**Electronic Supplemental Material**

ESM Video Clip 1. Clip from novel object trial with Mary (SDZ) using mylar balloons.

ESM Video Clip 2. Edited, sped-up clips of novel object trial with Achara and Bamboo (OKC) using a burned log.

ESM Video Clip 3. Edited clip of novel object trial with Maharani (NZP) using lion urine.

ESM Video Clip 4. Sped-up clip of problem-solving trial with Mary (SDZ) on the Boxed Ball.

ESM Video Clip 5. Clip of problem-solving trial with Devi (SDZ) on the Rod Ball.

ESM Video Clip 6. Clips of problem-solving trial outcomes (solve, blow-over, and trap) with OKC elephants on the Trap Tube.

**SI Documents**

**SI Document 1**

*Specifications About Puzzle-box Tasks*

The Boxed Ball’s steel box was 53.34 cm long by 53.34 cm wide by 48.26 cm high. The ball (a Boomer Ball) had a 12.7 cm by 12.7 cm hole in it and was counterweighted with pieces of wood glued to one side. The ball had a steel rod running through it that was bolted to two sides of the box such that the ball did not touch the internal base of the box.

The Rod Ball’s steel rod was 1.19 m long, 8.89 cm in diameter, and 0.64 cm in thickness. The Rod Ball’s ball was a repurposed polar bear Boomer Ball and was approximately 50.8 cm in diameter.

The Trap Tube was 1.22 m long.

