Supporting Information
Appendix

Part One: <u>Behavioral descriptions of innovations</u>

Here are the descriptions of the kinds of innovations observed in 2007-2011. The codes at the end of each entry state: (1) how many of the nine possible groups independently invented the same behavior, (2) whether the innovation was repeated on multiple days by the innovator (1=yes, 0=no) (with one exception involving interspecies interactions), and (3) whether the behavior was practiced by multiple individuals in the same group (1=yes, 0=no). Example: G2/I-11/S-01 means that it was seen in two groups, that the innovator performed the behavior multiple times in both of these groups, and that there was spread of the behavior to other group members in one of these two groups. These behaviors are presented in four sections, corresponding to the four behavioral domains that are discussed separately in the paper.

<u>Social behaviors:</u>
Arm drumming: One male drums or taps his fingers on the hand or arm of a friend, usually while the friend is sucking on his ear. G1/I-1/S-0 Sometimes he rubs it as well (G1/I-0/S-0).

Bite coalition partner's tail: A female alternates between threatening an opponent or human and repeatedly biting the tail of her coalition partner (not hard enough to break the skin) while they are in contact, displaying against the common opponent, as if encouraging greater enthusiasm from the partner in the joint threats. This was practiced by high-ranking females in two groups, one of them doing it with multiple partners, and the other doing it just once. G2/I-01/S-00

Bounce-slap display: A male bounces up and down on a female, slapping her with both hands as he threatens a human. G2/I-00/S-00

Cartwheel face kick: One monkey does backward cartwheels and then slaps/kicks the face of the alpha male, who is forming an overlord against him. G1/I-0/S-0

Circle bounce: A male did a series of aggressive bounces, with a female in "overlord" position on his back, making a circle around the individual who was the target of his aggression. G1/I-0/S-0

Clitoral manipulation: Oral manipulation of partner's clitoris. G1/I-0/S-0

Dental exam: One monkey opens and investigates the mouth of the other. This can consist of probing the interior of the mouth with the fingers and perhaps picking at the teeth or handling the tongue or gums. G5/I-11111/S-11111.

Eat earwax: One male eats the earwax from another male's ear. G1/I-0/S-0

Elbow caress: A new alpha male calmed a highly aroused infant (who was trembling, squirming, vocalizing, and cautiously touching his rump), by reaching back and gently kneading and caressing the infant's elbow. (This was noteworthy because males generally ignore or swat away infants who act this way, and also because of the unusual form this reassurance took.) G1/I-0/S-0

Eyepoking (dyadic): The finger of one monkey is inserted into the eye socket (between eyeball and lid) of another monkey. There are many minor variations on this theme. The behavior can be initiated either by the "poker" or recipient of the finger in the eye. Generally the one being poked holds the partner's hand steady. There is variation in how deep the finger is inserted, sometimes just barely in the corner of the eye, but often deep into the eye socket up to the first knuckle. One the toes, rather than the fingers, were inserted in the eye. This behavior can be bidirectional, but usually only one monkey is being poked in the eye at any given moment, while the other monkey is receiving some other form of facial manipulation. This behavior typically occurs in a relaxed social setting for extended periods of time (several seconds, often several minutes). Video footage of this behavior can be viewed at: http://capuchinfoundation.org/research/traditions.html
G1/I-1/S-1

Face cover hug: An adult female hugs an adult male from behind and holds his head; she covers his nose and eyes with her hand, and he gently bites her fingers. This was practiced by one dyad on multiple occasions (G1/I-1/S-0). In a variant on this theme that was seen only once in the same dyad, the male sucks his own tail while the female holds his head

Face lick: An adult male grabs the facial hair of an immature male and licks his face, in the context of an interaction bout that involved passing a flower from mouth to mouth, mutual kissing, and a dental exam. G1/I-1/S-0

Finger-in-mouth game: Monkey A bites firmly down on the finger of Monkey B. This may start in the context of a dental exam or finger-sucking bout. Monkey B tries to pry open Monkey A's mouth, using fingers, feet or his mouth, to retrieve his bitten finger. Once he succeeds, he either reinserts the finger, or the two monkeys switch roles so they can continue playing. G4/I-0010/S-1011

Foot branch shake: A female shakes branches at a human observer using only her foot. G1/I-0/S-0

Food present: One monkey presents a fruit to another monkey, holding it in his mouth, and it is accepted by the other monkey. G1/I-0/S-0

Forced mount: One female tries to force another female into sexual mount position by grabbing her tail with her foot. G1/I-0/S-0

Hair game: Monkey A bites a large tuft of hair out of the face or shoulder of Monkey B. Monkey B pries open the first Monkey A's mouth (usually with the fingers, but sometimes using mouth) to retrieve the hair. The two monkeys pass the hair back and forth in this manner until it has all been lost. At that point they may pull out another tuft of hair to renew the game. Video footage of this behavior can be viewed at:
http://capuchinfoundation.org/research/traditions.html
G1/I-0/S-1

Hand bite hug: While hugging, one male takes the hand of another male in his mouth and bites it softly. G1/I-0/S-0

Hand pull: Two monkeys stand across from one another, locking the distal ends of their fingers, and pulling back and forth for 15-20 seconds. G1/I-0/S-0

Handsniffing (dyadic): One monkey has its fingers (or toes) in or on the nose of another monkey. Typically a finger (or toe) is inserted up a nostril, but occasionally the hand is cupped over the nose. This can be initiated by either partner and may be unidirectional or mutual. Sometimes the hand is steadied by the partner's hand. Photos of this behavior can be viewed at: http://capuchinfoundation.org/research/traditions.html
G4/I-0011/S-0001. One variant of handsniffing, in which one monkey actively rubs her nose on the partner's hand, was seen in only one dyad in one group and was scored as a separate innovation G1/I-0/S-0

Head bumping: Two young males stand off, face to face, repeatedly bumping their heads together during a play bout. G1/I-0/S-0

Hug drag: A male hugs a female from behind and drags her. G1/I-0/S-0

Infant retrieve game: A young adult female has an infant on her back who then dismounts and walks about 20 body lengths away from the female. The female walks over to the infant, puts it on her back, and returns to their original starting point. This is repeated at least three times in rapid succession. G1/I-0/S-0

Infant ride fakeout: An infant is on a young female's back. The infant dismounts, and the female runs a short distance away. The infant twitters to the female, who returns almost to contact of the infant, only to have the female dart away again. The infant re-approaches, the female crouches to invite a ride, and the infant gets on her back. They repeat this sequence of behaviors several times at almost the same location on the branch. G1/I-0/S-0

Juggle partner: An adolescent male grabs an infant female by the tail, throws her up in the air, and tosses/juggles her body. G1/I-0/S-0

Lick head: An adult male licks the head (not the face) of another male. G1/I-0/S-0

Mouth hold: Two males alternate holding on to one another's mouths. G1/I-0/S-0 (i.e. one dyad).

