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Validation of a novel cognitive bias task based on difference in quantity of reinforcement for assessing environmental enrichment

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Abstract Cognitive bias tasks purport to assess affective states via responses to ambiguous stimuli. We hypothesized that a novel cognitive bias task based on positive reinforcement using quantity differences would detect changes in affect in captive grizzly bears (*Ursus arctos horribilis*). We trained bears ($n = 8$) to respond differently (nose or paw touch) to two stimuli (light or dark gray cue cards), with responses counterbalanced across bears. The two cues signaled a small or large food reward, respectively. Responses to ambiguous probe stimuli (i.e., shades of gray) intermediate to the trained stimuli were classified as either 'optimistic,' appropriate for the larger reward, or 'pessimistic,' appropriate for the smaller reward. In Experiment 1, we explored the contrast in reward size necessary to detect a change in response across probe stimuli (large reward, 3 or 6 apple slices: small reward, 1 slice). We observed a change in response across probe stimuli, with no difference in response between reward-value groups, indicating that a contrast of 3:1 apple slices was sufficient to affect responses. In Experiment 2, we investigated cognitive bias after 2.1 h of exposure to enrichment items varying in attractiveness. Results were unaffected by enrichment type or time spent interacting with enrichments, indicating that the task failed to demonstrate criterion validity for comparing mood following exposure to different enrichment items. However, greater time spent pacing prior to testing was associated with 'optimistic' judgments. The data provide some support for use of cognitive bias tasks based on quantity differences in animal welfare assessments involving captive wildlife.

Keywords Cognitive bias · Grizzly bear · Animal welfare · Affective state · Stereotypic behavior · Environmental enrichment

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Introduction

Cognitive bias refers to the interpretation of neutral stimuli in light of previous experiences and current emotional states. People tend to perceive novel stimuli as more positive when in a positive mood and more negative when in a negative mood. Cognitive bias can be subdivided into three components: attentional bias, memory bias, and judgment bias (Mendl et al. 2009). Attentional bias determines which stimulus (in whole or part) receives the most attention (Bower 1981; Lerner and Keltner 2000), whereas memory bias refers to the influence of current affective state on the type of memories that are recalled (Bower 1981; Duncan and Barrett 2007). Judgment bias refers to a skew in response to choice (Mendl et al. 2009). Putting it together, emotion directs attention toward a stimulus or its components, influences the retrieval of memories related to the stimulus or coping with the situation (Isen et al. 1978; Bower 1981), and influences the subject's judgment of what course of action should be taken to achieve the best possible outcome (Lerner and Keltner 2000; Mendl et al. 2009).

In the laboratory, cognitive bias is measured using tasks based on associative learning. Harding et al. (2004) were the first to report cognitive bias in animal subjects. In their task, rats were trained to press a lever in response to one auditory tone to access a food reward and to avoid the lever when presented with a different tone to prevent presentation of white noise (an aversive stimulus). The resulting task type is termed 'go/no-go.' Cognitive bias was then measured by presenting ambiguous tones (probe stimuli) between the two conditioned tones and recording the subject's response, categorized as either 'optimistic,' appropriate for the food reward, or 'pessimistic,' appropriate for avoiding the noise. In all 'go/no-go' tasks, an 'optimistic' response means that a subject responds as though expecting a positive outcome and is considered reflective of a positive affective state, whereas a 'pessimistic' response means that the subject responds as though expecting a negative outcome and is considered reflective of a negative affective state. In the human literature, optimistic and pessimistic judgments have been correlated to temperament (Lerner and Keltner 2000; Hansen and Jeppesen 2006; Haselton and Nettle 2006) and mood (Isen et al. 1978; Lerner and Keltner 2000; Siemer 2001). Most animal studies have focused on mood by testing subjects following exposure to experimental treatments ranging from hours (Burman et al. 2009, 2011; Doyle et al. 2010a; Bateson et al. 2011; Salmeto et al. 2011; Sanger et al. 2011; Boleij et al. 2012) to days or weeks (Harding et al. 2004; Bateson and Matheson 2007; Burman et al. 2008; Matheson et al. 2008; Brilot et al. 2010; Brydges et al. 2011; Doyle et al. 2011; Bethell et al. 2012; Richter et al. 2012).

Since Harding et al.'s (2004) original study, the topic of cognitive bias assessment in animals has received growing attention, resulting in several variations in the task, primarily using the 'go/no-go' strategy (Bateson and Matheson 2007; Burman et al. 2008, 2009, 2011; Doyle et al. 2010b, 2011; Enkel et al. 2010; Mendl et al. 2010; Bateson et al. 2011; Salmeto et al. 2011; Sanger et al. 2011; Bethell et al. 2012). However, the use of a 'go/no-go' task can reduce responding to probe stimuli over time, potentially from learning when reinforcement is and is not available (Doyle et al. 2010b). Lack of response to a probe stimulus then becomes difficult to interpret as it may no longer be related to mood state (Mendl et al. 2009) but, instead, may signify a tactic of 'playing it safe' or not wasting energy. With the growing popularity of cognitive bias tasks for assessing the affective experience of non-human animals, it is important to refine the methodology to eliminate ambiguity.

One improvement is to require an active response to both trained stimuli using positive reinforcement. The functionality of cognitive bias tasks based solely on positive reinforcement relies on there being an appreciable difference between the outcomes for each behavior. Brydges et al. (2011) and Pomerantz et al. (2012) achieved this using a difference in quality of food rewards. However, the tendency for tastes to be perceived differently over time as well as variation in individual taste preferences (Cabanac 1971; Berridge 1991; McCaughey 2008) led us to explore a task requiring discrimination of differences in food quantity rather than quality. This approach is supported by evidence of sensitivity to food quantity and counting ability across a variety of mammalian species (Hiestand and Davis 1996; Held et al. 2005; Beran et al. 2008; Vonk and Beran 2012). Previous cognitive bias studies using two amounts of food as positive reinforcers have yielded mixed results, but lack of success may have been due to difficulty of the discrimination task (Matheson et al. 2008) or insufficient contrast between rewards (Parker 2008 cited in Mendl et al. 2009). In the current study, therefore, we investigated the amount of contrast in reward size needed to detect differences in judgment across a range of ambiguous stimuli.

