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A “How-To” Guide for Designing Judgment Bias Studies to Assess Captive Animal Welfare

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Robust methods to assess nonhuman animal emotion are essential for ensuring good welfare in captivity. Cognitive bias measures such as the judgment bias task have recently emerged as promising tools to assess animal emotion. The simple design and objective response measures make judgment bias tasks suitable for use across species and contexts. In reviewing 64 studies published to date, it emerged that (a) judgment biases have been measured in a number of mammals and birds and an invertebrate; (b) no study has tested judgment bias in any species of fish, amphibian, or reptile; and (c) no study has yet investigated judgment bias in a zoo or aquarium. This article proposes that judgment bias measures are highly suitable for use with these understudied taxa and can provide new insight into welfare in endangered species housed in zoos and aquariums, where poor welfare impacts breeding success and, ultimately, species survival. The article includes a “how-to” guide to designing judgment bias tests with recommendations for working with currently neglected “exotics” including fishes, amphibians, and reptiles.

Keywords: amphibians, animal welfare, cognitive bias, fish, emotion, reptiles

You wake up feeling happy. You go to the kitchen and step on the mouse head your cat has left for you. The milk in the fridge is off. It is raining outside. Had you woken up in a bad mood or if you suffer from anxiety or depression, any one of these events might have sent you back to bed. But you woke up happy, so you thank the cat for the present, have a rejuvenating juice, and appreciate how lush and green the garden is before heading out. How you interpret day-to-day events, therefore, depends largely on your mood (see [Table 1](#) for glossary terms).

Empirical data from humans show that happy, content people make more positive judgments about ambiguous information, recall more positive information, expect more positive events to occur in the future, and attend more readily to positive stimuli (Standage, Harris, & Fox, 2014). Having a tendency to make positive judgments about ambiguous or neutral stimuli increases the chances for positive biases in the other domains, leading to an upward spiral, or maintenance, of a positive affective state (Seligmann, 1991).

People who are anxious or depressed, on the other hand, make more negative judgments about ambiguous information, recall more negative information, expect more negative events to

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TABLE 1
Glossary of Terms

<i>Term</i>	<i>Definition</i>
Affect	A general term that covers short-lived emotions and longer-lasting moods. Affect and mood are diffuse states. An emotion is elicited by a stimulus.
Cognition/ cognitive Cognitive bias	Information processing in the brain. In its broadest sense, this includes attention, interpretation, action selection, and storage and retrieval (memory) processes. In the field of animal cognition and welfare, this term describes the influence of affect on cognition. Positive emotions are coupled with positive cognitions, negative emotions with negative cognitions. In humans, emotion–cognition interaction feeds into the conscious experience of feelings that underpin psychological well being.
Emotion	A short-lived response to a stimulus that guides animals toward rewards (e.g., food and mates) and away from danger (e.g., freeze, flight, and fight). Emotions have behavioral, physiological, and neural components and can occur without awareness in humans and other animals.
Feeling	The subjective experience of an underlying affective state, including (conscious) awareness of (preconscious) emotion.
Judgment bias	The influence of affect on the interpretation of, and response to, ambiguous stimuli. The model presumes that positive emotion or mood is reflected in more positive judgments about ambiguous stimuli (“glass half full”), whereas negative emotion or mood is reflected in more negative judgments about ambiguous stimuli (“glass half empty”).
Judgment bias task	A task in which an animal is trained to discriminate between two stimuli that differ along one dimension (e.g., size, color, and location). One cue (e.g., “left location”) is rewarded, and the other cue (e.g., “right” location) is not rewarded. During a judgment bias task, an ambiguous cue is presented (i.e., an intermediate location). Speed and frequency of response reflect whether the animal judges the intermediate cue to be more positive or negative.
Operant task	A task in which an animal learns to associate an action (e.g., flip lid, approach bowl, and touch target) with an outcome (e.g., get food).
Parsimonious	The law of parsimony states we should use the simplest explanation for a phenomenon (i.e., one that makes the fewest assumptions).
Reinforcer	A reinforcer is something an animal will work to gain (food is a positive reinforcer) or to avoid (electric shock is a negative reinforcer). Food and shock are known as primary reinforcers because they are intrinsically rewarding and aversive. Secondary reinforcers are cues that come to be associated with a primary reinforcer through learning (e.g., that a black lid signals food and a white lid signals nonreward).
Welfare	The physical health and physiological functioning of an individual, the opportunity to express natural behaviors, and the balance of positive emotions with negative emotions. Definitions of welfare vary greatly between disciplines and are often restricted by those components considered “measurable” using each discipline’s methods. All acknowledge it may include a psychological or affective component, even if the means to measure these components have been lacking.
Well being	“Welfare” with particular emphasis on the psychological and affective components. It may include a conscious experience. The terms welfare and well being are used interchangeably here, as both definitions include psychological and affective components.

occur in the future, and attend more readily to negative information (Bradley, Mogg, Millar, & White, 1995; MacLeod & Byrne, 1996; Mogg, Bradbury, & Bradley, 2006; Richards et al., 2002; Richards, Holmes, Pell, & Bethell, 2013). Negative affective states can have adaptive emotional underpinnings in a threatening environment: Increased arousal in anxiety speeds responses to threat (Mogg, Bradley, & Williams, 1995); social withdrawal in depression conserves energy and may keep one away from harm (Nettle & Bateson, 2012). The heightened

emotional response and accompanying feelings subside once the threat has passed and allow time to attend to the more rewarding aspects of life (LeDoux, 1996). Anxiety and depression are “negative” affective states because, by definition, they make us “feel” bad, but their short-term survival value is high. Having a tendency to make negative judgments about ambiguous or neutral stimuli increases the chances for negative biases in the other domains potentially leading to a “downward spiral” toward poor mental well being, reduced quality of life, and ultimately clinical levels of anxiety or depression (Eysenck, Payne, & Santos, 2006).

JUDGMENT BIAS IN ANIMALS

The first study to explore judgment bias in animals was conducted by Harding, Paul, and Mendl (2004; Figure 1a). The researchers trained rats on a discrimination task in which they learned to press a lever when they heard a tone that signaled reward (conditioned stimulus CS +) and not to press the lever when they heard a tone that signaled nonreward (conditioned stimulus CS-). Rats were then housed in either normal housing (and were therefore in a putatively more positive affective state) or poor housing (and were therefore in a putatively more negative affective state). After 9 days, researchers played intermediate tones to those the rats had heard previously (ambiguous “probes”). Rats in normal housing made more frequent and faster lever presses (“Go”) to intermediate tones compared with rats in poorer-quality housing; in other words, rats in the better housing made more “optimistic” judgments about the ambiguous tones compared with their more “pessimistic” counterparts.