Nurse invite: A mother tries to get a sleeping baby to nurse, using her arm to tuck its head under her armpit while trilling at it. G1/I-1/S-0

Nurse prevent: The mother gently but firmly squeezes her arm between the infant and her nipple, causing the infant to stop nursing from one nipple and switch to the other nipple. She did this several times in one day. G1/I-0/S-0

Scratch with partner hand: A monkey takes another monkey's hand and uses the partner's hand to scratch his own head. G1/I-0/S-0

Shaking of coalition partner's body parts: The alpha female grasps the hand, foot or tail of her coalition partner and shakes or swings it at her opponent, sometimes actually hitting the target with the coalition partner's body part. Practiced by a single alpha female, with multiple partners. G1/I-1/S-0

Slobber grooming: An adult male continually mouths the shoulder and back of another adult male who is sleeping; he soaks his spinal region in slobber as he does this for a prolonged period of time. G1/I-0/S-0 (1 dyad)

Social masturbation: This occurs when one monkey is riding dorsal, or is sexually mounted, on another monkey. The bottom monkey grabs the tail of the top monkey and rubs the top monkey's tail rhythmically on the bottom monkey's clitoris or penis. G1/I-0/S-0

Sucking of body parts: One individual sucks on some portion of the partner's body for a prolonged period of time (several seconds, but often several minutes). Usually it is a long, thin part of the body, such as finger, thumb, toe, ear, hand, foot, or tail. A few of the more innovative sucking incidents involved parts of the body that were more difficult to insert into the mouth, such as cheek, armpit hair, elbow, lip, shoulder, and back. Video of this behavior can be viewed at http://capuchinfoundation.org/resources/ethogram.html
G4/I-0011/S-1011

Swing whack: A juvenile swings back and forth over the alpha male's head and whacks him on the head each time he passes him, while exhibiting a play face. G1/I-0/S-0

Tail bite spin: An alpha male spins around with his tail in his mouth while staring at human observers. G1/I-0/S-0

Tail chew face kick: The alpha male chews a subordinate male's tail while repeatedly kicking him in the face. G1/I-0/S-0

Tail nips: One male does short soft nips on a partner's tail as they cuddle. G1/I-0/S-0

Tail pull sex invite: A male pulls on a female's tail to initiate sex. G1/I-0/S-0

Tap wrestling: A male taps and pats an adult female while she is screaming at another male, and then tries to play wrestle with her. G1/I-0/S-0

Tongue kiss: Two individuals repeatedly lick each other's tongues for an extended duration G2/I-0/S-0

Toy game: Monkey A takes an object (non-edible) in its mouth. Monkey B pries open the mouth of Monkey A (usually with the fingers, but sometimes using mouth and/or feet as well) to retrieve the object. The object may be passed from mouth to mouth multiple times, with the two monkeys switching roles. Objects used generally include sticks, pieces of bark, leaves, and non-edible fruits, though occasionally flowers or insects are used. We lumped these observations together as a single innovation, regardless of what the "toy" was. G1/I-1/S-1

Tug-o-war: This is a minor variation on the toy game. In this variant, the two partners tug simultaneously on the object, holding it in their mouths. G5/I-00000/S-00000

Vine tangle dive: Two immature males repeatedly chase each other up a branch, dive into the center of a vine tangle where they hang by their tails and wrestle one another, then run up the same branch to do it all again. G1/I-0/S-1

Foraging and drinking innovations:

Acacia slap: Pounding or slapping an *Acacia sp.* stick to get the ants off of it before biting into the thorns. G1/I-0/S-0

Bowl: Use of a concave pounding surface to catch the wind dispersed seeds from *Luehea* fruit when pounding them. G1/I-0/S-0

Coati slapping: Monkey presses the coati pup (*Nasua narica)* to a branch and slaps it with the other hand. G1/I-0/S-0

Drinking drips: Sitting below a wet monkey and catching the drops of water that fall from its body, to drink them. G1/I-0/S-0

Fish catch: Trying to grab fish out of the water. G1/I-0/S-0

Food wash: A monkey washes the shoots of a terrestrial bromeliad (*Bromelia pinguin*) to clean the dirt off before eating it. G1/I-0/S-0

Fruit pounce: Playfully pouncing on a fruit repeatedly. G2/I-00/S-00

Hot potato squirrel: Throwing a squirrel into the air and tossing it from hand to hand repeatedly, as if juggling- like the American childhood game of "hot potato" G1/I-0/S-0

Leaf scrub fruit: Wrapping a *Sloanea terniflora* fruit (which is covered in sharp hairs) in a leaf and scrubbing it between the leaves to remove the hairs. An example of tool use G1/I-0/S-0

Leaf sheath: Wrapping *Automeris* caterpillars (which are covered in extremely painful urticating hairs) in a leaf to scrub their spines off. An example of tool use. G2/I-11/S-11

Pound and scrub termite nest: The monkey pounds and scrubs a chunk of a termite nest. G1/I-0/S-0

Reel-in: Monkey grabs a vine or a strand of silk and uses it to reel in prey (caterpillar on a long silk thread, or leaves or bark that might have insects, at the end of a vine).
G3/I-000/S-100

Sponge for drinking: Use of leaves, spiky fruit (*Apeiba tiborou*/monkey's comb), or paper wasp nest to soak up water from a river or treehole to drink. G2/I-00/S-00