Another problem with previous tasks requiring discrimination between two food quantities may have been overexposure to unreinforced probe stimuli (ranging from 33 % unreinforced, Brilot et al. 2010, to 67 % unreinforced, Matheson et al. 2008), which presents an opportunity for learning which cues are not reinforced, resulting in extinction. To minimize this possibility, we presented only 10 % probe stimuli in each test session. Furthermore, because use of a secondary reinforcer slows extinction (Zimmerman 1957) without enhancing acquisition of a new behavior (Roberts et al. 1984; Smith and Davis 2008), we

used a secondary reinforcer (clicker) to preserve responding during probe trials without solidifying a specific response to those stimuli.

We explored the use of our novel cognitive bias task with captive grizzly bears (*Ursus arctos horribilis*). Although there is anecdotal evidence of tool use in brown bears (Deecke 2012) and evidence of counting ability (Vonk and Beran 2012) and concept formation (Vonk et al. 2012) in black bears, there is a lack of experimental evidence of other cognitive abilities in bears. Nevertheless, bears are generally considered to be highly intelligent, so we expected that they would have no difficulty learning the cognitive bias task used in this study.

Bears are prone to exhibiting high levels of stereotypic behavior in captive settings (Carlstead et al. 1991; Clubb and Mason 2003; Vickery and Mason 2005), prompting efforts to provide them with environmental enrichment (Carlstead et al. 1991; Carlstead 1998; McGowan et al. 2010). Evaluation of enrichment efforts in zoos has focused on changes in behavioral measures (e.g., time spent engaged in abnormal repetitive behaviors), changes in endocrine parameters, and changes in physical health and reproductive success (Carlstead and Shepherdson 1994; Newberry 1995; Swaisgood et al. 2001; Shepherdson 2003; Shepherdson et al. 2004; Swaisgood and Shepherdson 2005; Liu et al. 2006; Quirke and O'Riordan 2012). While these measures continue to be evaluated, their link to psychological well-being remains elusive (Swaisgood et al. 2001). There is a need for additional measures of the effectiveness of enrichment (Swaisgood and Shepherdson 2005), particularly ones that are quickly and easily implemented yet still reliable (Canino and Powell 2010; Quirke and O'Riordan 2012). We explored cognitive bias as an additional tool for gaining insight into the psychological well-being of captive wildlife that, if validated, could be relatively quick and practical to implement in zoos.

There is a need, in particular, to understand the link between stereotypic behavior and psychological well-being. Previous studies on captive starlings and capuchin monkeys have revealed a correlation between 'pessimistic' judgments on cognitive bias tasks and a high prevalence of stereotypic or abnormal repetitive behaviors (Brilot et al. 2010; Pomerantz et al. 2012). Pomerantz et al. (2012) concluded that the temporal relationship of stereotypic behavior (head twirling, specifically) with the cognitive bias response in their study supports an interpretation that the stereotypic behavior reflected the current affective state of the animals rather than an emotional 'scar' from previous welfare deficits (Mason and Latham 2004; Pomerantz et al. 2012). There remains the possibility that other stereotypies, such as pacing that may result from the motivation to seek stimuli such as food (Mason 1993; Carlstead 1998; Waitt and Buchanan-Smith 2001) or mates (Mason 1993), do not always stem from a negative affective state and therefore may not always result in a pessimistic judgment. Indeed, there was a lack of association between pacing and cognitive bias judgment in the study by Pomerantz et al. (2012).

The current study represents the first use of a cognitive bias task for assessing affect in captive large carnivores, particularly in relation to enrichment efforts and stereotypic behavior. We hypothesized that our novel cognitive bias task based solely on positive reinforcement would detect changes in optimism in grizzly bears. Our prediction was that bears would respond with increasing 'optimism' as ambiguous probe cues became more similar to the high reward stimulus, resulting in a positive linear trend across the probe stimuli. To explore the amount of contrast between reinforcers required to detect a change in response across probe stimuli, in Experiment 1, we contrasted one apple slice as the low-value reward against a high-value reward of either three or six apple slices. Experiment 2 explored the effect of different enrichment items on cognitive bias response in grizzly bears relative to the amount of time spent with the item and amount of stereotypic behavior expressed. We predicted that bears would respond more 'optimistically' to the central (most ambiguous) probe cue after receipt of an enrichment item with which they spent more time interacting [by giving the high-reward behavior more frequently than expected by chance (50 %)] and more 'pessimistically' to the central cue after longer periods engaged in stereotypic behavior (by giving the low-reward behavior more frequently than expected by chance).

Methods

General methods

Subjects and housing

Eight adult grizzly bears (*Ursus arctos horribilis*) from the Washington State University Bear Research, Education, and Conservation Center participated in this study. Bears were housed in pairs in 32-m² indoor/outdoor concrete-floored enclosures equipped with a hanging tire for enrichment and given daily access to a 0.81-ha semi-natural exercise yard, climbing frame, wooden logs, and water bath, with other socially compatible individuals. The facility was equipped with security cameras (Open Eye, Liberty Lake, WA, USA) such that all indoor dens, outdoor runs, and the sidewalk area leading to the yard were continuously recorded. An additional 'pan-tilt-zoom' camera could be remotely controlled from inside the facility to monitor activity in the yard.

The research took place during the active part of the year (April to August), with hibernation occurring in the winter months. Bears were fed two meals daily (primarily dry dog food pellets and apples) providing approximately 30 % of ad libitum intake, which was typical for non-lactating adult bears in the facility during spring and summer (McGowan et al. 2010), and gained some additional nutrients from foraging in the yard. Their daily ration of apples was fed during training sessions, and water was available ad libitum.

Stimuli

Five, 20.3 cm × 20.3 cm paper squares were shaded at 20, 35, 50, 65, and 80 % gray, respectively, using a basic word-processing program. They were mounted on cardboard squares with handles for ease of presentation and laminated for durability. The 20 and 80 % gray cues were the rewarded cues, and the three intermediate cues were the probe stimuli. At least two copies of each stimulus were used to ensure that bears responded to the gray shade of the cues rather than any inconsistencies in the printing of the stimuli or marks from use. Stimuli were cleaned each day and as needed so that no physical marks or scents were consistently present that might serve as extra cues.