**SI Table 1**

*Ethogram of Behaviors*

|  |  |
| --- | --- |
| Body Movement | Description |
| Aggress | Includes: **Bite -** Aggressor puts tail or other body part of another elephant in its mouth; **Charge -** Rapidly approaches another with trunk tucked under head, head up, and chin tucked; **Hit** - Striking another elephant with foot (kick) or trunk; **Displace -** Approach of the focal elephant causes another to move within 5 sec.; **Push -** One elephant shoves another, often causing the latter to move without pushing back; **Trunk Swing -** Whips the trunk about violently; and **Ears Erect -** Ears extended perpendicular to head. |
| Bathe | Individual lies or stands in pond/standing water or shower/hose, or individual squirts water through trunk onto head or body. Includes: **Wallow -** Lies down and wiggles in mud, dirt, or sand; **Dust/groom -** Throws browse, dirt, dung, hay, or sand on self. May be self-directed or social (directed to another animal or received from another animal). Also includes scratching (scraping of fingernails or trunk across the skin); and **Mud Bath -** Elephant lies down in mud, or stands and throws mud over herself/himself using its trunk. |
| Beg | Individual exhibits repeated behavior that usually results in her/him gaining a food reward (e.g., “posing,” chirping); extends trunk toward out-of-reach food. |
| Body touch | Initiates head or body contact with another elephant, including: **Lean -** One elephant rests on another while standing; **Trunk to Genital** - Trunk tip touches anus or genitalia of another elephant; **Trunk to Mouth** - Elephant touches trunk tip to mouth of another elephant; **Trunk to Temporal Gland -**Trunk tip touches temporal gland; **Trunk to Trunk -** Trunk tip touches trunk; **Trunk to Head/Body** - Trunk tip touches head, legs, or other body part, such as the back, ear, or tail; and **Trunk to Mouth** - Trunk tip inserted in mouth while not eating or drinking. |
| Drink | Seeks or ingests water/juice. Often includes sucking water into trunk and blowing it into mouth. |
| Forage | Seeks or ingests food in place or while walking. Often involves gathering food with trunk and lifting into mouth. Animal is not engaged in any other behavior. |
| Investigate | Hovers/touches nasal openings over/onto object/food/elephant with or without contact. Includes: **Check/Finger Touch -** Touches trunk tip onto object/food/elephant; **Flehmen** - Touch with tip of trunk, then places trunk in roof of mouth (where vomeronasal organ ducts open). Usually lasts 3-8 seconds; **Manipulate Object -** Moves, pushes, tosses, or picks up objects or enrichment provided within enclosure such as toys, logs, grass, rocks, stick, dirt, etc.; **Throw -** Lifts or uproots objects using trunk or feet, and throws them in the air; **Dig -** Uses trunk and/or foot movements to stab into ground, often when feeding; and **Periscope/smell -** Raises trunk so that it makes an “S” shape and points tip toward area—perhaps to smell. |
| Mount | Weight on hind legs, forelegs resting on recipient’s hips.  |
| Nurse | One or a series of mouth-on-nipple incidents separated by less than 60 seconds. |
| Other | Elephant exhibits any behavior not included in this ethogram.  |
| Out of view-Active | Elephant is visibly engaged in a behavior, but the behavior itself is not discernible. |
| Out of view | Elephant is not visible or its behavior is not discernible.  |
| Rest | Includes: **Trunk Rest** - Places trunk on rock or object and stands still. May close eyes.; and **Lie -** Individual is in lateral recumbence. Weight is no longer supported by legs. No other behaviors are occurring simultaneously. |
| Rub/Scratch | Places head or body against wall, tree, or object and moves head back and forth. Rakes trunk tip against individual’s own skin. Flicks body with tail. |
| Share food/object | Eats from the same pile of browse or food simultaneously with another elephant, within the same observation minute, or is simultaneously in physical contact with the same object as another elephant. |
| Social Play | Wrestling, trunk-to-trunk contact, and other similar behaviors between two elephants, without an individual attempting to flee the interaction. May include bowing and vocalizing. Posture is floppy or relaxed. Also includes **Spar/Wrestle:** Head-to-head contact between two elephants, including hits, tusking, or trunk entwining. Posture may be stiff with tail erect. One elephant may walk rapidly away to conclude the sparring bout. |
| Stereotypy | Any behavior that occurs in repetitive pattern, including pacing, swaying, or head bobbing. |
| Urinate/Defecate | Releases liquid from genitals in a steady stream; usually accompanied by wide stance of back legs/Excretes (several) pellets of dung from anus. |
| Walk | Animal takes two or more steps in any direction but not in a stereotypic pattern. Is not playing, feeding, or exhibiting any other overt behavior simultaneously. Also includes: **Approach** - Elephant moves to within one body length of another elephant while facing it; **Chase** - Focal elephant runs after another in an attempt to reduce the separation between animals. May be moving at a fast walking space. Trunk, head, and tail are floppy.; and **Retreat** - Elephant moves away (at least one body length) from another elephant within 10 seconds of approaching that elephant. |
| Vocalizations |  |
| Chirp/Squeak | Short, high-pitched vocalization produced by blowing air out of the trunk when the trunk tip is pinched shut. Produced by Asian elephants when they are fearful or excited.  |
| Roar | Loud vocalization produced with open mouth. Occurs during movement and/or to intimidate other elephants in response to aggression. Also used during joyful reunions between/among elephants.  |
| Rumble | Purr- or motor-like, low vocalization. Produced with the mouth closed. Occurs during non-aggressive, social contexts or when elephants are moving. Can be used to communicate over long distances or for greetings or reassuring other elephants.  |
| Trumpet | Double-voicing (two sets of closely-spaced harmonic bands appear within a single vocalization), produced by pushing air through the trunk when the trunk is usually pointed upward. Occurs in response to disturbance, and sometimes is accompanied by squeaks. Could be accompanied by threats (e.g., throwing objects, charging). |
| Trunk-bounce | Quick rebound of the trunk while the trunk is curled beneath the chin and inflated with air and the tip of the trunk is shut. Sounds like an inflated ball bouncing on the ground. Usually accompanied by behavior indicating fear or excitement.  |

*Note.* A priori ethogram of elephant behaviors and their descriptions are shown. Bolded behaviors highlight those that are grouped. Locomotion and some social behaviors (i.e., Approach, Chase, and Retreat) were combined into “Walk” because there were relatively few occurrences of each of the behaviors and because they all involve movement. We therefore decided to use the Walk category to evaluate elephants’ activity levels.