Squirrel whacking: Monkey slaps and pounds a squirrel (*Sciurus variegatoides*), sometimes flailing it as well. G1/I-0/S-0. In a minor variant on this behavior, a monkey dips the squirrel in a treehole full of water and then scrubs and pounds it before consuming. G1/I-0/S-0

Tail capture of wasp nests: A monkey breaks off a branch containing a paper wasp (*Polistes spp.)* nest with her prehensile tail and runs off with it. This enables a speedier get-away from the stinging wasps protecting the nest than the usual technique of just grabbing the nest with the hand. G1/I-0/S-0

Tail dipping for drinking: Insertion of the tail into a body of water (river or tree hole) in order to obtain drinking water, using the tail as a sponge. In the case of tree holes, monkeys do this when the water level is too far down for the water to be accessible with an arm (the tail is longer than the arms and legs). Video of this behavior has been uploaded to the supplementary information section. Treehole: G1/I-1/S-0; River: G1/I-0/S-0

Investigative (Environmental exploration)**:**
Anteater groom: Monkey grooms anteater. G1/I-1/S-0

Biting rocks: Monkeys bite or mouth rocks, sometimes after rolling them. G3/I-0/S-0

Branch drumming: Drumming on a branch with the hands. G1/I-1/S-0

Bubble pop: Poking at bubbles in the river. G1/I-0/S-0

Carry branch in tail: A monkey carries a large branch in the tail. (In one case, the branch was the width of the monkey's thigh and longer than his body, but he climbed a tree while carrying the branch in his tail without dragging it, apparently as a display.) This differs from a more common display where branches are dragged through the leaf litter, making a large amount of noticeable sound. G2/I-00/S-00

Coordinated slide: Two monkeys are facing one another on a branch, and one slides backwards as the other approaches him, sliding forward. G1/I-0/S-0

Cow pie seesaw: A juvenile flips over a cow pie (dung) which has dried sufficiently to keep its form and stands on it, rocking back and forth. Video of this behavior has been uploaded to the supplementary information section. G1/I-0/S-0

Cow play: Pulling cows' tails. G1/I-0/S-0

Exploration of unusual items left by humans: Although opportunities to interact with these objects were relatively limited, most if not all group members did have a chance to do so, but did not, so we decided that explorations of these objects qualifies as an innovation. Handling and probing inside beer cans and plastic bottles, handling a rachet, playing with a burlap swing, playing with string (untying, untangling, biting string left tied to trees), playing with a doll that was tied to a tree, spinning and biting aluminum tree tags. Each of these behaviors was seen just once, by a single innovator in a single group. G5/I-0000/S-0000

Fetch fruit game: Juvenile holds a fruit down and jump up and down in front of it. She then lets go of the fruit and lets it roll into the river. Then she retrieves it and repeats all of these actions. G1/I-0/S-0

Fruit in tree hole game: Repeatedly placing fruits in a water-filled tree hole and taking them out again, splashing water in the process. G1/I-1/S-0

Fruit tap-roll: Holding a round unripe *siempreverde* fruit *(Jacquinia sp.)* in the open mouth and tapping it so that it rolls around in the mouth. (Play) G1/I-0/S-0

Fulcrum stick snap: Repeatedly pressing a stick perpendicular to a branch, with hands on both ends of the stick, until it snaps. G1/I-0/S-0

Handstand/cartwheel: The monkey stands on its hands on the ground and then flips over to land eventually on all fours. G1/I-0/S-0

Hanging locomote: A monkey hangs from a branch by its feet and "walks" along the branch while hanging, using just the hind legs. G1/I-0/S-0

Hot potato: tossing an object (e.g. unripe fruit or rock) from hand to hand repeatedly, as if juggling- like the American childhood game of "hot potato" G4/I-0000/S-0101

Howler corpse inspection: Touching and sniffing a dead howler monkey. G1/I-0/S-0

Howler groom: Grooming howler monkey. G1/I-0/S-0

Howler play: Rough and tumble play with howler monkey. G2/I-10/S-01

Juggling: Rapidly passing or tossing sticks (or, in one case, a rock) from hand to hand or from foot to hand, sometimes while hanging from the tail (G4/I-0000/S-1000). In another variant, a monkey juggles a rock one-handed (G1/I-0/S-0)

Licking, biting and hitting spiky Bromelia pinguin *leaves playfully*: G1/I-0/S-0

Mango/rock hitting game: Doing hard, double-handed hits on a mango or a rock for 4-5 minutes at a stretch. G1/I-1/S-0

Manipulating leaves: Playing with leaves. G2/I-00/S-10

Mirror view: Staring in the mirror of the car repeatedly. G1/I-0/S-1

Mouth rope feed: Using one hand to feed a rope into the mouth and another hand to pull it through the mouth, then using both hands to pull the rope, hand over hand, until it can go no further (because it is tied to a tree and has a knot at the other end); then reversing directions G1/I-0/S-0

Mud push: A juvenile playfully pushes mud in front of him as he runs. G1/I-0/S-0

Mud slap: Slapping mud below the water. G1/I-0/S-0

Open palm slapping of branches. G2/I-00/S-00

Plant wrestle: Wrestling with plants (e.g. leaves, bark, mango fruit), sometimes while hanging from the tail or rolling on the ground, combined with other actions (e.g. biting, hitting, rolling). G4/I-1000/S-0000

Porcupine groom: Grooming a Mexican porcupine, *Coendou mexicanus*. G1/I-0/S-0

Pounding on a metal structure with the palm of the hand (presumably to make noise). G1/I-0/S-0

Pounding rocks: Pounding rocks. G1/I-0/S-0

Pushing leaves: Pushing piles of leaf litter down a slope. G1/I-0/S-1

Putting leaves in a treehole: Playing with leaves by inserting them in treeholes. G1/I-0/S-0

Reel-in vine game: Lying down, the monkey uses both hands and sometimes the feet to pull up a vine (occasionally passing it through the mouth and tail too). Once it has been pulled up as far as it can go, the vine is dropped and the game repeated. G1/I-0/S-0

Rolling pin stick play: Rolling sticks on a branch as if they were a rolling pin. G1/I-1/S-0

Rolling rocks: Rolling rocks as an aggressive display. G1/I-0/S-0

Sand play (backwards throw): tossing sand backwards, between the legs. G2/I-00/S-10

