individually. This suggests that social learning did not occur. Rather, learning by trying different motor patterns until achieving the desired outcome—trial and error learning (e.g., Tomasello, Davis-Dasilva, Camak, & Bard, 1987), may explain the variability in how these otters performance on the task improved over time. In particular, the male subject O2 completed the tool use task correctly on the first several trials. His performance overall was the most consistent, showed no significant side preferences, and had the highest frequency of correct task completions of any other otter. His early success on the task could be indicative of spontaneous trial and error learning, that allowed for faster learning as to the correct use of the tools. It would be interesting to note if opportunities for observational learning were incorporated into the methodology, if the other otters' performance on the task would have improved by the ability to watch subject O2.

Sex differences were present; males performed significantly better than females on the forced choice tool use task. Similar differences favoring males have been reported in tool-use research in human infants. For example, infant girls showed slightly increased performance on easier tasks, but performed more poorly than boys on more difficult tasks (Bates, Carlson-Luden, & Bretherton, 1980). Chimpanzees have also been reported to exhibit sex differences in tool-use behavior. Lonsdorf, Eberly, and Pusey (2004) found that female chimpanzees exhibit more proficient termite fishing tool-use behaviors, but this ability seemed to develop via observational learning and imitation of their mother. Conversely, males were able to fish for termites successfully with minimal to no observational learning. In the current study, no training occurred prior to trials, and otters were not able to observe one another during trials. The lack of opportunities for observational learning and modeling may have attributed to the sex differences observed in task performance.

While sex differences were present in the current study, Perdue et al. (2011) found no sex differences present for Asian small-clawed otters on solving a spatial cognitive task. As male and female otters share monogamous relationships and home ranges (Sivasothi & Burhanuddin, 1994), the *range size hypothesis* supports the lack of sex differences in spatial abilities (Gaulin & Fitzgerald 1986, 1989; Gray & Buffery, 1971). Whereas tool-use behaviors may be related to developmental differences of problem solving abilities between sexes, as the otters in the present study were all juveniles (2 years of age). However, due to our small sample size it would be imperative to repeat or conduct other tool-use assessments in more groups of Asian small-clawed otters, ideally with a wider range of ages and equal distribution of males and females to determine if sex differences in tool-use behaviors mirror trends in any other mammalian species.

For all otters, latency to approach and make a choice on the tool-use task decreased over time, regardless of success. This may indicate that the subjects were motivated to interact with the apparatus, as a form of enrichment. Hanna and colleagues (2016) found a sea otter's use of a similar forced choice tool use task to be highly rewarding as a form of environmental enrichment, evidenced by the otter's decrease in latency to approach the apparatus over time and increase in time spent interacting with the apparatus over trials. In addition, Perdue et al. (2013) use of a spatial memory task to investigate the cognitive abilities of Asian small-clawed otters showed the otters more readily approached and engaged with the feeders over time. Cognitive tasks such as the foraging tasks (e.g., subjects solved a problem and obtained food) used by Perdue et al. (2013), Hanna et al. (2016), and the present study are considered valuable methods of providing enrichment to an animal (Clark, Davies, Madigan, Warner, & Kuczaj, 2013; Kuczaj, Lacinak, & Turner, 1998). The use of foraging tasks such as the present study's apparatus do not need to be representative of environmental conditions in the wild to be effective, but must model the conditions and behaviors involved in obtaining food (Boccia, 1989; Heath, Shimoji, Tumanguil, & Crockett, 1992; Lutz & Novak, 2005). As such, the present study presented an opportunity solve a problem to obtain food, and the subjects more readily approached and interacted with the apparatus over time, indicative that the tool-use task provided a form of enrichment to the animals.