WHY IS JUDGMENT BIAS IMPORTANT?

Judgment bias is the most widely explored of a number of cognitive bias measures that present new methods to study animal welfare (see also Bethell, Holmes, MacLarnon, & Semple, 2012b; Burman, Parker, Paul, & Mendl, 2008b). This work builds on a long history of discussion about animal emotions (e.g., Darwin, 1872) and earlier work developing cognitive theories of emotion in animals (e.g., Dawkins, 1990; Désiré, Boissy, & Veissier, 2002; Duncan & Petherick, 1991; Spruijt, van den Bos, & Pijlman, 2001; Wemelsfelder, 1997).

Harding et al. (2004) used the term “cognitive bias” to describe the effect of emotion on judgments about ambiguous cues. During the last decade, the paradigm has been reframed as the “judgment bias task” to reflect its presumed sensitivity to evaluative and expectancy processes (i.e., judgments about the reward value of ambiguous cues). The task may also be sensitive to other cognitive processes such as attention and memory (reviewed in Mendl, Burman, Parker, & Paul, 2009), and the term “judgment bias” may reflect as much the focus of researchers as the processes being measured. Herein, I follow the literature and use the term “judgment bias task” to refer to variants of the original task developed by Harding et al. I use the term “cognitive bias” when discussing cognition–emotion interaction generally.

Arguments for the utility of cognitive bias over other (physiological and behavioral) measures are diverse (Otvic & Hutchinson, 2015; Paul, Harding, & Mendl, 2005; cf. Wemelsfelder, 1997). First, cognitive bias measurements provide a metric for assessing positive emotions in animals. There are few, if any, objective measures of positive emotions in animals despite widespread physiological and behavioral measures of negative emotions (Mellor, 2015;

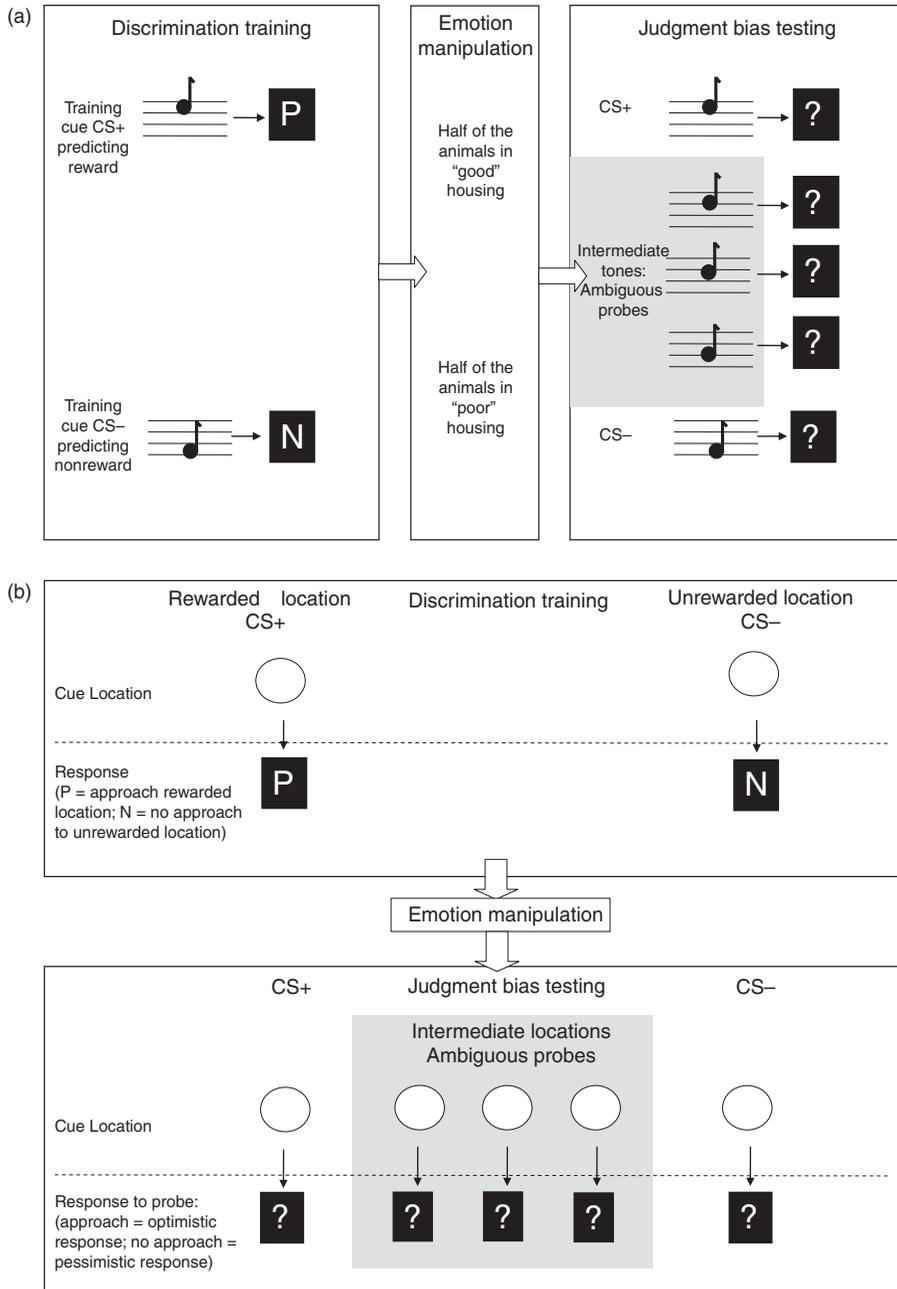


FIGURE 1 The judgment bias task. (a) Go/No-Go task with tone cues used by Harding et al. (2004). Adapted with permission. Discrimination training: P = On hearing the CS + tone, rats learned to press the lever for a reward; N = On hearing the CS- tone, rats learned not to press the lever to avoid a negative outcome; ? = the response variable, a higher proportion or speed of responses to ambiguous probes suggests a more optimistic judgement bias. (b) Go/No-Go task with location cues. P = approach the CS + for reward; N = do not approach the CS-, to avoid nonreward.

