Cognitive bias tasks: a new set of approaches to assess welfare in nonhuman primates

Emily J. Bethell[1,2], Dana Pfefferle[3,4]

[1]Research Centre in Brain and Behaviour, School of Psychology, Liverpool John Moores University, Liverpool, L3 3AF, UK

[2]Research Centre for Biological Anthropology, School of Biological and Environmental Sciences, Liverpool John Moores University, Email: E.J.Bethell@ljmu.ac.uk; Tel: +44 (0)151 231 2488

[3]Welfare and Cognition Group, Cognitive Neuroscience Laboratory, German Primate Center, Kellnerweg 4, 37077 Göttingen, Germany

[4]Leibniz-ScienceCampus Primate Cognition, German Primate Center. Email: dpfefferle@dpz.eu; Tel: +49 (0)551 3851 361

Abstract

At the start of the new millennium the ‘cognitive bias’ paradigm emerged as a new approach to assessing animal emotion. In the animal welfare literature cognitive bias describes how emotions such as anxiety and depression are associated with changes in the way the brain processes information. For example, studies with humans have long demonstrated that anxious people are more vigilant for negative cues and depressed people interpret the proverbial glass of water as ‘half empty’ rather than ‘half full’. In this chapter, we review how methods developed to study cognitive bias in humans have been adapted to measure the interaction between emotion and cognition in nonhuman primates. We focus on judgment bias and attention bias tasks and discuss study design, controls, confounds, as well as advantages and limitations of each. We also indicate future research directions. This chapter is intended to introduce readers with little or no experience of cognitive bias tasks to theory and practical considerations around designing these tasks.

Keywords:

Cognitive bias, judgment bias, attentional bias, nonhuman primate, monkey, welfare assessment

11. The Potential of Cognitive Bias Tasks for Assessing Nonhuman Primate Welfare

Evaluating the psychological component of welfare (‘psychological wellbeing’) in animals who cannot tell us directly about how they feel is a key challenge in animal welfare research (Russell and Burch 1959; Dawkins 2017). Welfare researchers commonly acknowledge that it is justifiable on ethical grounds to discuss the potential for subjective experience in other species (e.g., Goodall 1986; de Waal 2006; Broom 2010; Panksepp 2011). However, scientific debate about the capacity of animals to suffer has been limited by lack of quantifiable measures. Recent developments in animal welfare science, borrowing theory and methods from the field of human cognitive psychology, have resulted in the development of novel measures of underlying emotional and cognitive processes, specifically, cognitive biases (Harding et al. 2004). In humans, cognitive biases can be measured objectively using experimental tasks in the laboratory. Studies have shown that cognitive biases may occur outside of awareness and are reliably associated with people’s self-reported (subjectively experienced) feelings (Mendl and Paul 2004; Mathews and MacLeod 2005; Evans 2008). If these cognitive bias measures in humans are associated with subjective experience, can cognitive bias methods provide a window into the subjective worlds of other species?

Cognitive bias, in its broadest formulation, describes a tendency for the brain to process information in a way that deviates from a presumed norm (Tversky and Kahneman 1974). Applied to human and animal welfare, cognitive bias describes the way in which changes in mood are associated with changes in cognitive processes, i.e., what individuals look at, what they think about it, and how they remember it (MacLeod et al. 1986; Mathews 1990; Williams et al. 1996; Bradley et al. 1998; Clark 1999; Harding et al. 2004; Mendl et al. 2009; Bethell et al. 2012a). This rapidly expanding field of research is grounded in evolutionary theory, draws on earlier work in classical conditioning, and incorporates more recent methodological developments from the biological and cognitive sciences (Mendl and Paul 2004). Current evidence shows that basic emotions (e.g., fear, anger, lust) are common mechanisms that are essential for survival and reproduction across animal taxa (LeDoux 1996; Panksepp 1998; Lang et al. 2000). Emotions are now considered central to a scientific understanding of human and animal cognition and behavior; cognition cannot be studied without considering emotion, and vice versa (leDoux 1996; Lang et al. 2000; Seligmann and Csikszentmihalyi 2000)

When terms are adopted from one literature to another their definitions can change. Used in the human literature, the term cognitive bias covers a broad range of contexts that do not necessarily imply a role of emotion. Tversky and Kahneman (1974), for example, discussed cognitive biases in terms of how human brains in general processes information, separate from (and without mention of) emotions. In the animal welfare literature, the term is used to mean ‘emotion-mediated cognitive bias'. From herein we use the term cognitive bias broadly to cover a number of experimental paradigms that assess the relationship between emotion and cognition.