Asian small-clawed otters are a highly social species, and familial groups share strong bonds between individuals (Sivasothi & Burhanuddin, 1994). As such, while otters underwent trials alone, they were not acoustically isolated. Vocalizations are thought to serve an important role in a group-living mustelid species, especially in regulating intragroup social interactions (Wong, Stewart, & MacDonald, 1999). Vocalizations in Asian small-clawed otters can encode identity information that can be discriminated between familial and non-familial members in both males and females, as well as contain contextual information such as stress vs. non-stress, feeding vs. pre-feeding, and separation vs. reunion conditions (Lemasson, Mikus, Blois-Heulin, & Lodé, 2013, 2014; Scheifele, Johnson, Fry, Hamel, & Laclede, 2015). Similar to the otters in the current study, siblings of the same age group are known to exhibit a marked preference for interaction and communication with one another (Lemasson et al., 2014). During trials, it was noted on few occasions that females O5 and O6

would ignore the reward when it was available. It was suggested that for these females, the completion of a trial (i.e., making a choice on the tool-use task regardless of success) was associated with the reunion and continued social interactions with group members, which was considered a highly rewarding form of enrichment. While it is difficult to determine if this was indeed occurring, it offers one possibility for the poor performance on the task that was observed for these particular females. The noted increases in vocalizations during trials between the study otter and other members could be attributed to contact calls that encoded identification information, but no acoustic analysis was capable with the current dataset to empirically support this anecdote. However, all other otters (O1-O4) were highly motivated by the task's original reward, suggesting that an individual's drive to complete the tool-choice task can be attributed to individual differences in motivation (Hanna et al., 2016; Kuczaj et al., 2002).

The overall significant trend for the otters to choose the left side tool object appeared to be driven by 4 of the otters significant use of the left-side tool (O1, O4, O5, & O6). Tool choice for subjects O2 and O3 indicated no significant side bias. This is what was expected as half (50%) of the trials were oriented so the left side was correct and half so the right side was correct. Trial order was randomized, but this preference toward the left side in several otters persisted. It is unknown currently what may have influenced this apparent left-side bias; factors considered include learning as well as visual, auditory, olfactory, or lateralization preferences. Handedness, or lateralized preference for use of a hand, has been hypothesized to have developed due to the emergence of tool-using behaviors (Cochet & Bryne, 2013; Fitch & Braccini, 2013; Frost, 1980). Lateralization preferences for the left (e.g., handedness) could possibly account for the observed side preferences. Future directions for this research include incorporating assessments of handedness in relation to performance on this tool-use task in Asian small-clawed otters, and should be accounted for in future cognitive assessments.

Additionally, subjects O1 and O5 both exhibited the side preference for the left and a decrease in performance between the first half of trials compared to the second. It is possible that these subjects learned to associate use of the left side with successful completion of the tool-use task, and were unable to unlearn this fixed action to accurately complete the task during trials. It is unknown if a succession of correct left-side choices contributed to this performance decrease and side preference, or if there were other variables that influenced this association. While potential cuing of the subjects to one side was controlled for by consistently exposing the apparatus in the same location with personnel located outside trial enclosures; there were other people, animals, and ongoing activity that took place in the holding area that the subjects were exposed to that was not possible to control for during the study period. An experimental setup that allows for increased control over possible surrounding visual stimuli and cues would be beneficial for future studies or replications.

The non-significant findings due to mixed performance on the forced choice tool use task does not mean that the otters who exhibited poor performance are not capable of using a novel tool. In some species, tool use occurs in only a subset of populations or individuals, or the rate of tool use drastically varies due to individual differences (Humle & Matsuzawa, 2002; Mann et al., 2008). In other two-choice apparatus designs, several species of primates initially fail to discriminate between the two tools, but with continued experience or training successfully learn how to complete the task (e.g., Fujita, Kuroshima, & Asai, 2003; Girndt, Meier, & Call, 2008; Hauser, Pearson, & Seelig, 2002). The number of trials each otter completed may not have been sufficient to account for individual differences in problem solving or learning for the current population. Thus, continued research in an experimental setting (and in the wild) of cognitive abilities in Asian small-clawed otters is imperative to increase our understanding of their behavior repertoire. Future experimental studies that test for cognitive abilities have immense potential to inform conservation and management efforts for this species and other yet unexplored taxa.

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Submitted: August 15th, 2016

Resubmitted: October 5th, 2016

Accepted: October 27th, 2016