Sand play (digging): Digging in the sand, sometimes burying part of the body (e.g. feet, tail), sometimes splashing the sand. In one variant, the monkey digs by jumping in the sand and pulling the sand towards her as she lands G4/I-0100/S-0100

Sand play (rolling): lying in the sand and rolling about. G2/I-00/S-00

Sand play (sifting): sifting sand through the fingers. G1/I-0/S-0

Scrub rocks: Scrubbing rocks by rubbing them against a branch. G1/I-0/S-1

Scrub rocks on rocks: One monkey scrubs rocks against other rocks, producing white marks that are then inspected by her mother. G1/I-0/S-0

Seesaw (dyadic): Two monkeys create a see-saw with a branch, each riding on different ends of it. (Seen only once, in one group)

Splash water from treeholes: Monkeys playfully slap water in treeholes, causing it to splash out of the tree. G4/I-0000/S-0011

Swinging stick while holding it in the tail. G1/I-0/S-0

Tree swing water splash: Jumping onto a branch and swinging through the water repeatedly, dunking about half of the body each time the branch passes through the water. G1/I-0/S-1

Turtle flip: Investigating a turtle by picking it up and turning it over. G1/I-0/S-1

Upward splash: Cupping the hands in the water and throwing it up in the air. G1/I-0/S-0

Wash arms in treehole: Washing arms in treehole water, either by soaking them or by actively rubbing the water into the fur. G3/I-100/S-000

Water dig: Hanging from the tail and feet and splashing the water with the hands, using a digging motion. G1/I-1/S-0

Water dip: A juvenile dips her body into the water and then rushes up a tree, repeating this sequence many times in rapid succession. G1/I-1/S-0

Water grab: sitting on a branch above the water and "grabbing" the water by moving the hands and feet through it in motions suggestive of doggy paddle swimming. G1/I-0/S-0

Self-directed behavior:

Body part hold: The monkey sits still, holding some specific body part for a prolonged period of time, usually while in a resting position. This could be the head, arm, armpit, back, rump, chest, ear, flank, foot, forearm, hand, hip, knee, neck, nose, nipple, shoulder, belly, tail, tailbase, or wrist. G1/I-1/S-1

Methods note about "Body Part Hold": Individual capuchins are somewhat prone to adopting idiosyncratic postures that involve clutching some part of the body, and these habits, once adopted, can last for years. Holding any particular part of the body as an isolated incident is not novel enough, in our view, to qualify as an innovation, as touching or grasping a body part is something that would logically occur to any individual who had an itch or pain in that location. However, adopting a new postural habit seemed innovative to experienced observers. Thus, to qualify as a postural innovation, the individual had to be the first member of a particular group seen repeating the same postural behavior at least three times spanning a time period of at least 2 months, during 2007-2011, and then we made sure that no other member of that group had been a practitioner of that same behavior during the "buffer period," as described above.

Fist-nose rub: Vigorously rubbing the nose with the fist, inducing sneezing. G1/I-1/S-1

Floss teeth with a stick or vine. G3/I-100/S-001

Masturbation with branch: Rubbing the clitoris rhythmically against a branch. G1/I-0/S-0

Masturbation with own tail: The monkey alternately rubs her own tail and her own hand against her clitoris, while doing exaggerated and prolonged pelvic thrusts and twittering constantly. G2/I-00/S-01

Rubbing/scraping teeth on a branch. G3/I-000/S-000

Self-eyepoke: The monkey inserts a finger in its own eye for a prolonged period of time. This can happen when the monkey is alone, or sometimes as an interval in a sequence of interactions with a partner. G2/I-11/S-11

Toothpick: poking stick in own mouth between teeth. G1/I-0/S-0

Twig trim: Snapping twigs off from above a resting spot, apparently to avoid having them tickle the monkey who is trying to nap. G1/I-0/S-1

Table S1: List of innovations. For each unique innovation type, it lists (a) the number of groups in which the innovation occurred during 2007-2011, (b) whether or not the innovator was seen to repeat the behavior on other days, and (c) whether the behavior was subsequently observed in other members of the innovator's group.

Domain	Behavior	No. of groups	Repeated by innovator?	Seen in other individuals or dyads in that group?
foraging	*Acacia slap*	1	no	no
foraging	*Bowl*	1	no	no
foraging	*Coati slapping*	1	no	no
foraging	*Drinking drips*	1	no	no
foraging	*Fish catch*	1	no	no
foraging	*Food wash*	1	no	no
foraging	*Fruit pounce*	2	no	no
foraging	*Hot potato squirrel*	1	no	no
foraging	*Leaf scrub fruit*	1	no	no
foraging	*Leaf sheath*	2	2 of 2	2 of 2
foraging	*Pound and scrub termite nest*	1	no	no
foraging	*Reel-in*	3	no	1 of 3
foraging	*Sponge for drinking*	2	no	no
foraging	*Squirrel whacking*	1	no	no
foraging	*Tail capture of wasp nests*	1	no	no
foraging	*Tail dipping for drinking from river*	1	no	no
foraging	*Tail dipping for drinking from treeholes*	1	yes	no
investigative	*Anteater groom*	1	yes	no
investigative	*Biting rocks*	3	no	no
investigative	*Branch drumming*	1	yes	no
investigative	*Bubble pop*	1	no	no
investigative	*Carry branch in tail*	2	no	no
investigative	*Coordinated slide*	1	no	no
investigative	*Cow pie seesaw*	1	no	no
investigative	*Cow play*	1	no	no
investigative	*Exploration of unusual items left by humans*	5	no	no
investigative	*Fetch fruit game*	1	no	no
investigative	*Fruit in tree hole game*	1	yes	no
investigative	*Fruit tap-roll*	1	no	no
investigative	*Fulcrum stick snap*	1	no	no