Cognitive bias methods present a valuable approach to assessing animal welfare because we already know so much about how cognitive biases manifest in humans and their relationship with subjective well-being. In clinical studies, people suffering with anxiety or depression exhibit different thought patterns to people who are not anxious or depressed (Tversky and Kahneman 1974; Williams et al. 1996; Bar-Haim et al. 2007; Yiend 2010). Anxious people are vigilant for negative information (e.g., they are faster at detecting an angry face in an array of smiling faces and look at such faces for longer) compared with non-anxious people (Bar-Haim et al. 2007). Depressed people tend to interpret ambiguous information more negatively and to recall more negative past events than do non-depressed people (Mathews and MacLeod 2005). Importantly, people are often not aware of emotional responses to stimuli shown outside of awareness (e.g., when shown stimuli for such a short amount of time that they cannot say what was shown), although they may demonstrate a shift in their cognitive bias when tested on automated tasks and report a general shift in their feeling state (Evans 2008). The relationship between emotions and cognitive processes is therefore bidirectional. In essence, having negative thoughts induces negative emotions that, in turn, induce negative thoughts, and this becomes a feedback loop colloquially referred to as the 'downward spiral' of anxiety or depression.

The potential of cognitive bias tasks for assessing nonhuman primate welfare is promising, but in these early days of the application of these methods, it is important to ensure studies are well designed, definitions are clear, and that we take heed of lessons from the human literature. Here we present a summary of the current methods used to study cognitive bias in nonhuman primates with a focus on study design. We discuss limitations and indicate future research directions.

11.2 Cognitive Bias Tasks Explained: Design and Application

The adaptation of cognitive bias methods developed with humans for use with other species has been rapid (Harding et al. 2004; Mendl et al. 2009; Panksepp 2014; Bethell 2015; Dawkins 2017), and meta-analytical studies are now becoming possible (e.g. Neville et al 2020). In the animal welfare literature, the terms 'cognitive bias' and 'judgment bias' have been used interchangeably as a consequence of the use of the term cognitive bias in the first study presenting what has now been termed the judgment bias task (Harding et al. 2004). In this chapter, the experimental paradigms we discuss under the umbrella term cognitive bias are: judgment bias tasks and attention bias tasks.

11.3 Judgment bias

11.3.1 What is it?

Judgment bias describes the way in which changes in emotional state, or mood, are associated with changes in judgments individuals make about ambiguous information (Mathews and MacLeod 2005). Consider a day when you are in a good mood and compare it to a day when you are in a bad mood. On your ‘good mood’ day you are more likely to make positive judgments about otherwise ambiguous events (an odd comment from a work colleague or email from a stranger) than you would on a ‘bad mood’ day. The judgment bias paradigm tests for similar changes in judgments about ambiguous events in animals. In a recent review (Bethell 2015), 64 studies of judgment bias across taxa were identified, overall highlighting the suitability of the paradigm for use across species and contexts.

11.3.2 Method – The Basics

For the judgment bias task, simple operant conditioning is used to train the subjects that one cue (e.g., a particular color such as black) signals a reward if they make response ‘A’, while a different cue (e.g., color white) signals low-reward, non-reward or punishment if, or unless, the subject performs response ‘B’. We therefore have two responses, ‘A’ and ‘B’, which reflect whether our subject expects reward or not. Typically, response ‘A’ is a ‘Go’ response (e.g., approach to touch the black cue) and response ‘B’ is a ‘No Go’ (e.g., do not approach or touch the white cue). Cues intermediate in form to the learned cues (e.g., intermediate shades of grey) are then presented. To assess whether animals have a more positive or negative judgment bias, we calculate the proportion of ‘A’ responses (e.g., ‘Go’) made to the intermediate cues. A greater proportion of ‘A’ responses indicates a more positive judgment bias.