Training

All training was conducted using protected contact and positive reinforcement techniques ('clicker training'). Four bears were trained to touch a light gray square (20 % gray) with their nose and a dark gray square (80 % gray) with their paw/foreleg. The other four bears were trained to perform these behaviors to the opposite cues. All correct behaviors were rewarded with one slice of apple approximately equal to ¼ of a small (<8 cm in diameter) apple. Incorrect behavioral responses to these cues resulted in a brief 'time-out' lasting approximately 3 s.

Bears received one training session per day. Each session consisted of 30 trials, comprising 15 presentations of each trained stimulus. An assistant handed the stimuli to the experimenter according to a predetermined pseudo-random order, with the constraint that no cue shade was presented more than 3 times in succession. Different stimulus orders were used for each bear each day, and stimulus orders were randomly assigned to each bear. The assistant recorded the response as being correct or incorrect, and all sessions were video recorded (example shown in Online Resource 1) for later verification and assessment of inter-rater reliability. Successful training was defined as five successive sessions at 90 % accuracy or greater.

After this first stage of training was complete, bears entered the 'reward-value' phase of training in which one behavior was rewarded at a higher level than the other, balanced across behavior and cue shade. The amount of contrast between rewards differed between experiments as outlined below.

Cognitive bias testing

Cognitive bias test sessions consisted of 30 trials, with one of the three intermediate shades of gray interjected in every ten trials according to a predetermined pseudo-randomization such that each intermediate cue was seen only once per session. To account for contrast effects, presentation of intermediate shades was balanced across sessions such that they were preceded an equal number of times by the trained light cue and dark cue, and intermediate shades were never presented as the first or last stimulus in a session. The assistant handed the stimuli to the experimenter in the predetermined order. Only trained stimuli were marked so the experimenter knew how to reward the bear appropriately. The experimenter was blind to the order of probe stimulus presentation. To help maintain responsiveness to the probe stimuli, the first response to the probe stimulus was rewarded with the secondary reinforcer (clicker) but no food.

We set a minimum inclusion criterion of 70.4 % accuracy (binomial probability <0.05) across the 27 trained stimuli presented during a testing session to ensure that bears were attending closely to the cues. All sessions for Experiment 1 met this criterion, and five sessions were excluded from analyses for Experiment 2.

Cognitive bias data consisted of responses to the intermediate probe trials, which were later categorized as 'optimistic' if the behavior corresponded to the high reward value or 'pessimistic' if the behavior corresponded to the low reward value. For analysis of inter-rater reliability, all responses were verified by another observer blind to the probe stimuli using video of the sessions.

Experiment 1

Experiment 1 was conducted in May–August of Year 1 to determine the feasibility of the task and the amount of contrast required to detect a change in judgment across probe stimuli. We assigned the bears to two age- and sex-matched experimental groups (3 and 6 reward groups, respectively), each comprising two adult females with extensive positive reinforcement training experience (e.g., voluntary blood draws, collaring, and echocardiograms, using honey water as the reinforcement), one adult male with little training experience, and one adult female with no prior training experience. The two pairs of extensively trained females (Kio and Peeka; Luna and Mica) were 5 and 7 years of age, respectively, and were hand-reared at

the facility. The males (Frank and John) were brought to the facility as juveniles and had been there for 9 years. The untrained females (Cooke and Oakley) were brought to the facility as adults after removal from the wild. They had been at the facility for 2 years, and their ages were both estimated at 6–7 years.

The four bears in one group (3 reward group) were rewarded with 3 apple slices for the high-reward behavior, and the four bears in the other group (6 reward group) were rewarded with 6 apple slices, which were fed to the bears through the fence sequentially using caution not to allow our fingers to cross the plane of the fence. We chose 3 and 6 apple slices as our high-reward conditions because we expected them to be easily discriminable based on the results from other species (e.g., Hiestand and Davis 1996; Ward and Smuts 2006) but it was unknown whether these quantity differences would translate to an appreciable differential affective response by the bears. For all bears, the low-reward behavior was reinforced with 1 apple slice. Bears were given 15 sessions to learn the association between the behavior/cue shade and reward size. To confirm that bears were responding to the trained stimuli and not unintentional facial or bodily cues from the experimenter, a second trainer performed at least one session with 6 of the 8 bears. Then, four test sessions were conducted with each of the bears except one (John) who became temporarily unavailable for study.

Experiment 2

Experiment 2 was conducted in May–July of Year 2. First, the bears were retested post-hibernation for their performance in the trained cue discrimination task, using 1 apple slice as the reward for both behaviors. After each bear exhibited 90 % or greater accuracy for 5 consecutive sessions, the reward levels were changed to 1 apple slice as the low reward and 4 apple slices as the high reward for all bears. Based on the data from Year 1, when all bears learned the behavior–reward size association at greater than 90 % accuracy within 10 reward-value sessions, we allowed for 10 sessions to learn the association in this experiment. Bears were then exposed to enrichment conditions in the yard in groups of four socially compatible bears (Kio, Peeka, Luna, Mica; Frank, John, Cooke, Oakley), with each 2.1-h 'enrichment condition' session followed by individual cognitive bias testing. One bear (Oakley) was delayed in beginning the experiment and regaining the required response accuracy, and because we were unable to house and test her separately from her cohorts, enrichment exposures were begun with her group before she had completed training. Therefore, no data were collected from her in the first 8 enrichment sessions of her group, and her data set was considered to begin on Session

9 to match the rest of her group and account for her prior exposures to the enrichment conditions.

We investigated bear responses to three types of enrichment item that, in preliminary observations, varied in amount of time bears spent interacting with them. These items were traffic cones (low interest), a puzzle feeder (medium interest), and a cow hide (high interest). Two traffic cones (Cone18C, Boston Industrial, Weymouth, MA, USA) were used per session to increase the likelihood that bears would find them and spend at least some time interacting with them. One set of traffic cones was labeled and reserved for each group of four bears to prevent any additional interest due to smells of other bears. If cones received any damage, they were replaced with new cones so that cones would be comparable across all 'cone' sessions. The puzzle feeder (TS Weeble, Otto Environmental, Milwaukee, WI, USA) was filled with ten apples sliced into eighths and 6 cookies broken into quarters. The 'cow hide' condition consisted of ½ of a cow hide acquired from the Washington State University Meats Lab, with fresh hide being used for each enrichment session. One enrichment type was placed in the yard per day. For a fourth 'no enrichment' condition, no enrichment was added to the yard. Bears received a total of 6 exposures to each enrichment condition, and order was randomized within blocks controlling for the number of times each condition preceded another. Two non-test days were inserted between blocks of four enrichment conditions to minimize any carryover effects from previous exposures.