**SI Table 2**

*Intraclass Correlation Coefficients (ICC) and Associated P-values for Zookeeper Rated Traits*.

|  |  |  |  |
| --- | --- | --- | --- |
|  | NZP | OKC | SDZ |
| Rated Trait | ICC | P | ICC | P | ICC | P |
| **Active** | **.98** | **<.0001** | **.81** | **.002** | **.94** | **<.0001** |
| **Affectionate** | **.65** | **.037** | **.96** | **<.0001** | **.89** | **<.0001** |
| **Aggressive** | **.94** | **<.0001** | **.85** | **.0004** | **.65** | **.031** |
| **Anxious** | **.8** | **.003** | **.86** | **.0002** | **.87** | **<.0001** |
| Attentive | .83 | .009 | .87 | .0002 | .288 | .25 |
| **Curious** | **.76** | **.006** | **.92** | **<.0001** | **.81** | **.001** |
| **Defiant** | **.62** | **.049** | **.77** | **.005** | **.75** | **.006** |
| Dominant | .91 | <.0001 | .325 | .23 | .77 | .004 |
| **Excitable** | **.88** | **.00012** | **.94** | **<.0001** | **.74** | **.008** |
| Fearful | .221 | .3 | .73 | .011 | .9 | <.0001 |
| Intelligent | .416 | .17 | .95 | <.0001 | .84 | .005 |
| Irritable | .509 | .11 | .598 | .058 | .66 | .029 |
| **Mischievous** | **.81** | **.0018** | **.83** | **.001** | **.74** | **.008** |
| Playful | .5 | .11 | .94 | <.0001 | .86 | 0.0002 |
| Predictable | 0.093 | 0.38 | 0.69 | 0.023 | 0.75 | 0.007 |
| Protective | **0.79** | **.0032** | **.91** | **<.0001** | **.73** | **.009** |
| Quitting | .355 | .21 | .55 | .085 | .66 | .029 |
| **Sociable** | **.62** | **.048** | **.97** | **<.0001** | **.91** | **<.0001** |
| **Solitary** | **.91** | **<.0001** | **.93** | **<.0001** | **.94** | **<.0001** |
| **Shy** | **.78** | **.004** | **.9** | **<.0001** | **.94** | **<.0001** |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

*Note.* Bolded traits were significantly (p < .05) repeatable (ICC > .60) at all three institutions and were retained for further analyses. Values were rounded to the nearest tenth digit for analyses.

**SI Table 3**

*Behavioral Coding Repeatability*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Behavior | R  | SE | LOW CI | HIGH CI | P |
| **Aggress** | **.216** | **0.097** | **0** | **0.352** | **<.0001** |
| Bathe | .15 | 0.033 | 0.088 | 0.215 | <.0001 |
| Beg | .034 | 0.023 | 0 | 0.091 | .019 |
| **Body Touch** | **.634** | **0.048** | **0.498** | **0.693** | **<.0001** |
| Drink | .03 | 0.102 | 0.279 | 0.692 | <.0001 |
| Forage | .033 | 0.018 | 0 | 0.069 | .0003 |
| **Investigate** | **.383** | **0.102** | **0.279** | **0.692** | **<.0001** |
| Rest | .159 | 0.042 | 0.072 | 0.242 | <.0001 |
| Roar | 0 | 0.007 | 0 | 0.024 | <.0001 |
| **Rub** | **.375** | **0.08** | **0.193** | **0.498** | **<.0001** |
| Rumble | 0 | 0.008 | 0 | 0.026 | .5 |
| Share Food | .007 | 0.009 | 0 | 0.028 | <.0001 |
| Social Play | .009 | 0.013 | 0 | 0.042 | .305 |
| Squeak | .036 | 0.024 | 0 | 0.089 | .014 |
| Stereotypy | .02 | 0.011 | 0.002 | 0.047 | <.0001 |
| Trumpet | 0 | 0 | 0 | 0 | 1 |
| Trunk Bounce | .131 | 0.051 | 0.044 | 0.24 | <.0001 |
| Urinate | .008 | 0.013 | 0 | 0.044 | .325 |
| **Walk** | **.356** | **0.073** | **0.186** | **0.468** | **<.0001** |

*Note.* Repeatability estimates (*R*), *SE*s, low and high 95% *CI* limits, and associated *P*-values for behavioral coding behaviors across 32 trials are shown. Bold values indicate significant (p < .05) repeatability (R > .20) estimates.