Paul et al., 2005). Good welfare requires the presence of positive states and a low occurrence of negative states (Boissy et al., 2007; Dawkins, 1990; Fraser & Duncan, 1998). In humans, positive emotions are associated with positive judgment biases; therefore, in animals, it is possible that positive judgment biases reflect positive emotions.

Moreover, the measurements may identify discreet emotions. In humans, anxiety is associated with an increased expectation of negative events, and depression is associated with both an increased expectation of negative events and decreased expectation of positive events (Eysenck et al., 2006). Changes in response to ambiguous cues to reward and ambiguous cues to nonreward may allow us to distinguish different emotion states in animals (Bethell & Koyama, 2015; Mendl et al., 2009).

The measurements also provide an inroad to assessing subjective feeling states in animals. Judgment—and other cognitive—biases provide an objective measure of emotion that is associated with subjective human experience (Fox, Cahill, & Zougkou, 2010; Mogg et al., 1995). The basic emotions are evolutionarily old survival mechanisms that arise from highly conserved brain structures that drove survival and reproduction throughout species' evolution (fear facilitates predator avoidance, attraction facilitates mating; Darwin, 1872; LeDoux, 1996). In the absence of evidence to the contrary, it is parsimonious to consider species who exhibit precursor processes that underlie subjective experience in humans and may possibly experience subjective feeling states too (Paul et al., 2005).

In addition, the measurements distinguish emotion from arousal. Physiological measures such as corticosteroids measure arousal, but they do not distinguish arousal associated with positive emotions (e.g., excitement and exploratory behavior associated with foraging and mating activity or an enriched environment; Mendl, Burman, & Paul, 2010) from arousal associated with negative emotions (e.g., distress in fight or flight; Hemsworth, Mellor, Cronin, & Tilbrook, 2015; Selye, 1976). Cognitive bias tasks, by design, illicit responses that can be categorized as positive and negative, irrespective of level of arousal.

The measurements are sensitive to emotions not detected by behavioral measures. Behaviors may become dissociated from the underlying affective state (e.g., Higham, MacLarnon, Heistermann, Ross, & Semple, 2009), be hard to distinguish (e.g., few overt behaviors distinguish a contented resting animal from one who is depressed or has learned helplessness), or only reflect extreme levels of suffering (e.g., stereotypies). Judgment bias may detect more subtle shifts in emotions that lack distinguishable behavioral indexes.

The measurements are also advantageous because they allow a-priori hypotheses and predictions. Judgment bias tasks provide an opportunity to make a-priori predictions about responses following affect manipulations, which could provide a useful means of assessing the effectiveness of husbandry interventions to improve mood state. (For example, improved housing, social introductions, and therapeutic drugs should all lead to more optimistic judgment bias.) A positive shift in judgment bias (i.e., more positive responses to one or more ambiguous probes) would allow staff to monitor improvements (or, by contrast, deterioration) in emotional or psychological state.

Cognitive bias measurements should be adaptable for all species. There is an adaptive benefit for all organisms to distinguish rewarding stimuli from dangerous stimuli (Nettle & Bateson, 2012). With careful design, the task should be adaptable to any animal species. The test has particular value as a tool to assess emotion in taxa for which measures of emotion do not currently exist, are limited, are considered too difficult to study, or are simply ignored due to our

anthropocentric approach to the study and attribution of animal emotions (Morris, Knight, & Lesley, 2012) and cognitive abilities (Eddy, Gallup, & Povinelli, 1993).

The measurements also provide a generalizable measure across species and contexts. Outcome measures from the judgment bias task may be generalizable across species and settings. This generalizability would allow for comparison of emotion states of the same species across different captive environments and between different species in similar settings and would improve our understanding of species similarities and differences in emotion and cognition.

There are clear theoretical arguments for developing cognitive bias measures such as the judgment bias task. These measures should improve our understanding of animal emotions within and across taxa.

METHODS TO MEASURE JUDGMENT BIAS

Well-designed operant tasks—such as those developed by Harding et al. (2004)—can be used to measure an animal’s judgment bias by “asking” them whether they expect positive or negative outcomes following certain behaviors. Three types of judgment bias tasks have been developed.

Go/No-Go Task (+ , -)

The Go/No-Go task, using tone cues, has been adapted for use with dogs (Starling, Branson, Cody, Starling, & McGreevy, 2014) and pigs (Douglas, Bateson, Walsh, Bédoué, & Edwards, 2012; Table 2). Starling et al. (2014) developed an automated test and found individual differences in rates of discrimination training (9–33 sessions) and judgment bias in dogs who were categorized on a scale from “optimistic” to “pessimistic.” Douglas et al. (2012) developed a judgment bias test using tones for pigs and validated it using environmental enrichment. Enrichment led to a positive shift in judgment bias, suggesting enriched pigs were more optimistic.

The Go/No-Go task, using spatial cues (Burman, Parker, Paul, & Mendl, 2008a; Figure 1b), has been more widely adopted. Animals are trained to approach one location for food and to avoid approaching another location that has no food, unpalatable food, or some other mildly aversive reinforcer. Tendency and speed to approach the intermediate probe locations are then tested. The Go/No-Go task with spatial cues has been developed for use with goats, pigs, sheep, horses, dogs, cats, mice, hamsters, rats, and chickens (Table 2). For each of these animal groups, there is at least one study reporting judgment bias effects.

In two studies with sheep, location cues were combined with color cues (Verbeek, Ferguson, de Monjour, & Lee, 2014; Verbeek, Ferguson, & Lee, 2014). In both studies, mood was manipulated with food restriction and so the CS + and the CS– were social companions and a dog, respectively, avoiding confounding effects of hunger on the reward value of the CS+. In a third study with sheep, Vögeli, Lutz, Wolf, Wechsler, and Gygax (2014) positioned an air blower behind the “negative” location. It was left on through all trials and provided an additional cue to the location of the CS–. In most studies, however, spatial location is used without any additional cues.