Throughout the 2.1-h 'enrichment condition' sessions, bears were observed via the Bear Center's camera system. Bears not visible on one of the continuously recording cameras (dens, runs, or sidewalk) were followed for 1-min periods in a random, predetermined order using the 'pan-tilt-zoom' camera. At the end of the 2.1-h session, bears were returned to their indoor dens, the enrichment item (if any) was removed from the yard, and bears were released one at a time for cognitive bias testing. Bears were always tested in the same order to allow for predictability and manageability of shifting bears out into the yard after testing.

Testing was divided between two experimenters blind to the enrichment conditions to avoid potential bias or cues that might be perceived by the bears. The same experimenter performed all tests within a block of four consecutive enrichment conditions. To assess inter-rater reliability, two observers blind to the enrichment conditions verified cognitive bias and trained cue discrimination responses using videos of the test sessions.

Video data were analyzed for percent of time on-camera spent engaged with the enrichment item when present ('enrichment') and 'pacing.' Because the bears were housed in pairs, observation sessions began when both

enclosure doors were opened such that all four bears had access to the yard, and ended when the first den door was closed. Of the 2.1-h session, the first 5 min of each 15-min time segment was sampled for a total of nine samples per session. Time engaged with enrichment was defined as being within one bear length of the enrichment item, with head oriented toward the object. Pacing was defined as repetition of the same route with or without head tossing/ pirouetting. Any break in pacing lasting more than 10 s was considered a break in stereotypic behavior, and resuming the behavior constituted a new bout. A second observer independently recorded behavioral data from a sampling of videos for the assessment of inter-rater reliability.

Statistical analysis

Paired sample t tests were used to assess whether bears were responding similarly to each experimenter during cognitive bias testing and to determine concordance for behavioral data collected from the videos. Percent concordance between two observers, and Kappa values, were calculated to evaluate the level of agreement on the bears' responses to each cue. Logistic regression modeling 'optimism' in relation to cue shade was used to determine trends across the probe stimuli. Because it was possible that bears would generalize to probe stimuli that closely approximated the trained stimuli, we used the binomial test to assess the potential effects of cognitive bias at the central (most ambiguous) probe cue by determining whether bears performed the high-reward ('optimistic') behavior at levels significantly greater or less than 50 %. We used logistic regression to compare response proportion across cues for bears trained to the light versus dark cue as predictive of the high reward to confirm whether the central cue was the most perceptually ambiguous. Comparison of reward-value groups in Experiment 1 was conducted using a repeated-measures generalized linear mixed model (Proc Glimmix, SAS version 9.2.2) with a logit link function to model the binary response variable of 'optimism'/'pessimism' based on the cue shade and reward value. The logit link served to linearize the sigmoidal raw proportions. Bear was the blocking factor (random effect). A direct comparison of the reward-value groups at the central probe cue was made using a least squares means contrast t test.

Proc Glimmix with a logit link function was used in Experiment 2 to model the binomial response ('optimistic'/ 'pessimistic') at the central probe cue as a function of enrichment condition, time spent engaged with the enrichment item, and time spent engaged in stereotypic behavior. Bear was again a blocking factor and the Satterthwaite approximation for unequal sample size was used. Due to low sample size that precluded fitting a full model,

models were built using forward stepwise procedures. The 'no enrichment' condition was removed from the analysis for time spent interacting with enrichment because there was no equivalent measure.

Due to changes in behavior across the 2.1-h session, a single exploratory post hoc analysis per behavior type (stereotypy and engagement with enrichment) was conducted using a Glimmix model to investigate the effect of behavior within time period (beginning, middle, and end) on cognitive bias response. We did not use a Bonferroni correction in these analyses because pairwise comparisons were not made.

Results

Experiment 1

In the first stage of training, bears took 19.9 ± 2.47 sessions (mean $\pm$ SE) to reach 90 % accuracy for the first time (binomial probability <0.001). All bears except one (Kio) met the criterion of 90 % accuracy for 5 days in a row by 35.7 ± 2.80 sessions. Kio was given 50 sessions, and though she did not reach criterion, she was considered to have learned the task after exhibiting at least 80 % accuracy (binomial probability <0.001) on more than half of the 50 sessions. Accuracy of the bears was similar between experimenters ($t_{20} = 0.66$, $p = 0.517$).

Bears' average performance temporarily declined in the second and third sessions after the larger reward was introduced. Accuracy returned to 90 % in Session 4 and remained steady throughout the remainder of the 15 reward-value sessions except for one decline at Session 9 (87.5 %). On average, bears performed at 90 % accuracy or greater in 11.5 ± 1.40 of the 15 reward-value sessions and had achieved 5 sessions in a row at 90 % or better by 8.9 ± 0.99 sessions.

In 100 % of the cognitive bias trials, all bears gave one of the two trained responses when presented with a probe stimulus, with no decline in responding across test sessions. There was 99.5 % concurrence ($\kappa = 0.99$) between observers for response choice over all test sessions. Concurrence for response to the probe stimuli was 100 % ($\kappa = 1$). Results of the logistic regression indicate that the probe cue shown affected which of the two trained behavioral responses a bear would perform in a given trial ($\chi^2_2 = 7.08$, $p = 0.029$). As predicted, there was a positive slope across the probe stimuli, indicating that bears were more likely to choose the high-reward behavior when the probe cue more closely resembled the trained high-reward cue and the low-reward behavior when the probe cue more closely resembled the trained low-reward cue ($m = 17.86$ %, $p = 0.007$, Fig. 1). The cue serving as the high reward