investigative	*Handstand/cartwheel*	1	no	no
investigative	*Hanging locomote*	1	no	no
investigative	*Hot potato*	4	no	2 of 4
investigative	*Howler corpse inspection*	1	no	no
investigative	*Howler groom*	1	no	no
investigative	*Howler play*	2	2 of 2	1 of 2
investigative	*Juggle rock one-handed*	1	no	no
investigative	*Juggling*	4	no	1 of 4
investigative	*Licking, biting and hitting spiky Bromelia pinguin leaves*	1	no	no
investigative	*Mango/rock hitting game*	1	yes	no
investigative	*Manipulating leaves*	2	no	1 of 2
investigative	*Mirror view*	1	no	yes
investigative	*Mouth rope feed*	1	no	no
investigative	*Mud push*	1	no	no
investigative	*Mud slap*	1	no	no
investigative	*Open palm slapping of branches*	2	no	no
investigative	*Plant wrestle*	4	1 of 4	no
investigative	*Porcupine groom*	1	no	no
investigative	*Pounding on a metal structure*	1	no	no
investigative	*Pounding rocks*	1	no	no
investigative	*Pushing piles of leaf litter down slope*	1	no	yes
investigative	*Putting leaves in treehole*	1	no	no
investigative	*Reel-in vine game*	1	no	no
investigative	*Rolling pin stick play*	1	yes	no
investigative	*Rolling rocks as aggressive display*	1	no	no
investigative	*Sand play (backwards throw)*	2	no	1 of 2
investigative	*Sand play (digging)*	4	1 of 4	1 of 4
investigative	*Sand play (rolling)*	2	no	no
investigative	*Sand play (sifting)*	1	no	no
investigative	*Scrub rocks*	1	no	yes
investigative	*Scrubbing rocks on rocks to make white marks*	1	no	no
investigative	*Seesaw (dyadic)*	1	no	yes
investigative	*Splash water out of treeholes*	4	no	2 of 4
investigative	*Swinging stick while holding it in the tail*	1	no	no
investigative	*Tree swing water splash*	1	no	yes
investigative	*Turtle flip*	1	no	yes
investigative	*Upward splash*	1	no	no
investigative	*Wash arms in treehole*	3	1 of 3	no
investigative	*Water dig*	1	yes	no
investigative	*Water dip*	1	yes	no
investigative	*Water grab*	1	no	no

self-directed	*Body part hold*	1	yes	yes
self-directed	*Fist-nose rub*	1	yes	yes
self-directed	*Floss teeth with a stick or vine*	3	1 of 3	1 of 3
self-directed	*Masturbation with branch*	1	no	no
self-directed	*Masturbation with own tail*	2	no	1 of 2
self-directed	*Rubbing/scraping teeth on a branch*	3	no	no
self-directed	*Self-eyepoke*	2	2 of 2	2 of 2
self-directed	*Toothpick*	1	no	no
self-directed	*Twig trim*	1	no	yes
social	*Arm drumming*	1	yes	no
social	*Arm rub*	1	no	no
social	*Bite coalition partner's tail*	2	1 of 2	no
social	*Bounce-slap display*	2	no	no
social	*Cartwheel face kick*	1	no	no
social	*Circle bounce*	1	no	no
social	*Clitoral manipulation*	1	no	no
social	*Dental exam*	5	5 of 5	5 of 5
social	*Eat earwax*	1	no	no
social	*Elbow caress*	1	no	no
social	*Eyepoking (dyadic)*	1	yes	yes
social	*Face cover hug*	1	yes	no
social	*Face cover hug with tailsuck*	1	no	no
social	*Face lick*	1	yes	no
social	*Finger-in-mouth game*	4	1 of 4	3 of 4
social	*Food present*	1	no	no
social	*Foot branch shake*	1	no	no
social	*Forced mount*	1	no	no
social	*Hair game*	1	no	yes
social	*Hand bite hug*	1	no	no
social	*Hand pull*	1	no	no
social	*Handsniffing (dyadic)*	4	2 of 4	1 of 4
social	*Handsniffing (dyadic) - nose rub variant*	1	no	no
social	*Head bumping*	1	no	no
social	*Hug drag*	1	no	no
social	*Infant retrieve game*	1	no	no
social	*Infant ride fakeout*	1	no	no
social	*Juggle partner*	1	no	no
social	*Lick head*	1	no	no
social	*Mouth hold*	1	no	no
social	*Nurse invite*	1	yes	no
social	*Nurse prevent*	1	no	no

social	*Scratch with partner hand*	1	no	no
social	*Shaking of coalition partner's body parts*	1	yes	no
social	*Slobber grooming*	1	no	no
social	*Social masturbation*	1	no	no
social	*Sucking of body parts*	4	2 of 4	3 of 4
social	*Swing whack*	1	no	no
social	*Tail bite spin*	1	no	no
social	*Tail chew face kick*	1	no	no
social	*Tail nips*	1	no	no
social	*Tail pull sex invite*	1	no	no
social	*Tap wrestling*	1	no	no
social	*Tongue kiss*	2	no	no
social	*Toy game*	1	yes	yes
social	*Tug-o-war*	5	no	no
social	*Vine tangle dive*	1	no	yes

Table S2. Model parameter estimates for mASRMG. Intercepts are represented by α and slopes are represented by β.

Parameter	**Main Effects**		**Varying Effects**		
	Posterior Mean	*Posterior SD*	σid	$\sigma domain$	$\sigma group$
α_p	-0.85	0.87	1.01	0.61	1.56
α_l	-2.24	0.76	0.32	1.19	0.21
βage_p	0.94	0.87	0.89	2.89	0.6
βage_l	-0.34	0.44	0.28	0.61	0.35
$\beta sociality_p$	-0.49	0.65	1.13	0.64	0.53
$\beta sociality_l$	-0.23	0.39	0.08	0.66	0.25
$\beta rank.high_p$	0.34	0.72		0.69	0.53
$\beta rank.high_l$	0.37	0.41		0.46	0.32
$\beta rank.low_p$	0.69	0.82		0.85	0.75
$\beta rank.low_l$	0.68	0.37		0.42	0.28
$\beta male_p$	-0.36	0.69		0.76	0.76
$\beta male_l$	0.27	0.36		0.42	0.27
$\beta groupsize_p$	0.06	0.02			
$\beta groupsize_l$	0.26	0.09			

Table S3: Observation hours for each time period.