**SI Table 4**

*Novel Object Repeatability*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Response | R  | SE | LOW CI | HIGH CI | P |
| Latency to Face | 0 | 0.097 | 0 | 0.31 | 1 |
| Proportion of Time Spent Interacting | .018 | 0.1 | 0 | 0.331 | .483 |

*Note.* Repeatability estimates (*R*), *SE*s, low and high 95% *CI* limits, and associated *P*-values for novel object response behaviors across three trials, each with a different object, are shown.

**SI Table 5**

*Correlations of Trait Ratings and Behaviors*

|  |  |
| --- | --- |
|  | Rated Traits |
| Active | Affectionate | Aggressive | Anxious | Curious | Defiant | Excitable | Mischievous | Protective | Sociable | Solitary | Shy |
| Coded Behaviors | Aggress | .28 | .38 | -.04 | -.49 | **.55** | -.16 | .30 | .06 | .46 | **.52** | -.41 | -.40 |
| Body Touch | .15 | -.23 | -0.00 | -.25 | .05 | .28 | -.28 | .47 | -.01 | .02 | -.12 | -.30 |
| Investigate | .25 | .30 | .33 | -.22 | .35 | **.55** | .01 | .41 | **.64** | .45 | -.51 | -.49 |
| Rub | .32 | .23 | .03 | .08 | .39 | .47 | .11 | **.57** | **.57** | .34 | -.46 | -.04 |
| Walk | **.66** | -.07 | .08 | .31 | **.60** | .18 | -.03 | .22 | .15 | .27 | -.13 | -.42 |

*Note.* Correlations of repeatable average trait ratings and repeatable average numbers of behaviors observed are shown. Bolded values indicate significant correlations (r > .50, *p* < .05). No correlations were significant after a Bonferroni correction (*p* < .0008).