stimulus (light or dark) affected percent 'optimism' ($\chi_1^2 = 11.53$, $p = 0.001$, Fig. 2a), with bears responding near 50 % to both the central and near dark cues ($\chi_1^2 = 1.33$, $p = 0.249$). Although bears differentiated between the low (1 apple slice) versus high reward size (3 or 6 apple slices), there was no difference in level of 'optimism' demonstrated in response to the central probe cue between bears that received three apple slices as the high reward and bears that received six slices as the high reward ($t_5 = -0.31$, $p = 0.766$). Across both groups, the mean (±SE) level of 'optimism' (use of the high-reward behavior) at the ambiguous central probe cue was 60.7 ± 6.23 %, which was not significantly different from chance (Binomial test, $p = 0.113$).
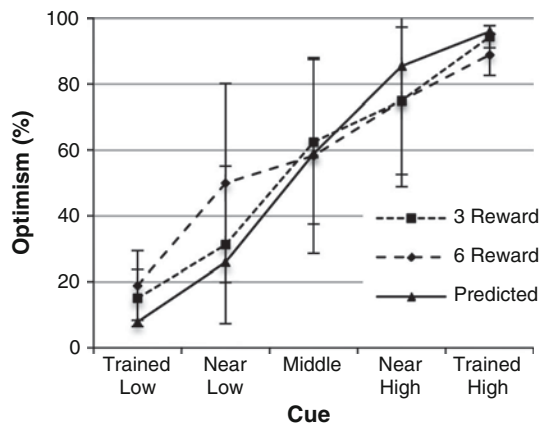

Fig. 1 Comparison of percent 'optimism' (mean ± SE) at each cue between reward groups in Experiment 1 indicates a positive linear trend across probe cues ($\chi_2^2 = 7.079$, $p = 0.029$), with 'optimism' increasing as the cue shade more closely approximated the high-reward cue ($m = 17.86$ %, $p = 0.007$), and no difference in cognitive bias response between bears that received three apple slices ($n = 4$) as the large reward and bears that received six apple slices ($n = 3$) as the large reward ($t_5 = -0.31$, $p = 0.766$). Predicted 'optimism' was based on the logistic regression model (predicted $m = 23.60$ %)
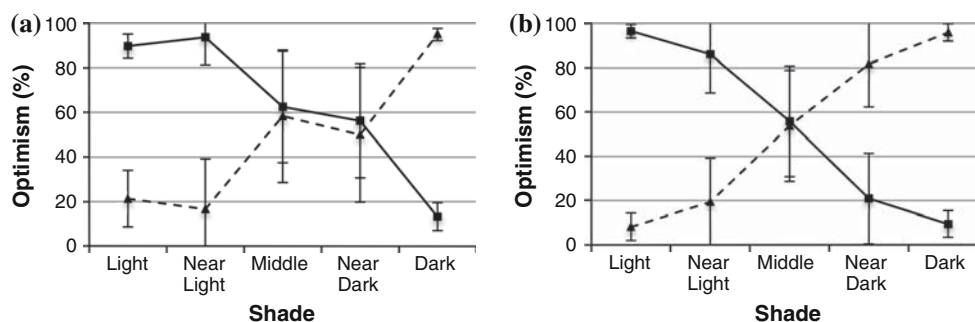
Experiment 2

When presented with the trained cues, bears took 4.3 ± 0.70 sessions to perform at 90 % accuracy for the first time post-hibernation and 16.5 ± 3.67 sessions to reach the criterion of 90 % or greater accuracy on 5 sessions in a row. When reward values were changed, average performance ranged from 87.1 to 94.6 % over all sessions except Session 9, when average performance declined to 72.9 %. Accuracy returned to 94.6 % on Session 10. On average, bears performed at 90 % accuracy or greater in 6.6 ± 0.80 of the 10 reward-value sessions.

When tested for cognitive bias, logistic regression confirmed that bears continued to respond to the probe cues in the predicted direction ($m = 30.98$ %, $p < 0.0001$), with probe cue being a significant predictor of response ($\chi_2^2 = 119.59$, $p < 0.0001$). In this experiment, bears showed a trend toward responding differently depending on which cue (light or dark) served as the high reward stimulus ($\chi_1^2 = 2.99$, $p = 0.083$, Fig. 2b). However, there was no indication that response to the central probe cue changed over repeated exposures ($F_{23, 1} = 0.48$, $p = 0.837$), and bears responded similarly to the central probe cue regardless of which experimenter conducted the sessions ($t_{72} = 1.08$, $p = 0.282$). There was 99.5 % concurrence ($\kappa = 0.99$) between observers for response choice over all test sessions, and concurrence for response to the probe stimuli was 100 % ($\kappa = 1$).

Behavioral data from video observations were not different between independent observers ($t_{179} = 0.26$, $p = 0.792$). The enrichments elicited different levels of interaction by the bears as predicted ($F_{3, 132} = 78.54$, $p < 0.0001$, Table 1). However, enrichment condition was not a significant predictor of cognitive bias response at the central probe cue ($F_{3, 169.1} = 1.01$, $p = 0.390$, Fig. 3). Logistic regression indicated that the slope across probe cues did not differ by enrichment condition ($\chi_3^2 = 2.81$, $p = 0.423$), and the mean (±SE) level of 'optimism' at the

Fig. 2 Comparison of percent 'optimism' (mean ± SE) at each cue shade between bears trained to the light cue as predictive of the high reward (*solid line*) and bears trained to the dark cue as predictive of the high reward (*dashed line*). **a** Bears responded to the central cue as being more similar to the near dark cue than the near light cue in Experiment 1 ($n = 7$, $\chi_1^2 = 11.53$, $p = 0.001$). **b** Bears tended to respond differently between groups in Experiment 2 ($n = 8$, $\chi_1^2 = 2.99$, $p = 0.083$)

Table 1 Table of enrichment and stereotypy effects including mean percent time engaged with each enrichment item, mean percent time engaged in stereotypic behavior by enrichment condition, standard errors, and significant differences

Enrichment condition	Mean time engaged with enrichment (%)	SE (%)	Mean time engaged in stereotypy (%)	SE (%)
None	0[a]	0	11.9[b]	4.86
Cones	0.2[a]	0.13	12.4[b]	5.57
Feeder	5.9[b]	3.05	7.9[ab]	3.83
Hide	36.7[c]	8.85	3.7[a]	2.51