Group	2007	2008	2009	2010	2011	Buffer period
AA	1530	1417	1643	1457	807	12023
CU[a]	266	399	298	119	311	0
FF	1468	1250	1043	664	1218	8859
FL[a]	998	674	685	322	469	2716
MK[a]	487	271	321	136	805	1883
NM	11	105	263	407	1231	48
RF[a]	274	1201	1022	546	441	0
RR	1542	1352	1455	1404	722	11653
SP[a]	21	25	195	1290	391	235
other	26	62	203	1381	569	149

[a] fission products

Fig. S1: Model predictions for the effect of age on probability of innovating (1 − p) (Panels a-d) and the number of innovations observed per individual per year conditional on being an innovator (Panels e-h). Dark lines lie at the posterior median, and lighter lines are 100 randomly sampled posterior predictions. Points are raw data, with darker shades indicating more data lying at that value. All non-zero values are plotted at 1.

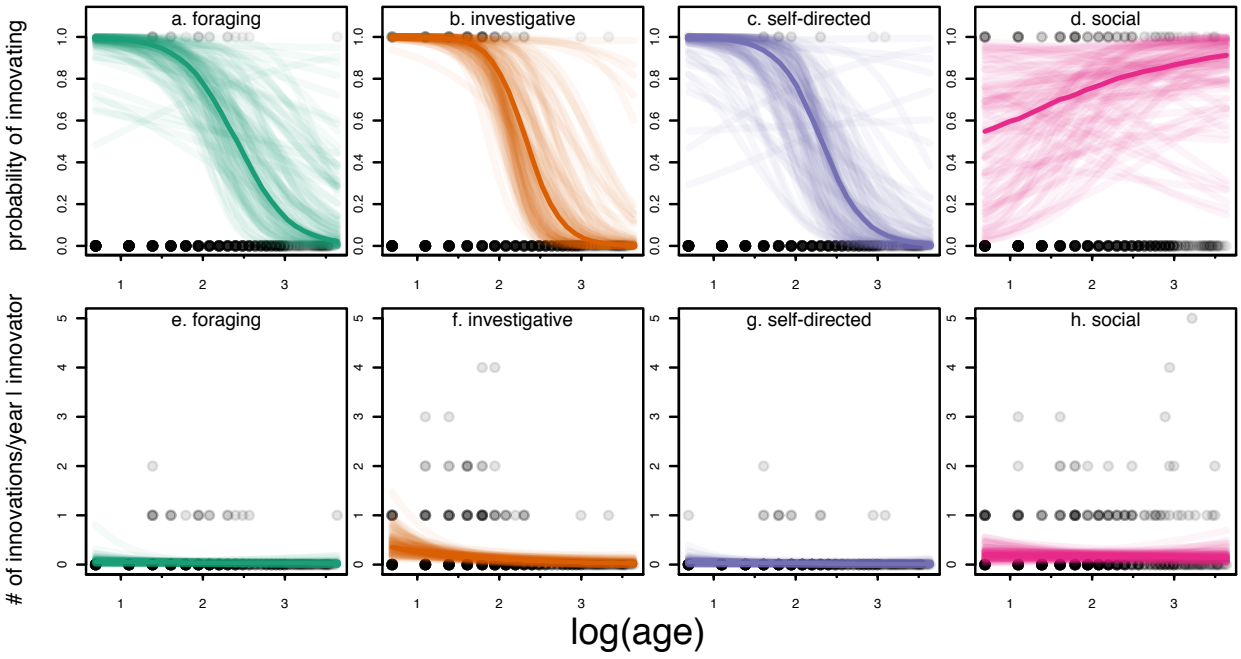


Fig. S2: Model predictions for the effect of sociality on the probability of innovating ($1 - p$) (Panels a-d) and the number of innovations observed per individual per year conditional on being an innovator (Panels e-h). Dark lines lie at the posterior median, and lighter lines are 100 randomly sampled posterior predictions. Points are raw data, with darker shade indicating more data lying at that value. All non-zero values are plotted at 1.

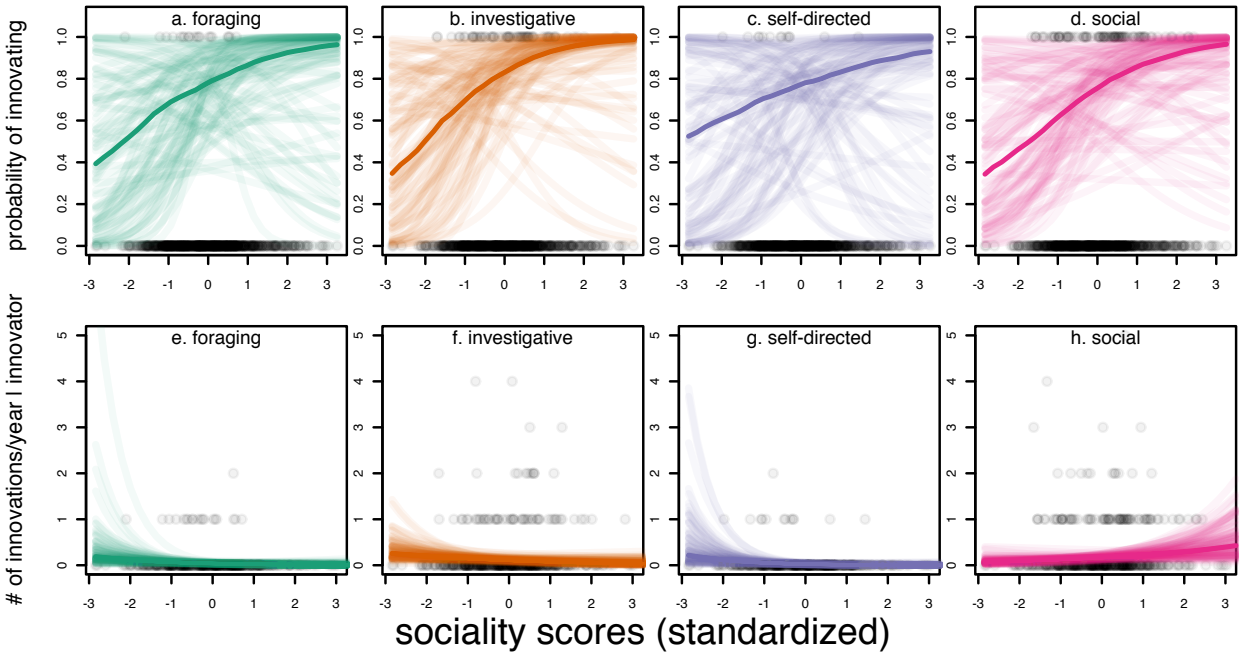


Fig. S3: Effect of sex on (a) annual innovation rate, (b) the probability of innovating in a given year, and (c) the number of innovations in a given year conditional on being an innovator. Large, dark points lie at the posterior median, while bars indicate an 89% credible interval. Lighter dots are posterior median predictions of varying effects for each individual.