11.3.3 Examples of application for measuring primate welfare

Since Harding et al.’s (2004) seminal paper that described the development of the judgment bias task with rats, the judgment bias task has been adapted to assess welfare in a range of nonhuman primates (marmosets: Gordon and Rogers 2015; capuchins: Pomerantz et al. 2012; Schino et al. 2016; macaques: Bethell et al. 2012; Mcguire et al. 2017 and chimpanzees, Bateson & Nettle, 2015). We describe them here as examples of the different experimental designs and applications.

Currently, two designs of the judgment bias task have been used with non-human primates, i.e., the ‘Go-No Go’ discrimination task and the ‘active choice’ task. The ‘Go-No Go’ discrimination task is the classic judgment bias paradigm in which one cue is presented on each trial. By contrast, the active-choice task requires participants to choose one of two cues presented at the same time. Cues may vary in size, color, type or location. Suitable cue types should be determined by pilot work as to which a given species can discriminate with good accuracy (we recommend >80%).

a) The Classic Task: 'Go-No Go' – size cues

The first study to apply the judgment bias paradigm to nonhuman primates was Bethell et al. (2012a). In this study, we created a visual analogue of the original auditory judgment bias 'Go-No Go' task by Harding et al. (2004; Figure 1). We first trained twelve adult male rhesus macaques (*Macaca mulatta*), who were naïve to cognitive testing, to touch a line presented on a touch screen to gain a reward. This required shaping monkeys' responses from initially reaching towards the screen to touching the exact location of a stimulus shown on the screen. First, we habituated monkeys to the apparatus by covering an old (sacrificial) computer monitor with honey and leaves and allowing monkeys to feed freely on these food items. Touches anywhere on the screen were rewarded with a secondary reinforcing tone and delivery of a food pellet into a tray in front of the monkey, both of which were manually triggered by the experimenter sitting in an adjacent room and watching progress via a live video link. Once a monkey was reliably retrieving leaves from the monitor, we connected the monitor to a laptop and introduced a white square which appeared at random locations on the screen. When the monkey now touched the screen to retrieve a leaf around the location of the white square the reinforcing tone and pellet were delivered. Over successive days, depending on each monkey's rate of progress, we reduced the amount of honey and leaves until none was required for a monkey to touch the screen, and only touches at the exact location of the white square were rewarded. Likewise, we reduced the duration the white square remained on the screen from several minutes to several seconds. Touches were reinforced on 100% of touches with the tone, and on 30% - 50% of touches with a food pellet. Once the monkey was touching the white square on the monitor for pellets, we introduced the automated touchscreen and, following a period of habituation to the new screen, the monkey was ready for cognitive bias testing.

Once monkeys had learned to work with the touchscreen we began training on the judgment bias discrimination task. During training, monkeys were shown a single yellow line on the screen for 2 seconds on each trial, for 62 trials per day. Two training stimuli were used: a long line and a short line (Figure 11.1a, 11.1b). For three monkeys, the rewarded stimulus was the long line and the unrewarded stimulus was the short line. For four monkeys this was reversed. Touching the rewarded line within 2 seconds resulted in receiving the tone (on all trials) and two small food pellets (on 40% of trials). Touching the unrewarded line resulted in a mildly punishing 16 second delay to the next trial. Not touching either the rewarded or the unrewarded line did not result in any feedback, and after 5-6 seconds the next trial started automatically. Seven out of 12 monkeys reached our training criterion (70% correct responses for 'Go' and 'No Go' trials) taking between 19 and 43 daily training sessions to learn the judgment bias task. All monkeys who learned the task were under 7.5 years of age (range 3.6 – 7.4 years). The monkeys who failed to learn the 'Go-No Go' task discrimination were mostly older individuals (range 9.9 – 25 years).

Fig 11.1

Our aim was to test the validity of the judgment bias task as a measure of emotional stress, and so we tested monkeys on presumably low stress and high stress days. We opted to run our high stress testing sessions in the week during which monkeys underwent their quarterly veterinary health checks. Low stress sessions were run during a quiet week without the presence of the veterinarian or any other disruptions to the usual daily routine, and with some additional enrichment.