Different letters within the same column denote statistical differences ($p < 0.05$). Time engaged with traffic cones did not differ from zero (no enrichment), but significant differences in interaction time existed between enrichment items, with cow hide eliciting the most interaction, the puzzle feeder eliciting an intermediate level of interaction, and traffic cones eliciting a low level of interaction. Percent time engaged in stereotypic pacing did not differ between the no enrichment, traffic cone, and puzzle feeder conditions. A difference did occur between cow hide and both no enrichment and traffic cone conditions, but not between cow hide and puzzle feeder conditions
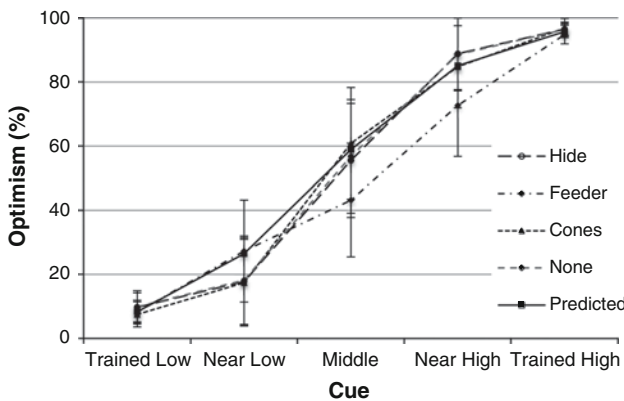
Table 2 List of models tested for predicting cognitive bias in Experiment 2, including parameters, degrees of freedom, F values, and p values for each model

Model parameters	df	F value	p value
Model 1: Enrichment condition	3,169.1	1.01	0.390
Model 2: Total percent time engaged with enrichment	1,160.9	0.16	0.686
Model 3: Total percent time engaged in stereotypic pacing	1,47.7	2.54	0.118
Model 4: Total percent time engaged in stereotypic pacing by time period (beginning, middle, and end)			
Beginning	1,67.9	0.52	0.474
Middle	1,169.0	0.18	0.674
End	1,121.8	4.07	0.046

Enrichment item and percent time spent interacting with enrichment were not significant predictors of cognitive bias at the central probe cue. Percent time engaged in stereotypic behavior showed a trend toward significance, and further division of stereotypic behavior into three segments across the session (beginning, middle, and end) indicates that percent of time engaged in stereotypic pacing at the end of the enrichment session was a significant predictor of 'optimism'
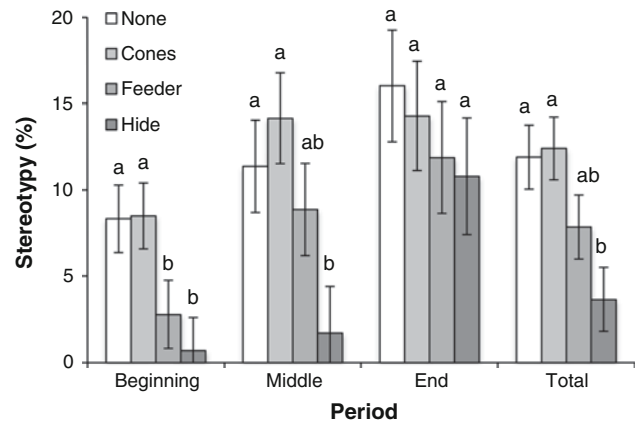

Fig. 3 Percent 'optimism' (mean ± SE) at each cue in Experiment 2 indicates a positive linear trend across probe cues ($\chi_2^2 = 119.59$, $p < 0.0001$), with bears responding with increasing 'optimism' as the probe cue became more similar to the high-reward trained cue ($m = 31.56$ %, $p < 0.0001$), and no difference in cognitive bias response between enrichment conditions ($F_{3, 169.1} = 1.01$, $p = 0.390$; $n = 8$). Predicted 'optimism' was based on the logistic regression model (predicted $m = 23.37$ %)

Fig. 4 Percent time (mean ± SE) engaged in stereotypic pacing differed between enrichment conditions in the beginning ($F_{3, 175} = 4.14$, $p = 0.007$) and middle segment of the enrichment sessions ($F_{3, 173} = 3.94$, $p = 0.009$), but not the end segment ($F_{3, 170} = 0.52$, $p = 0.672$), and enrichment condition had a significant effect on overall stereotypic pacing ($F_{3, 175} = 4.94$, $p = 0.003$). *Different letters* within time period denote statistical differences ($p < 0.05$)

central probe cue was 54.2 ± 17.66 %, which was not significantly different from chance (binomial test, $p = 0.148$). Similarly, percent of time on-camera spent interacting with the enrichment item did not significantly affect cognitive bias response at the central probe cue ($F_{1, 160.9} = 0.16$, $p = 0.686$, Table 2). Parsing percent time engaged with the enrichment item into three segments (beginning, middle, and end) did not alter this outcome.

Percent time engaged in stereotypic pacing behavior during the 2.1-h 'enrichment condition' sessions differed by condition ($F_{3, 175} = 4.94$, $p = 0.003$) and was negatively

correlated with time spent engaged with enrichment ($r = -0.29$, $p < 0.0001$). Percent time engaged in stereotypic pacing showed a weak trend toward predicting cognitive bias response ($F_{1, 47.7} = 2.54$, $p = 0.118$, Table 2). A difference in time engaged in stereotypic pacing depending on enrichment condition occurred in the beginning ($F_{3, 175} = 4.14$, $p = 0.007$) and middle ($F_{3, 173} = 3.94$, $p = 0.009$) segments of the enrichment sessions, but was no
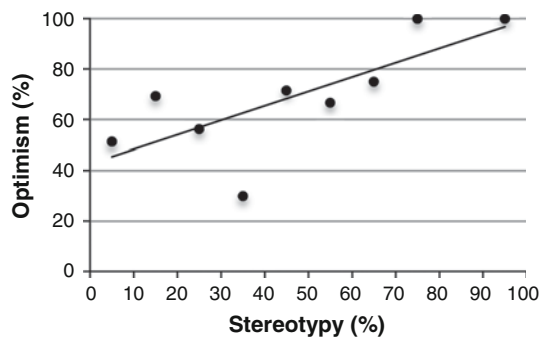
Fig. 5 Average 'optimistic' response (mean ± SE) across all values within each 10 % increment of stereotypic behavior shows a positive linear relationship with percent time engaged in stereotypic pacing at the end of enrichment sessions
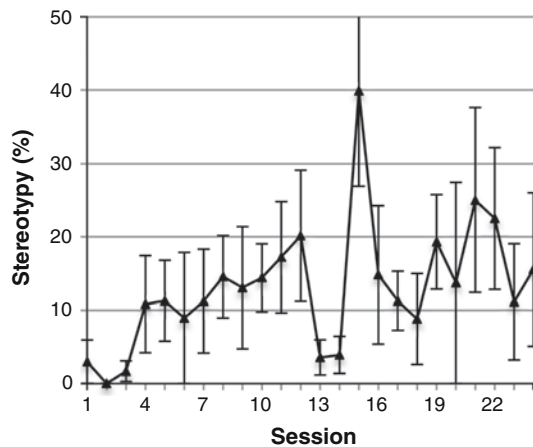