The Go/No-Go task has also been developed with visual cues—usually lids that cover a container concealing either food or an unpalatable item—and lines of different length (primates, Bethell, Holmes, Maclarnon, & Semple, 2012a), and predator shapes (chicks, Hymel & Sufka, 2012) have also been used. This version of the Go/No-Go task has been developed with cattle,

TABLE 2
Published Studies of the Judgment Bias Task Arranged by the Six Major Animal Classes

Animal Group/Species	Test Design	Cues	Resp.	Training Session Days (n Trials)	Training Accuracy	Setting	References	N
Mammals (26*) Artiodactyla (even-toed ungulates) <i>Capra hircus</i> Goat			App.	3 (18)	Latency (+ < -)	D	Briefer & McElligott, 2013	18
<i>Bos taurus</i> Dairy cattle			App.	> 16 (> 368)	85% × 3 days	U	Daros, Costa, von Keyserlingk, Hörzel, & Weary, 2014	13
			Nose	> 50 (> 850)	90%	U	Neave, Daros, Costa, von Keyserlingk, & Weary, 2013	8
<i>Sus scrofa</i> Pigs			App.	6 (66)	Latency (+ < -) × 5 days	U	Düppjan, Ramp, Kamitz, Tuchscherer, & Puppe, 2013 ^x	30
			App.	30 (105)	Latency (+ < -) × 6 trials	F	Scollo, Gottardo, Contiero, & Edwards, 2014	40
			App.	16 (380)	80% (16/20)	F	Douglas, Bateson, Walsh, Béduc, & Edwards, 2012	10
			App.	30 (364)	80%	F	Murphy, Nordquist, & van der Staay, 2013 ^x Murphy, Kraak, van den Broek, Nordquist, & van der Staay, 2015	15 16

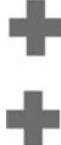
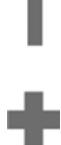
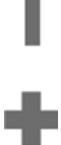
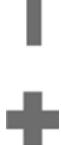
<i>Ovis aries</i> Sheep				App.	18 (76)	10/10 × 2 days	F	Destrez, Deiss, Leterrier, Calandrea, & Boissy, 2014 Destrez et al., 2013	30
				App.	> 15 (> 69)	Feed from positive bucket	F	Doyle, Hinch, et al., 2011 Destrez, Deiss, Belzung, Lee, & Boissy, 2012	26
				App.	< 36 (< 180)	Prop (binomial)	F	Guldimann, Vögeli, Wolf, Wechsler, & Gyga, 2015	24
				App.	> 15 (> 67)	App. 9/12 “+” in < 10 s; No-go 6/8 “-” buckets × 4 days	U	Doyle, Fisher, Hinch, Boissy, & Lee, 2010 Doyle, Lee, et al., 2011 Sanger, Doyle, Hinch, & Lee, 2011	20
				App.	30 (45)	20/20 × 4 days	U	Doyle, Vidal, et al., 2010	17
				App.	23 (> 85)	25/25 × 5 days	F	Verbeek, Ferguson, de Monjour, & Lee, 2014 Verbeek, Ferguson, & Lee, 2014	41
				App.	30 (> 150)	15/15 × 3 days	F	Vögeli, Lutz, Wolf, Wechsler, & Gyga, 2014	24
				App.	6 (24)	Latency (+ < -, p < .05) × 2 days	F	Freymond et al., 2014	12

Perissodactyla (odd toed ungulates)

Equus caballus

Horse – mares

TABLE 2 – continued

Animal Group/Species	Test Design	Cues	Resp.	Training Session Days (n Trials)	Training Accuracy	Setting	References	N
Carnivora <i>Ursus arctos</i> Grizzly bear			Nose vs. paw press	35–50 (> 1530)	90%	U	Keen et al., 2014 ^x	8
<i>Canis familiaris</i> Domestic dog			App.	1 (15–61)	All latencies to “+” < any latencies to “-” on last 6 trials (3+; 3-) or last 10 trials (5+; 5-)	D	Titulaer, Blackwell, Mendl, & Casey, 2013 ^x Karagiannis, Burman, & Mills, 2015; Walker, Waran, & Phillips, 2014 ^x	53 12
			App.	2 (< 140)	All latencies to “+” < any latencies to “-” on last 6 trials (3+; 3-) or last 10 trials (5+; 5-)	D	Mendl, Brooks, et al., 2010; Müller et al., 2012 ^x	23–24
			App.	1 (21–45)	All latencies to “+” < any latencies to “-” on last 6 trials (3+; 3-) or last 10 trials (5+; 5-)	D	Kis, Hermádi, Kanizsár, Gácsi, & Topál, 2015	64
<i>Felis sylvestris</i> Domestic cat			App.	3 (90–220)		U	Burman et al., 2011	12
			Nose	9–33 (< 1,986)	80%	D	Starling, Branson, Cody, Starling, & McGreevy, 2014	40
			App.	6–12 (72–144)	Latency (+ < -, p < .05) × 2 days	D	Tami, Torre, Compagnucci, & Manteca, 2011	9

Primates <i>Callithrix jacchus</i> Marmoset		Flip lid	10–22 (200–440)	85% × 3 days	U	Gordon & Rogers, 2015	12
<i>Macaca mulatta</i> Macaque		Visual (line length) Hand touch target	19–43 (1,678–2,666)	70% × 3 days	U	Bethell, Holmes, MacLarnon, & Semple, 2012a	7
<i>Cebus apella</i> Capuchin		Visual (line length) Hand touch target	14 (210)	14/18 × 3 days	U	Pomerantz, Terkel, Suomi, & Paukner, 2012	12
Rodentia <i>Mus sp</i> Laboratory mouse		App.	3 (13) 4 (21)	Latency (+ < -, $p < .05$) on all trials on day 3	U	Kloke et al., 2014	50
		App.	5 (25)				
		App	8 (12)	Latency to eat (+ < -, $p < .05$) (group 1 level analysis)		Bolejj et al., 2012	100
<i>Mesocricetus auratus</i> Hamster		App.	64%–84%	Latency (+ < -) × 3 days	U	Bethell & Koyama, 2015	24
<i>Rattus norvegicus</i> Rat		App.	6 (72)	Latency (+ < -, $p < .05$) on day 6	U	Burman, Parker, Paul, & Mendi, 2008a	24
		App.	5 (25)	Latency (+ < -, $p < .05$) on day 2	U	Burman, Parker, Paul, & Mendi, 2009	24
		App.	6–10 (37–85) 17–28 (180–376)	Latency (+ < -, $p < .05$) × 2 days	U	Richter et al., 2012 Wheeler, Swan, & Hickman, 2014	24 42