**SI Table 6**

*Summary Table of Problem-solving Models*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model | Type (Distribution) | df | R2 | AICc | ∆AICc |
| Boxed Ball Latency to Solve ~ Personality Measures + Location |  |  |  |  |  |
| \*Latency to Solve ~ PC 3 + Location | GLM (Poisson) | 4 | .78 | 940.3 | .00 |
|  Latency to Solve ~ Rub + Location | GLM (Poisson) | 4 | .69 | 968.4 | 28.08 |
|  Latency to Solve ~ PC 2 + Location | GLM (Poisson) | 4 | .75 | 972.7 | 32.37 |
|  Latency to Solve ~ Aggress + Location | GLM (Poisson) | 4 | .63 | 1107.2 | 166.96 |
|  Latency to Solve ~ Body Touch + Location | GLM (Poisson) | 4 | .59 | 1119.2 | 178.90 |
|  Latency to Solve ~ Investigate + Location | GLM (Poisson) | 4 | .61 | 1127.1 | 186.84 |
|  Latency to Solve ~ Walk + Location | GLM (Poisson) | 4 | .59 | 1129.2 | 188.94 |
|  Latency to Solve ~ PC 1 + Location | GLM (Poisson) | 4 | .63 | 1131.9 | 191.64 |
|  Latency to Solve ~ PC 4 + Location | GLM (Poisson) | 4 | .58 | 1240.4 | 300.15 |
| Boxed Ball Success Rate ~ Personality Measures + Location |  |  |  |  |  |
| \*Success Rate ~ PC 3 + Location | GLM (Beta) | 5 | .43 | -115.1 | .00 |
| Success Rate ~ PC 2 + Location | GLM (Beta) | 5 | .37 | -114.1 | 1.01 |
| Success Rate ~ PC 4 + Location | GLM (Beta) | 5 | .36 | -114.0 | 1.11 |
| Success Rate ~ PC 1 + Location | GLM (Beta) | 5 | .35 | -113.9 | 1.16 |
| Success Rate ~ Rub + Location | GLM (Beta) | 5 | .37 | -90.6 | 24.45 |
| Success Rate ~ Walk + Location | GLM (Beta) | 5 | .34 | -90.2 | 24.83 |
| Success Rate ~ Aggress + Location | GLM (Beta) | 5 | .34 | -90.2 | 24.90 |
| Success Rate ~ Investigate + Location | GLM (Beta) | 5 | .33 | -90.1 | 24.96 |
| Success Rate ~ Body Touch + Location | GLM (Beta) | 5 | .33 | -90.1 | 24.97 |
| Rod Ball Latency to Solve ~ Personality Measures + Location |  |  |  |  |  |
| \*Latency to Solve ~ Walk + Location | GLM (Poisson) | 4 | .56 | 751.6 | .00 |
| Latency to Solve ~ Investigate + Location | GLM (Poisson) | 4 | .36 | 841.7 | 90.11 |
| Latency to Solve ~ Rub + Location | GLM (Poisson) | 4 | .35 | 899.0 | 147.40 |
| Latency to Solve ~ Aggress + Location | GLM (Poisson) | 4 | .31 | 911.9 | 160.33 |
| Latency to Solve ~ Body Touch + Location | GLM (Poisson) | 4 | .32 | 913.1 | 161.49 |
| Latency to Solve ~ PC 2 + Location | GLM (Poisson) | 4 | .39 | 969.0 | 217.45 |
| Latency to Solve ~ PC 1 + Location | GLM (Poisson) | 4 | .36 | 1021.5 | 269.87 |
| Latency to Solve ~ PC 4 + Location | GLM (Poisson) | 4 | .30 | 1052.6 | 300.98 |
| Latency to Solve ~ PC 3 + Location | GLM (Poisson) | 4 | .29 | 1055.1 | 303.54 |
|  |  |  |  |  |  |
| Trap Tube Latency to Solve ~ Personality Measures + Location |  |  |  |  |  |
| \*Latency to Solve ~ Walk + Location | GLM (Poisson) | 3 | .27 | 282.7 | .00 |
| Latency to Solve ~ PC 3 + Location | GLM (Poisson) | 3 | .42 | 291.1 | 8.41 |
| Latency to Solve ~ PC 4 + Location | GLM (Poisson) | 3 | .31 | 332.1 | 49.45 |
| Latency to Solve ~ Aggress + Location | GLM (Poisson) | 3 | .21 | 332.3 | 49.59 |
| Latency to Solve ~ Investigate + Location | GLM (Poisson) | 3 | .31 | 338.9 | 56.25 |
| Latency to Solve ~ PC 1 + Location | GLM (Poisson) | 3 | .17 | 340.9 | 58.23 |
| Latency to Solve ~ Rub + Location | GLM (Poisson) | 3 | .20 | 349.1 | 66.46 |
| Latency to Solve ~ PC 2 + Location | GLM (Poisson) | 3 | .22 | 350.3 | 67.52 |
| Latency to Solve ~ Body Touch + Location | GLM (Poisson) | 3 | .21 | 350.6 | 67.93 |
| Trap Tube Success Rate ~ Personality Measures + Location |  |  |  |  |  |
| \*Success Rate ~ PC 3 + Location | GLM (Beta) | 4 | .43 | 5.2 | 0 |
| Success Rate ~ PC 1 + Location | GLM (Beta) | 4 | .35 | 5.2 | .04 |
| Success Rate ~ Walk + Location | GLM (Beta) | 4 | .34 | 7.4 | 2.22 |
| Success Rate ~ PC 2 + Location | GLM (Beta) | 4 | .37 | 8.5 | 3.30 |
| Success Rate ~ Aggress + Location | GLM (Beta) | 4 | .34 | 9.0 | 3.83 |
| Success Rate ~ PC 4 + Location | GLM (Beta) | 4 | .36 | 9.0 | 3.88 |
| Success Rate ~ Body Touch + Location | GLM (Beta) | 4 | .33 | 9.8 | 4.59 |
| Success Rate ~ Investigate + Location | GLM (Beta) | 4 | .33 | 10.1 | 4.93 |
| Success Rate ~ Rub + Location | GLM (Beta) | 4 | .37 | 10.1 | 4.93 |
| *Note.* Top models are indicated by an asterisk (\*). |  |  |  |  |  |