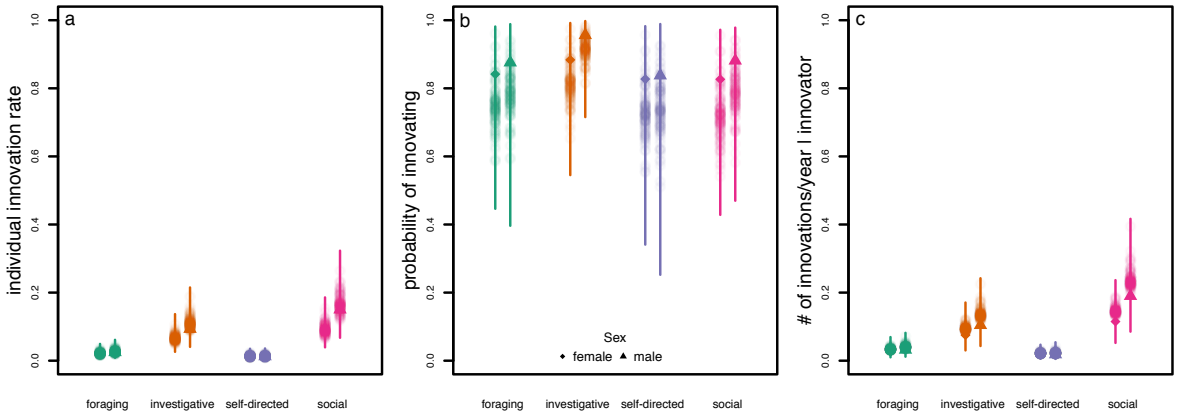
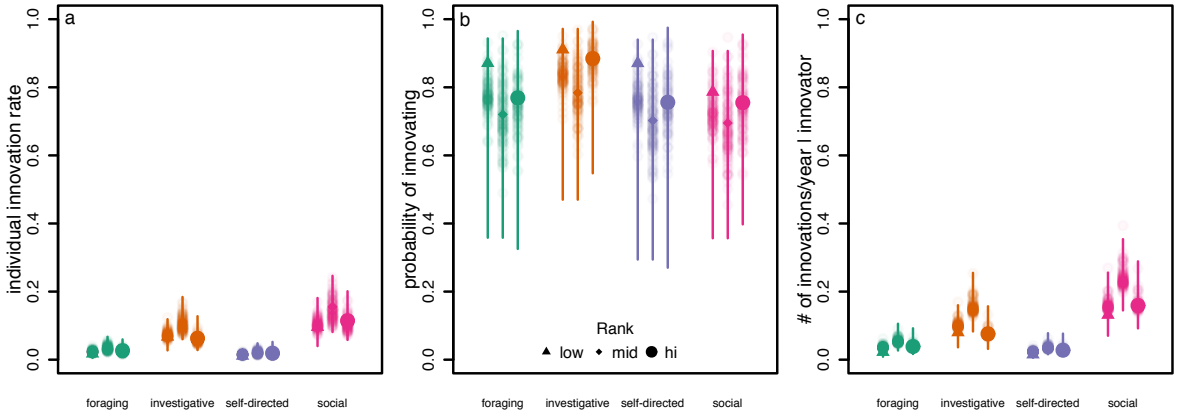


Fig. S4: Effect of rank on (a) annual innovation rate, (b) the probability of innovating in a given year, and (c) and the number of innovations in a given year conditional on being an innovator. Large, dark points lie at the posterior median, while bars indicate an 89% credible interval. Lighter dots are posterior median predictions of varying effects for each individual.



Appendix Part Two: <u>Predictors of potential social transmission</u>

We know that social learning and social traditions are common among monkey species (1), including capuchins (2), and therefore it is likely that some of the innovations in this study have been (or will be) transmitted via social learning, becoming traditions. Innovation can serve as the origin of some, but not all, behavioral traditions. While most of the innovations we observed were only recorded by one individual in the social group, many of were practiced by other members of the social group after the first observed innovation. Here we present a simple analysis of what predicts the potential transmission of a behavior through an animal's social group.

Before proceeding, we issue a *strong caveat*: we are not arguing that all of these innovations practiced by multiple individuals are necessarily socially transmitted. It is highly possible that some are independently innovated by multiple individuals in a social group. For some of these behaviors, including a few self-soothing, we think this might be the case. A suitable analysis to address whether a behavior is socially learned should account for both the peculiarities of an animal's social networks and their opportunities for observing a behavior, and ideally should account for both 1) individual and social learning and 2) the dynamic nature of an organism's social networks throughout their lifetime. An analysis of this scale is beyond the scope of this publication, but can be addressed using a variety of methods such as experience weighted attraction models (3) and network-based diffusion analyses (NBDA) (4).

Supplemental Methods:
We took the list of unique observed innovations per social group, using the criteria for an innovation described in the main methods section of this paper (i.e. the same list used to calculate the main dataset in the paper). As a (1,0) outcome, we scored whether the innovation was subsequently observed in other members of the group. Alongside each innovation, we recorded 1) its behavioral domain, 2) the social group it was observed in, and 3) the maximum group size in that year for each social group. For each individual per year, we calculated the age, rank, sociality, and sex of the innovator using methods described in the main paper.