TABLE 2 – continued

Animal Group/Species	Test Design	Cues	Resp.	Training Session Days (n Trials)	Training Accuracy	Setting	References	N
			Press lever	> 12	50% × 3 days	U	Harding, Paul, & Mendl, 2004	9
		Sandpaper of different grades	App.	> 10 (> 40)	3/4 trials/day × 4 days	U	Chaby, Cavigelli, White, Wang, & Braithwaite, 2013	12
			App.	> 25 (> 62)	3/4 trials/day × 5 days	U	Brydges, Leach, Nicol, Wrights, & Bateson, 2011	12
			Lever press	33 (> 1,400)	Performance significantly greater than chance (binomial test) × 3 days	U	Parker, Paul, Burman, Browne, & Mendl, 2014	16
			Lever press	> 16 (315)	70%	U	Enkel et al., 2010	16
			Lever press	< 62 (< 6,200)	80% × 2 days	U	Anderson, Munafo, & Robinson, 2013 ^x	20
			Lever press	3–36 (120–1,440)	70% × 3 days	U	Papciak, Popik, Fuchs, & Rygula, 2013; Rygula, Golebiewska, Kregiel, Kubik, & Popik, 2015; Rygula, Papciak, Popik, 2013; Rygula, Papciak, & Popik, 2014; Rygula, Pluta, & Popcik, 2012; Rygula, Szczech, et al., 2015; Rygula, Szczech, Papciak, Nikiforuk, & Popik, 2014	26–80

Birds (23*) Passeriformes <i>Sturnus vulgaris</i> Starlings			Flip lid	> 3 (> 48)	90%	U	Bateson & Matheson, 2007	6
			Flip lid	> 21 (> 366)	Latency (+ < -, $p < .05$)	U	Brirot, Asher, & Bateson, 2010	8
		Flashing colored lights	Peck light	33 (1,782)	68%–84%	U	Matheson, Asher, & Bateson, 2008	8
Galliformes (Fowl) <i>Gallus gallus</i>			App.	> 18 (> 198)	5 s faster app. “+” than “-”	U	Wichman, Keeling, & Forkman, 2012 ^x	25
		Predator shapes	App.	< 26 (< 123)	2 s faster app. “+” than “-” averaged across sessions	U	Seehuus, Mendl, Keeling, & Blokhuis, 2013	24
			App.	2 (2)	NA	U	Salmeto et al., 2011	40
Invertebrates (> 40*) <i>Apis mellifera</i> Bee		Odor	App.	1 (12)	NA	U	Bateson, Desire, Gartside, & Wright, 2011	147
			App.	2 (2)	NA	U	Hymel & Sufka, 2012	10–99
			App.	> 24 (> 82)	90%	U	Hernandez, Hinch, Lea, Ferguson, & Lee, 2015 ^x	20

TABLE 2 – continued

<i>Animal Group/Species</i>	<i>Test Design</i>	<i>Cues</i>	<i>Resp.</i>	<i>Training Session Days (n Trials)</i>	<i>Training Accuracy</i>	<i>Setting</i>	<i>References</i>	<i>N</i>
Reptiles (4*)							No published studies	
Amphibians (3*)							No published studies	
Fishes (~60*)							No published studies	

Note: *Approximate number of orders within the class. Mammals, birds and invertebrates are represented; reptiles, amphibians, and fishes have yet to be tested.
Test design: — Go-Nogo task; Active choice test, with positive reinforcement; Go-Go test, with negative reinforcement; Cues: spatial location task (*n* locations indicated); lids of different shades (*n* shades indicated); spatial location combined with different shades; tones of different frequency (*n* tones indicated); other cue types given as text.

Response: App. = approach to within a specified distance of the cue; nose = poke target with nose; nose vs. paw press = bears were trained to press one color target with their noses and the other target with a paw; flip lid = remove lid from container using any body part (beak, hand); hand touch target = touch target with hand or paw—typically on a touch-sensitive monitor; lever press = press an automated lever; peck light = birds were trained to peck lights of different colors.

Training days: indicative of number of daily training sessions required to reach criterion (*n* trials in parentheses).
Training accuracy: predetermined criterion for completing training as reported in “Methods” section, or training accuracy reached as reported in “Results” section.
Setting: D = domestic settings and rescue shelters; F = farming and agricultural settings; U = University and other research laboratories. ^xNo reported influence of affect manipulation on judgement bias.

dogs, primates, chicks, and starlings (Table 2), and all these studies showed evidence for judgment bias in the species tested.

Despite its widespread use, a criticism of the Go/No-Go task is that a “no go” may reflect any one of a number of different underlying processes including arousal, distraction, confusion, or lack of motivation from reduced hunger or thirst (Mendl et al., 2009).

Active Choice Task With Positive Reinforcement (+ , +)

A second type of judgment bias task, the active choice task, was developed to address problems of interpretation in the Go/No-Go task. Animals are trained to discriminate cues signaling high reward (CS +) or low reward (CS–) and are then tested on their responses to intermediate cues. The active choice task is more robust because the two responses (go) are equivalent and should not be differentially affected by changes in arousal, which is a problem for the Go/No-Go task. The active choice task has been developed for use with pigs (tone cues, Murphy, Kraak, van den Broek, Nordquist, & van der Staay, 2015), grizzly bears (colored lid cues, Keen et al., 2014), capuchin monkeys (visual length cues, Pomerantz et al., 2012), rats (tone cues, Parker, Paul, Burman, Browne, & Mendl, 2014; sandpaper cues, Brydges, Hall, Nicolson, Holmes, & Hall, 2012; Chaby, Cavigelli, White, Wang, & Braithwaite, 2013), starlings (flashing light cues, Matheson, Asher, & Bateson, 2008), and laying hens (colored lid cues, Hernandez, Hinch, Lea, Ferguson, & Lee, 2015). Evidence for an effect of emotion manipulation on judgment bias was reported in all studies except for the study by Hernandez et al. (2015).

Potential problems with the active choice task with positive reinforcement are that it may be more difficult to train animals to discriminate between the CS + and CS– (both are rewards), and although the test may be suitable for detecting shifts in judgments about possible future rewards, it may not be suitable for detecting shifts in judgments about possible future neutral or negative events (Mendl et al., 2009).