**SI Table 7**

*Top Model Summary Parameters*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Top Models | Estimate | Std. Error | Test statistic | p-value |
| Boxed Ball Latency to Solve ~ PC 3 + Location |  |  |  z |  |
| Intercept | 6.63 | .03 | 228.30 | < .0001 |
| PC 3 | -.35 | .02 | -17.44 | < .0001 |
| Location: OKC | -2.47 | .06 | -41.86  |  < .0001 |
| Location: SDZ | -2.34 | .06 | -41.13 |  < .0001 |
| Boxed Ball Success Rate ~ PC 3 + Location  |  |  |  |  |
| Intercept | -.55 | .61 | -.91 | .36 |
| PC 3Location: OKCLocation: SDZ | .421.881.96 | .39.85.97 | 1.082.202.02 | .28.03 .04 |
| Rod Ball Latency to Solve ~ Walk + Location |  |  |  z |  |
| Intercept | 4.59 | .06 | 71.73 | < .0001 |
| Walk | .08 | .01 | 12.98 | < .0001 |
| Location: OKC | -1.58 | .07 | -21.55 | < .0001 |
| Location: SDZ | -1.12 | .11 | -10.35 | < .0001 |
| Trap Tube Latency to Solve ~ Walk + Location |  |  |  z |  |
| InterceptWalkLocation: OKC | 4.94-.10-.34 | .10.01.13 | 50.72-7.76-2.62 | < .0001< .0001.009 |
| Trap Tube Success Rate ~ Personality Measures + Location |  |  |  z |  |
| Intercept | -1.88 | .66 | 2.51 | .005 |
| PC 3 | .94 | .39 | 2.38 | .02 |
| Location: OKC | 1.34 | .77 | 1.75 | .08 |
| Boxed Ball Learning ~ Investigate + Location |  |  | t |  |
| Intercept | 101.53 | 159.89 | -1.25 | .26 |
| Investigate | -10.58 | 8.44 | -1.25 | .26 |
| Location: SDZ | -128.32 | 156.70 | -.82 | .44 |
| Rod Ball Learning ~ Walk + Location |  |  | t |  |
| Intercept | 170.35 | 202.00 | .84 | .44 |
| Walk | -13.07 | 13.67 | -1.03 | .35 |
| Location: SDZ | -189.70 | 168.72 | -1.12 | .31 |
|  |  |  |  |  |

**SI Table 8**

*Repeatability of Behaviors Across Intervals*

|  |  |  |  |
| --- | --- | --- | --- |
|  | **2 Days** | **7 Days** | **14 Days** |
|  | **R**  | **P** | **R**  | **P** | **R**  | **P** |
| Aggress | .148 | .003 | **.327** | **.008** | **0** | **1** |
| Bathe | **.177** | **<.0001** | .116 | .001 | **.306** | **.0001** |
| Beg | 0 | 0.5 | 0 | 1 | 0 | 1 |
| Body Touch | **.624** | **<.0001** | **.422** | **<.0001** | **.553** | **.0009** |
| Drink | 0 | 1 | 0 | 1 | 0 | 0.5 |
| Forage | .021 | .096 | 0 | 0.5 | 0 | 0.5 |
| Investigate | **.338** | **<.0001** | **.174** | **.006** | **.414** | **.007** |
| Rest | **.197** | **<.0001** | .064 | .006 | .069 | .03 |
| Roar | 0 | 1 | 0 | 1 | 0 | 1 |
| Rub | **.236** | **<.0001** | **.156** | **.057** | **.254** | **.099** |
| Rumble | 0 | 1 | 0 | 1 | 0 | 1 |
| Share Food | .001 | 1 | 0 | 1 | 0 | 1 |
| Social Play | 0 | 1 | 0 | 1 | 0 | 1 |
| Squeak | 0 | 1 | 0 | 1 | 0 | 1 |
| Stereotypy | .03 | <.0001 | .051 | .0005 | **.323** | **<.0001** |
| Trumpet | 0 | 1 | 0 | 1 | 0 | 1 |
| Trunk Bounce | 0 | 1 | 0 | 1 | 0 | 1 |
| Urinate | 0 | 1 | 0 | 1 | 0 | 1 |
| Walk | **.280** | **<.0001** | **.240** | **.003** | **.357** | **.002** |

*Note.* Table of repeatability estimates (R) and p-values for various time intervals of behavioral coding behaviors are shown. Bold values indicate significant (R >.20) repeatability estimates.