Fig. 6 Over 24 enrichment sessions, percent time (mean ± SE) engaged in stereotypic pacing during the final third of each 2.1-h session

longer seen in the end segment ($F_{3,\ 170} = 0.52$, $p = 0.672$; Fig. 4). Exploratory analysis of the impact of pacing behavior in each of the three segments on cognitive bias response showed that percent time engaged in stereotypic pacing at the end of the session was a significant predictor of cognitive bias response, with higher levels of stereotypy at this time being associated with higher levels of 'optimism' (Table 2; Fig. 5). Level of stereotypic pacing in the 'end of session period' increased after 4 days of testing, but did not differ significantly across 24 days of testing ($F_{23} = 1.27$, $p = 0.198$, Fig. 6).

Discussion

Experiment 1

The data support our prediction that a cognitive bias task based on different quantities of reinforcer would produce changes in response across probe stimuli. Bears generally responded to the 'near high' probe cue as though it were predictive of the larger reward and the 'near low' (or less rewarding) cue as though it were predictive of the smaller reward. The positive slope across probe cues is consistent with our prediction that bears would respond with increasing 'optimism' as ambiguous probe cues became more similar to the high reward stimulus. However, it is possible that the linear slope resulted simply from generalization of response to the most similar trained cue. For this reason, we used responses to the central, most ambiguous, probe cue as our primary measure of cognitive bias because, as long as this cue was perceived to be truly intermediate between the two trained cues, bears could not chose one response over the other based on generalization. Because we did not directly manipulate the animals' environment or attempt to alter affect in any other way prior to testing, we expected that bears would be equally likely to give a nose or paw touch in response to the central probe cue, which they did.

All bears were confined to their indoor/outdoor enclosures prior to testing, and interactions between bears paired in the same enclosure during that time could not be controlled. Each animal was tested four times over consecutive days to minimize the effect of these daily experiences, but they may still have contributed some variability to the results. In both reward-size groups, responses to the probe cues followed the expected positive linear trend from the near-low- to the near-high-reward cues. Ad hoc observation of bears decreasing their speed of apple consumption across trials within training and testing sessions, particularly when receiving six apple slices as the large reward, suggests that the reward value of the larger reward may have been greater at the start of a session but declined with successive trials, resulting in no overall reward-value difference in 'optimism' for the session. A contrast between one and three rewards (Weber ratio = 0.33) appears to be sufficient for our cognitive bias task in grizzly bears and is consistent with findings of quantity discrimination abilities in other species (Ward and Smuts 2006; Evans et al. 2009). However, before use with other species or with a concurrent rather than sequential reward presentation, different reward values should be compared as sensitivity to quantity may differ. Attention should also be paid to responses to the task to confirm that the predicted slope and reward salience are being maintained.

Bears tend to be highly food-motivated, which may make them attuned to small differences in reward size. It would behoove bears to discriminate on a fine scale for optimal foraging, as acquiring sufficient calorie stores during the active season is essential to winter survival. While wild grizzly bears sometimes achieve their calorie intake through large prey items such as caribou or moose, they more frequently exploit comparably smaller food items, including voles, ground squirrels, and berries

(Servheen 1983; MacHutchon and Wellwood 2003), consistent with the idea that grizzly bears are sensitive to the seemingly small difference between one and three apple slices despite their large body size.

Experiment 2

In Experiment 2, we evaluated our cognitive bias task as a measure for assessing the psychological value of different types of manipulanda/food enrichments, a matter of practical importance at zoos when deciding how best to invest limited funds and keeper time for providing enrichment. We expected that 'optimism' in the cognitive bias task would increase in relation to the degree of preference for enrichment items, as measured by time spent interacting with different types of enrichment. Preliminary observations on time spent interacting with enrichment items led us to predict that interaction with a cow hide would produce the highest 'optimism,' followed by the puzzle feeder and, lastly, the traffic cones. Because we expected the traffic cones to attract little attention, we considered this enrichment condition a negative control.

As predicted, the traffic cones produced results similar to the 'no enrichment' condition, with level of 'optimism' at the central probe not significantly different from chance. However, contrary to our prediction, the task did not detect any significant increase in 'optimism' following exposure to the puzzle feeder or cow hide. This was a surprising finding given that, on average, the bears responded to the enrichment items as expected, spending the most time interacting with the cow hide, followed by the puzzle feeder and, lastly, the traffic cones. It is possible that there was too much individual variation in responses to the enrichment stimuli to detect a consistent difference in 'optimism.' For example, the puzzle feeder tended to be monopolized by one bear in each group of four, and the cow hide produced considerable competition among bears for access to the subcutaneous fat, albeit that this behavior had the appearance of play due to frequent exchange of the hide between individuals (Online Resource 2). These observations support the idea that psychological states varied among the bears. We expected that inclusion in the statistical model of the percent of on-camera time spent engaged with the different enrichment items would account for differences between bears, but this factor had no value in predicting outcomes in the cognitive bias test. We speculate that any differences in affect due to enrichment condition had effectively 'worn off' by the time that cognitive bias testing was conducted.

We gave bears approximately 2 h of exposure to enrichment items prior to testing, and some bears continued to interact with specific items longer than others resulting in variation in the interval between use of enrichments and

testing. Nevertheless, previous use of cognitive bias tests has been applied to comparisons between conditions imposed over longer periods than 2 h with positive results (e.g., Harding et al. 2004; Brydges et al. 2011; Doyle et al. 2011; Bethell et al. 2012). The effects of duration of exposure to conditions of interest, and time elapsing between events affecting cognitive bias and conduct of testing, remain topics for future research.