Active Choice Task With Negative Reinforcement (+ Z)

A third type of judgment bias task is the active choice task with negative reinforcement (e.g., electric shock; Rygula, Papciak, & Popik, 2014). Animals are rewarded for responses to the CS + , but responses to the CS– are now negatively reinforced so that animals “go” to the CS– to stop the onset of a negative reinforcer. Negative reinforcement is generally not suitable for welfare studies, but the results from this third approach, so far conducted with rats undergoing pharmacological manipulations (Table 2), concur with data from the Go/No-Go and active choice (reward–reward) tasks. Pharmacological studies using negative reinforcement are included in Table 2 for reference but are not discussed further for designing welfare studies.

Table 2 lists the 64 peer-reviewed studies of judgment bias that were available for download in April 2015, ordered by animal group, type of task, and cues used. These studies show that (a) animals in a putatively more positive emotion state display a more positive judgment bias for ambiguous cues than animals in a putatively more negative emotion state (55 studies reported finding some evidence for judgment bias); (b) judgment biases may be reliably measured using well-designed studies with species-specific protocols; (c) these biases exist in a range of animal taxa including mammals (54/64 studies), birds (9 studies), and an invertebrate (1 study); (d) only rats and sheep have been extensively studied (17 and 12 studies, respectively); (e) sample sizes are often modest (on average ~26; range = 6–147); (f) amount of discrimination training

needed and training accuracy vary greatly between species and research groups (range = 1–62 days of training; 50%–80% accuracy); (g) judgment bias has not been tested in any species of fish, amphibian, or reptile; (h) few studies have examined “exotics” (1 study with grizzly bears; 3 with nonhuman primates); and (i) no study has been conducted in a zoo or aquarium.

PROBLEMS AND PITFALLS

As the number of studies applying the judgment bias task has increased, issues in terminology, design, and interpretation have arisen. First, researchers use terms such as “optimistic bias” (Matheson et al., 2008) and “pessimism” (Bateson & Matheson, 2007) to describe changes in responses to the probes. However, the judgment bias task does not yet include a baseline against which to assess whether responses reflect categorically positive or categorically negative states. As a result, the task may therefore be less robust for measuring shorter-term emotions than longer-term moods.

In addition, experiments using longer-term affect manipulations showed mood-congruent shifts in judgment bias (e.g., Harding et al., 2004). Studies using shorter-term, acute stressors showed varying patterns. Doyle, Fisher, Hinch, Boissy, and Lee C (2010) and Sanger, Doyle, Hinch, and Lee (2011) tested sheep after restraint for sheering and found a positive shift in judgment bias, suggesting the task captured animals’ relief at the termination of the stressor.

Moreover, the order in which affect manipulations are conducted can influence results. Bateson and Matheson (2007) and Douglas et al. (2012) found that when animals were moved from enriched to standard housing, there was a pronounced negative shift in judgment bias. When animals were moved from standard to enriched housing, there was no shift or a much reduced shift in the other direction in starlings and pigs, respectively. Recent experience may therefore influence current performance.

Another issue is that animals often learn that the ambiguous probes are not rewarded over time. Doyle, Vidal, et al. (2010), Starling et al. (2014), Scollo, Gottardo, Contiero, and Edwards (2014), and Bethell and Koyama (2015) found that sheep, dogs, pigs, and hamsters, respectively, approached ambiguous probes less over repeated testing sessions. The task may therefore not be suitable for frequent or sustained testing.

A change in responses to the conditioned stimuli creates problems for interpreting responses to the probes. In Harding et al. (2004), rats in poor housing responded less to the CS + and the probes closest to it. Bees who had undergone a simulated predatory attack showed a reduction in responses to the CS– as well as the probe next to it (Bateson, Desire, Gartside, & Wright, 2011). In both cases, alternative explanations such as changes in food motivation, arousal, learning, memory, or risk-taking behavior cannot be ruled out.

Finally, early life experience and individual differences influence judgment bias. Brydges et al. (2012) found stress during the juvenile phase influences judgment bias in adult rats. Rats were trained on an active choice task with positive reinforcement. Female rats were faster to learn the discrimination task than male rats. Rats of both sexes who had experienced early life stress showed an (unpredicted) optimistic bias, suggesting sex and early life experiences can impact judgment bias as can confounding effects of impulsivity and risk-taking behavior by lighter-bodied animals in a foraging context. Briefer and McElligott (2013) found positive judgment bias in female, but not male, goats who had experienced former neglect. Starling et al. (2014) found variations in optimism and pessimism between dogs of different breeds. Gordon and Rogers (2015) found left-handed marmosets had a more negative judgment bias than right-handed marmosets.

The picture emerging is complex, but with further development, the judgment bias method should provide new insights and streamlined tools for assessing animal welfare. Probably the greatest value of cognitive bias measures for welfare will be in developing an individual animal’s profile and, using infrequent tests, assessing changes in judgment bias over time. Although we cannot yet identify categorically positive or negative emotion states, we can, at least, track shift in bias over time—identifying animals in downward or upward spirals. In the following sections, I apply the current state of knowledge to designing controlled judgment bias tasks for use with species who have yet to be tested.

HOW TO DESIGN A JUDGMENT BIAS STUDY: A STEP-BY-STEP GUIDE APPLIED TO FISH, AMPHIBIANS, AND REPTILES

Figure 2 presents a roadmap for designing judgment bias tasks (left column) with a worked example of the decision process applied to hamsters (middle column) and recommendations for designing studies with fish, amphibians, and reptiles (right column). For researchers designing studies with mammals, birds, or invertebrates—especially exotics in these categories—**Table 2** provides a breakdown of test design, cues, and response modalities tested to date, with information on training duration and training criteria that may be useful for planning.

Purpose

Is your purpose to (a) develop a protocol and validate the judgment bias task for use with your chosen species, or (b) refine your protocol to assess changes in emotion? The former usually requires an experimental emotion manipulation. Include additional tests to assess alternative explanations and identify confounds. Manipulations may include testing before and after disruptive handling procedures (examples for fish include Ashley, 2007; Brydges, Boulcott, Ellis, & Braithwaite, 2009) or enrichment (fish, Schroeder, Jones, Young, & Sneddon, 2014; reptiles and amphibians, Burghardt, 2013). Behavioral indicators of affect may include aggression, redirected activities, stereotypies, displacement behaviors, weight change, and change in skin color (fish, Ashley, 2007; reptiles, Silvestre, 2014). Consider the possible influence of sex, age, weight, and early life experience. Use a cross-over design to control for order of testing (e.g., Bateson & Matheson, 2007).