Statistical Analyses:
To analyze this data set we fit a series of hierarchical logistic generalized linear models in rSTAN and compared them using WAIC. As there was not a single highest ranked model according to model weights (i.e. wWAIC was not > 0.99 for a single model), we plotted model-averaged predictions with the assistance of the **ensemble** function from the "rethinking" package in R (5). WAIC values, and the parameters included in each model are reported in **Table S4**. We used varying intercepts for social group and behavioral domain, and varying slopes of domain for each of the 4 main predictors (age, sociality, sex, rank). Each model also included group size to account for masked relationships between group size and the predictors. All predictors were centered or standardized prior to analysis. Model and plotting code are available on one of the author's (BJB's) Github sites for this publication:
https://github.com/bjbarrett/cebusinnovation2017.

Supplemental Results:

Table S4. WAIC estimates for social transmission models.

Model	WAIC	dWAIC	wWAIC	SE
mAG	255.52	0	0.4	17.12
mRG	257.3	1.78	0.17	17.72
mSG	257.54	2.02	0.15	17.84
mG	257.59	2.07	0.14	17.31
mASG	258.24	2.72	0.1	18.21
mMG	260.63	5.11	0.03	17.82
mASMRG	264.95	9.43	0	18.92

Age: Model averaged predictions suggest that ignoring domain level differences, age is negatively related to the potential spread of innovations (Fig. S5a). In other words, the younger the innovator is, the more likely the behavior is to subsequently appear in other group members. However, this effect is not consistent across all behavioral domains. This negative effect was strongest in the social and investigative domains, but near zero in the foraging domain. An alternative explanation to biased social learning towards younger individuals is that if young monkeys innovate earlier in life, there are more opportunities for them to be copied by individuals in the future.

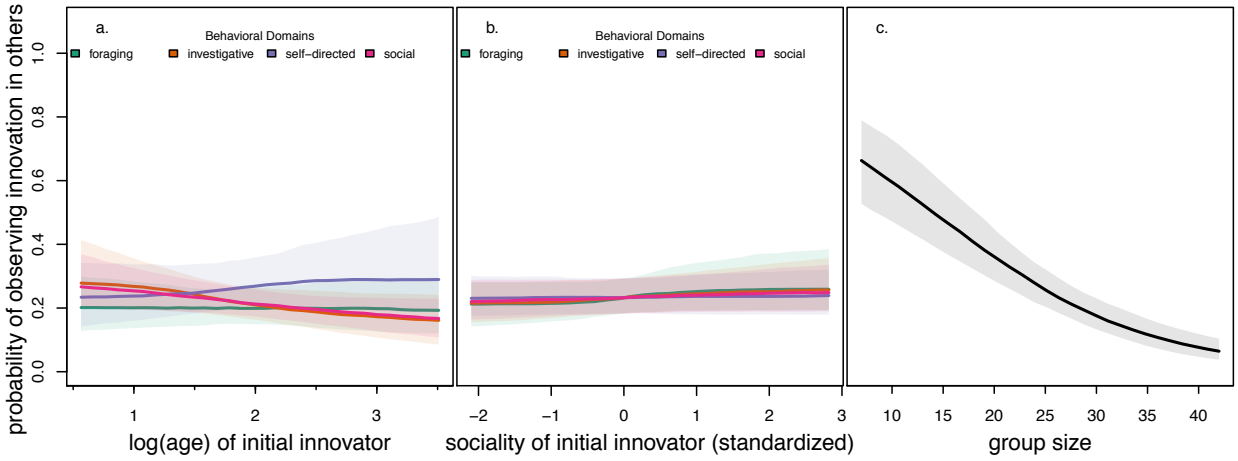
Looking at self-directed behaviors, we see the opposite relationship. Older individuals' self-directed behaviors are more likely to be socially transmitted. Many capuchins across all groups practiced (seemingly) unique quirks such as solo hand sniffing, body part holding or solo eye-poking. However, it is possible that these quirks are independently innovated as they are more widespread across groups and may serve a function to self-soothe animals. Interestingly, many of these self-soothing behaviors are incorporated into dyadic rituals, which are likely to spread through groups. Some of these self-directed behaviors may be particularly easy to independently invent.

Sociality: Model averaged predictions suggest that sociality has a weak, slightly positive relationship with the potential probability of social transmission of an innovation, i.e. more social individuals are more likely to have their innovations appear in other group members at a later time (Fig. S5b). We predict little variation across domains. This positive effect was more marked and variable across domains in mSG, however model averaging suggests that it has a relatively weak effect. This relationship is perhaps because more social innovators provide more opportunities to learn, but could be the product of an unevaluated trait that is collinear with sociality (i.e skill, friendliness, rank).

Group Size: Interestingly, group size had a strong negative effect on the potential probability of social transmission (Fig. S5c). Smaller groups might provide a smaller pool of individuals to interact with and potential innovations to copy, thus increasing the likelihood that a given

innovation is transmitted. Additionally, larger groups often have more complex social structures in which less social innovators may be less likely to interact with other group members than more social innovators do. This finding contrasts with theoretical predictions (6) of reliance on social learning increasing with group size, but as the temporal dynamics of learning are not explicitly modeled in this analysis, we remain hesitant regarding interpretation of these findings.

Fig. S5: Effects of (a) age, (b) sociality, and (c) and group size on potential transmission of innovations to other group members. Dark lines lie at posterior median, and shaded regions represent 50% credible intervals (to assist with data visualization). Each color is associated with a behavioral domain, with the exception of panel c.



Supplemental References:

1. Perry S & Manson JH (2003) Traditions in monkeys. *Evolutionary Anthropology* 12:71-81.
2. Perry S (2011) Social traditions and social learning in capuchin monkeys (*Cebus*). *Philosophical Transactions of the Royal Society B* 366:988-996.
3. McElreath R*, et al.* (2008) Beyond existence and aiming outside the laboratory: estimating frequency-dependent and pay-off-biased learning strategies. *Philosophical Transactions of the Royal Society B* 363(1509):3515-3528.
4. Hoppitt W, Boogert NJ, & Laland KN (2010) Detecting social transmission in networks. *Journal of Theoretical Biology* 263(4):544-555.
5. McElreath R (2016) *Statistical Rethinking: A Bayesian Course with Examples in R and Stan* (Chapman and Hall/CRC, New York).
6. King AJ & Cowlishaw G (2007) When to use social information: the advantage of large group size in individual decision making. *Biology Letters* 3(2):137-139.