Our final prediction was that bears would respond more 'pessimistically' after longer periods engaged in stereotypic behavior. We found that stereotypic pacing increased in the final third of the 2.1-h enrichment sessions and no longer differed between enrichment conditions in this last segment. Contrary to our prediction, there was a positive rather than negative correlation between pacing and 'optimistic' response bias.

The bears observed at our facility are known to express a dramatic increase in pacing before expected feeding times. If a change in daily feeding time is imposed, a corresponding adjustment in the timing of prefeeding pacing occurs within 5 days of the feeding time change (Ware et al. 2012), demonstrating that the pacing behavior is anticipatory of feeding, a presumed positive event. In the current study, we observed an increase in 'end of session' pacing after 4 days of exposure to the experiment schedule although this change was not statistically significant due to large individual variation. The timing of the majority of pacing just prior to testing and similarity in time spent pacing across all conditions at this time imply that bears had turned their attention away from the enrichment item and begun pacing in anticipation of testing. The associated 'optimistic' response bias suggests that cognitive bias testing itself was a positive event, overriding any differences in affect associated with earlier exposure to enrichment items.

The 'no enrichment' condition was included to help parse responses to the test sessions in the absence versus presence of added enrichment items. Surprisingly, the proportion of 'optimistic' responses in the 'no enrichment' condition was nearly equal to that of the traffic cone and cow hide conditions, further supporting our assertion that any enrichment effects were superseded by positive effects of the testing itself in some cases. Although the food rewards may have served as a primary motivating factor for the pretest pacing and associated 'optimistic' response bias, the cognitive bias sessions presented opportunities not only for food acquisition but also for cognitive stimulation and social interaction with the experimenters. Therefore, we cannot specify with certainty which aspect(s) of testing produced these results.

The question arises whether the pretest stereotyped behavior was indicative of a positive or negative affective state at the time when it was being performed. The positive relationship between stereotypic behavior and 'optimistic'

response bias in this study is contradictory to previous findings in cognitive bias tests, which have linked increased stereotypy to a 'pessimistic' response bias (Brilot et al. 2010; Pomerantz et al. 2012). The differences may be related to the history of the animals and the context and timing of the stereotypy. For example, Brilot et al. (2010) used newly wild-caught starlings as their test subjects, which may have been more prone to stereotypic behavior associated with attempts to escape than the bears in our study that had been in captivity for at least 2 years. Additionally, Pomerantz et al. (2012) found a relationship between head twirling and a 'pessimistic' response bias, but not pacing behavior. Contradictory results regarding stereotypic behavior and cognitive bias are likely related to motivational differences underlying different forms of stereotypy (e.g., escape attempts, food seeking) (Mason 1993) and whether the behavior is associated with a mild degree of relief under continued stressful conditions (i.e., coping) or with goal fulfillment (e.g., obtaining food) and resultant positive affective states.

General discussion

Our results show that the bears were capable of discriminating between the light and dark cues. They tended to respond to each 'near trained' cue as though it were the closest trained cue, which could have been due to generalization or differences in optimism. Data from Experiment 1 indicated an effect of cue shade on responses to the near light and near dark cues, with the near dark cue apparently perceived as more ambiguous than the near light cue implying a nonlinear scale of perceived brightness in grizzly bears. However, there was only a trend toward a difference in response in Experiment 2. Given that testing occurred outdoors, the degree of ambiguity of the cues may have been increased by fluctuations in light intensity on test days. Importantly, bears responded to the middle shade at near chance levels in both experiments, indicating that it was a truly ambiguous cue relative to the trained stimuli. Dogs have been shown to discriminate shades of even closer hue (Pretterer et al. 2004). Therefore, it is possible that a narrower range of gray stimuli may be useful in creating greater ambiguity in the probe cues, especially if testing occurs indoors under controlled light conditions.

We used a strong learning criterion to eliminate any doubt about the bears' knowledge of the task and possibility of subsequent responses being random. However, we think it may have been an additional benefit that the task had become seemingly habitual by the time cognitive bias testing began. The 'automaticity' of responses may help to circumvent cognitive processing when responding to probe stimuli, resulting in a greater influence of affective state on the outcome. Use of the term 'cognitive bias' can be misleading in that the intent is to measure affect rather than cognition. Cognitive bias tasks attempt to tap into subconscious processes and influences on judgment, but the bias is purported to be affective.

Variation at the central probe cue confirms that bears did not learn a specific response to this cue, supporting the hypothesis that changes in response to this cue indicate changes in affect. Additionally, the use of a secondary reinforcer (clicker) was successful in maintaining responsiveness without solidifying a specific behavioral response to the probe cues. We expected that, if bears chose a specific response to the central probe cue, we would see similar consistency as with the trained cues, whereas we found that no bear responded near the average accuracy rate (92.06 %) to the central probe cue (maximum 70.83 % of one behavior choice).

The difference in time spent interacting with the different enrichment types suggests that they differed in reward value, which is relevant to a zoo setting. However, changes in affect related to exposure to enrichment were not independently detected using the cognitive bias paradigm, indicating that the task has not, thus far, demonstrated criterion validity. Possibly, the maximum impact of the enrichment was temporally too far removed from the testing session to be detected during testing, given that the intervening time was likely to be occupied by stereotypic pacing.

Conclusion

A novel task for testing cognitive bias based on quantity of reinforcement resulted in the expected positive linear trend across ambiguous probe stimuli as they became more similar to the cue rewarded at a higher value. Comparison of groups receiving three or six apple slices as the high-value reward indicated that a contrast between one and three rewards was sufficient for creating a positive slope across probe stimuli. Response to probe cues was not affected by time spent interacting with enrichment items in this study. Conversely, percent of time spent engaged in stereotypic pacing was related to cognitive bias response, whereby increased pacing in the period just prior to testing was positively correlated with an increase in 'optimistic' response. This finding contradicts previous studies relating stereotypy to 'pessimistic' responses and suggests that the motivation for the stereotypy was anticipation of food and/or other rewards (e.g., interaction with humans) obtained during testing. This study represents the first animal study to successfully use cognitive bias methodology based on differences in reward quantities, as well as the first assessment of a cognitive bias task in a wild carnivore, the grizzly bear.

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