Assess the speed at which animals learn that probes are never rewarded with repeated trials over days or weeks (e.g., Doyle, Vidal, et al., 2010). Changes in motivation can be assessed by looking for reduced responding to the CS + or consumption of reinforcers. A change in responses to the CS+ or CS– may indicate a change in memory, motivation, arousal, or impulsivity, rather than changes in judgments about ambiguity. Additional indicators of arousal may include glucocorticoid levels and locomotion (fish, Ashley, 2007; reptiles, Silvestre, 2014).

Assess response to novelty. Brydges et al. (2012) measured neophobia in sticklebacks, bishops, and trout by placing fish in a tank with a bright plastic toy and recording the distance of the fish to the toy every 20 s for 10 min. Fish who spent more time away from the novel toy were considered more fearful. Because probes are novel stimuli, it is important to understand how your species responds to novelty. Finally, include at least three probes. Studies showed changes in responses at the different probes, and this may reflect different emotions associated with reward and nonreward (e.g., Bethell & Koyama, 2015).

"How-to" suggestions: fish, amphibians and reptiles	
<p>Decision tree</p> <p>Purpose?</p>	<p>Example decision process¹</p> <p>Purpose: develop and validate with hamsters.</p> <ul style="list-style-type: none"> • Emotion manipulation: enrichment. • Habituation and discrimination training: 4 weeks to maximize discrimination learning. • Testing: repeated over 2 weeks to investigate learning effects. • Control trials: to control for arousal and food motivation. • 3 intermediate probe locations enhanced chances of detecting an effect. • Additional tests: Open field, light-dark emergence and "novel" object to control for exploration, risk-taking behavior and neophobia. Locomotion score during testing to assess arousal. <p>Considerations:</p> <ul style="list-style-type: none"> • Emotion manipulation – robust, maintained. • Learning criterion achieved during training. • Task remembered during testing (control trials). • Motivation maintained (control trials; Do animals consume less of the CS+?; changes over time?). • Arousal (control trials, additional tests). • Response to novelty (neophobia tests). • Multiple probes; responses to probes closest to the CS+ may reflect different emotions than do responses to probes closest to the CS- (>3 probes). <p>Future directions: develop refined, quick, easy tasks including streamline designs with in-housing automated systems² and naturalistic stimuli.³</p>
<p>Which type of task?</p>	<p>Utilize species' natural preferences in task design.</p> <p>Fish exhibit natural preferences for foods, social contact and substrates,^{4,6} and show aversion to some tastes, falling stones, net trawl, colors, social and predatory cues.^{4,7} Some ability to count.⁸</p> <p>Amphibians exhibit natural preferences for some foods, social cues and environmental complexity,⁹⁻¹¹ and aversion to some social cues.¹⁰ Some ability to count.¹²⁻¹³</p> <p>Reptiles exhibit natural preferences for foods and social contact^{9,14} and show aversion to some social cues¹⁴ (anecdotal numerical skills⁹).</p> <p>Future directions: Active choice tasks (+ +) discriminating between secondary reinforcers* signalling high versus low rewards may be possible utilizing species' innate preferences and rudimentary numerical abilities.</p>

<p>Decision tree</p> <p>Example decision process¹</p> <ul style="list-style-type: none"> Literature review revealed hamsters reliably learn to discriminate spatial locations. Reward, non-reward, and intermediate locations were spaced to be perceptually distinguishable (distance between CS+ and CS- was ~1m). We removed potential odor cues from reinforcers with unreinforced control trials (alternative solutions could be food present but inaccessible,²² or rewards delivered to a central feeder after the response is made).²³ <p>Future considerations: Data were lacking for hamster color vision, hearing, touch and olfaction. Data from other rodent species suggest it may be worth exploring these cues in the future.</p>	<p>“How-to” suggestions: fish, amphibians and reptiles</p> <p>There are published protocols for training on discrimination tasks using visual, auditory, tactile and olfactory cues:</p> <p>Fish: Visual stimuli (e.g., geometric shapes, line length, quantities and some colors: zebrafish,⁴ sharks,⁵ mosquitofish).¹⁶ Auditory (sound-pressure) stimuli differing in frequency or tempo (elephantfish,¹⁷ carp).¹⁸</p> <p>Amphibians: Visual stimuli (e.g., black vs. white prey: toads;¹¹ quantity of prey: salamanders).¹² Auditory (sound-pressure) stimuli differing in pulse rate (frogs).¹⁹</p> <p>Reptiles: Visual stimuli (e.g., shades and colors: lizards,²⁰ turtles).²¹</p> <p>Future directions: Somatosensory and chemosensory senses, and naturalistic stimuli, are important. It is worth considering acknowledging species differences in perceptual abilities.²⁰</p> <p>Use natural responses to reward or threat, such as approach and feeding gestures:</p> <p>Fish can be trained to swim to reinforced locations. This is quicker and just as accurate as training to press a lever for food.¹⁶</p> <p>Amphibians “snap mouth” when food is expected (toads)¹¹ and “nose tap” pellets when social information is expected (salamanders).¹⁰</p> <p>Tortoises can learn to use touch-screens.²⁴ “Tongue-flick rate” may indicate expectation of food in lizards.²⁵</p>
<p>Which response?</p> <p>Manual data collection for frequency and latency to approach.</p> <p>Criterion for an “approach” was to move to within a few millimeters of the drinker.</p> <p>Future considerations: Training animals to approach a location, touch a target or flip a lid to directly access a reward (the primary reinforcers*) may require fewer trials than training animals to associate rewards with other types of secondary reinforcers* (e.g., a tone).</p>	<p>1. Bethell & Koyama (2015); 2. M. Mendi, personal communication, June 24, 2015; 3. Briot et al. (2009); 4. Blaser & Viri (2014); 5. Fuss & Schluessel (2015); 6. Schroeder et al. (2014); 7. Gerbi et al. (2009); 8. Agrillo & Bizassa (2014); 9. Burghardt (2013); 10. Jaeger & Forester (1993); 11. Jenkin & Laberge (2010); 12. Krusche et al. (2010); 13. Strancker et al. (2015); 14. Scott et al. (2013); 15. Lopez et al. (2014); 16. Agrillo et al. (2012); 17. Marvit & Crawford (2000); 18. Zinn et al. (2010); 19. Bee (2015); 20. Martin et al. (2015); 21. Leighty et al. (2013); 22. Wheeler et al. (2014); 23. Bethell et al. (2014); 24. Mueller-Paul et al. (2014). * glossary terms</p>

FIGURE 2 Judgment bias decision tree. The left-hand column shows a decision tree for designing a judgment bias task. The central column shows a worked example of how decisions were made in a study with hamsters. The right-hand column contains suggestions for designing judgment bias tasks with fish, amphibians, and reptiles. Note: Animal silhouettes downloaded from <http://www.PublicDomainPictures.net>

Type of Task

The majority of published studies used the Go/No-Go task (45/64; [Table 2](#)), indicating this may be the easiest to develop initially. Natural preferences for certain foods and situations can be co-opted for these tasks (e.g., zebrafish exhibit light and substrate color preferences, possibly shaped by early life experience, [Blaser & Vira, 2014](#); fire-bellied toads prefer lepidopteran larvae over other foods, depending on the season, [Jenkin & Laberge, 2010](#)). Evidence for rudimentary numerical abilities in fish (e.g., [Agrillo & Bisazza, 2014](#)), amphibians (e.g., [Krusche, Uller, & Dicke, 2010](#)), and reptiles (e.g., [Burghardt, 2013](#)) suggest active choice tasks with positive reinforcement could be developed with these taxa.

Cues

Most published studies used visual, location, and auditory cues ([Table 2](#)). [Figure 2](#) summarizes a number of studies in which fish, amphibians, and reptiles have been trained to discriminate visual and auditory cues. Fire-bellied toads were trained to discriminate video footage of black prey (crickets) from video of white prey ([Jenkin & Laberge, 2010](#)). Toads were rewarded (with a live cricket presented at eye level) for snapping at one video (CS+) but not for snapping at the other video (CS-). Toads took part in one 5-min trial per day, conducted at 3- to 4-day intervals, and learned the discrimination task within six (black-cricket group) or nine (white-cricket group) sessions. It would be small steps to include intermediate (grey) prey cues or to introduce unpalatable food for incorrect snaps to the CS-.

Touch and smell cues may also be appropriate for development. Fish ([Marvit & Crawford, 2000](#); [Zion, Karplus, & Barki, 2010](#)) and frogs ([Bee, 2015](#)) have been successfully trained to discriminate sound-pressure cues. [Zion et al. \(2010\)](#) trained carp to discriminate between two acoustic stimuli that differed in frequency and temporal pattern. Fish were rewarded for approaching a feeder when one tone (CS+) was played but not when the other (CS-) was played. Fish were played 36 trials per day (3 CS+ and 33 CS-) and learned the discrimination task in 21 days, but failed to learn on a schedule with fewer daily trials.

Response

Fish, amphibians, and reptiles have a number of behaviors they exhibit when anticipating food: Toads snap ([Jenkin & Laberge, 2010](#)) and lizards tongue-flick ([López, Ortega, & Martín, 2014](#)); salamanders nose-tap pellets they expect to contain useful chemosensory information (e.g., food, conspecifics; [Jaeger & Forester, 1993](#)). [Mueller-Paul et al. \(2014\)](#) successfully trained two juvenile tortoises to use a touch screen, taking a minimum of 15 sessions to learn to touch a single stimulus, although two other tortoises failed to learn the basic task.

Resources and Reviews

Reviews of cognitive theories of emotion present the rationale for using cognitive bias measures and discuss limitations and future directions ([Mellor, 2015](#); [Mendl et al., 2009](#); [Mendl & Paul, 2004](#); [Ostovic & Hutchinson, 2015](#); [Paul et al., 2005](#)). For researchers designing studies, there are a number of taxa-specific reviews (pigs, [Murphy, Nordquist, & van der Staay, 2014](#); rodents, [Hales, Stuart, Anderson, & Robinson, 2014](#); dogs, [Rayment, De Groef, Peters, & Marston, 2015](#); dogs and horses, [Starling, Branson, Cody, & McGreevy, 2013](#); farm livestock, [Baciadonna &](#)

McElligott, 2015; insects, Mendl, Paul & Chittka, 2011). Studies that review cognitive bias in the context of animal models of human psychopathology discuss the effect of pharmacological manipulations on cognitive processes and may be useful for designing studies around veterinary interventions (Cocker & Winstanley, 2015; Hales et al., 2014). For designing studies with as-yet unstudied taxa, Burghardt (2013) provided a recent review of reptile and amphibian cognition; and Braithwaite, Huntingford, and van den Bos (2013), Broglio, Rodriguez, and Salas (2003), and Brown, Laland, and Kruse (2008) provide good reviews of fish cognitive abilities.

Other Cognitive Bias Methods

I have focused on the judgment bias task because of the breadth of data available. A number of other cognitive bias measures are worthy of further exploration: attention biases, or innate biases in attention to biologically relevant stimuli (macaques' attention to facial expressions, Bethell et al., 2012b; starlings' attention to eye spots, Brilot, Normandale, Parkin, & Bateson, 2009; parrots' attention to a human observer, Cussen & Mench, 2014; sheep's attention to food, Verbeek, Ferguson, & Lee, 2014; for earlier discussion, see Mendl et al., 2009; Paul et al., 2005); expectancy biases, akin to optimism and pessimism regarding future events (rats, van der Harst, Baars, & Spruijt, 2003); and reward sensitivity, or susceptibility to despondency following loss or failure (rats, Burman et al., 2008b; Mendl et al., 2009). These processes likely feed into judgment biases and are worthy of more focused study in themselves.

CONCLUSION

In summary, the judgment bias task has been adapted to study emotion in a number of mammals and birds and an invertebrate, in domestic, research, and agricultural settings. Judgment bias has not yet been tested in many exotics, and in no species of fish, amphibians, or reptiles, nor has it been used in a zoo. In the first decade of judgment bias studies, investigators focused on identifying whether manipulations presumed to be negative (e.g., restraint) or positive (e.g., enrichment) lead to a change in judgment bias, while proving the concept and identifying appropriate cues and test designs for different species. Challenges for the next decade are to refine methods for working with small groups (e.g., high conservation-status individuals), to develop quicker and easier methods to assess welfare in real-world captive situations, and to validate the test for understudied groups such as the fishes, amphibians, and reptiles; data from these taxa may prove to be the most fruitful use of the judgment bias task yet.

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