During testing sessions monkeys were shown the same lines as in training (Figure 11.1a), interspersed with trials on which ambiguous probes - lines of intermediate length - were shown (Figure 11.1b). We predicted that during 'low stress' weeks monkeys would make more positive judgments about the ambiguous probes, and this would result in more touches to the probes. During high stress weeks we predicted monkeys would make more negative judgments, leading to fewer touches to the probes. Responses were as predicted. We interpreted this as monkeys becoming more pessimistic about ambiguous cues when they had recently been visited by the veterinarian.

b) The Classic Task: 'Go-No Go' – color cues

A subsequent study using the 'Go-No Go' discrimination task shows how the task can be applied using cues of different color, as well as assessing personality effects on judgment bias. Gordon and Rogers (2015) trained common marmosets (*Callithrix jacchus*) to lift lids on bowls to access food rewards. During training, one cue was a bowl with a black lid and the other a bowl with a white lid. Marmosets learned that the bowl with one color lid contained food while the bowl with the other color lid was always empty. Each trial lasted 2 minutes and marmosets completed 20 trials per day. It took 10 -22 days for 12 marmosets to reach the 85% accuracy level for testing. During testing marmosets were presented with a bowl with a grey lid and the proportion of trials on which the lid was lifted, and time taken, were recorded. Monkeys who were left-handed were less likely to remove the grey lid to inspect the ambiguous bowl than monkeys who were right-handed, irrespective of rate of learning, sex or age. Retrospective assessment of colony records revealed that the left-handed monkeys received more aggression than did right-handed individuals, likely altering their emotional state, and possibly reflecting hemispheric differences in processing and behavior between left- and right-handed marmosets.

c) Active Choice Task: 'Go-No Go' – various cue types

Active choice tasks require selecting one of two or more cues presented simultaneously. McGuire et al. (2017) published an ‘ambiguous cue task’ which was designed to maintain the ambiguity of the probes over repeated presentations. The authors attempted to train three lowland gorillas (*Gorilla gorilla*) to discriminate between the conditions under which three stimuli had unique reward associations. Stimuli were colored geometric shapes (Figure 11.2). For each gorilla, one stimulus was always rewarded when selected on a touchscreen monitor (‘P’), one stimulus was never rewarded when touched (‘N’), and a third stimulus was rewarded when paired with ‘N’ but not rewarded when paired with ‘P’, and was therefore an ambiguous cue (‘A’) with a context-dependent reward value. Interpretation of ambiguity could therefore be measured by recording the proportion of touches to ‘A’ when it was paired with novel shapes that had not previously been seen. An optimistic interpretation of ‘A’ would be evident in a greater proportion of touches to ‘A’, while a pessimistic interpretation of ‘A’ would lead to gorillas selecting the novel shape. Test trials were always rewarded regardless of the selection made, presumably to maintain motivation on the task. Overall the gorillas failed to adequately learn the initial ambiguous cue task. It was therefore not possible for the authors to test for changes in interpretation of the ambiguous cue following presumed manipulation of affective state. The test condition would have been a phase of enhanced forage enrichments vs. a phase with a standard-forage baseline. This study highlights the possibility for innovative experimental designs that can address some of the limitations of existing tasks (e.g., habituation and learning of the intermediate probes), and may reflect variation between species in training success on complex tasks (see also Allritz et al. 2016 and Cronin et al 2018).

Figure 11.2

d) Active Choice Task: ‘Go-Go’ - size cues

An alternative to the ‘Go-No Go’ paradigm is the ‘Go-Go’ paradigm in which individuals choose between two cues signaling higher and lower reward values (Figure 11.3). Pomerantz et al. (2012) presented rectangular blocks of different length to train tufted capuchins (*Sapajus apella*) on an active choice ‘Go-Go’ discrimination task in which monkeys could gain preferred or less preferred (but edible) foods. Rectangular blocks were presented on a plastic board in front of two wells, one of which was covered with a black sliding lid, and the other covered with a white sliding lid. In the ‘Go-Go’ task a line of one length indicated a presumed high value reward (marshmallow) under one color of lid (Figure 11.3a) and a line of another length indicated a reward of lower value (banana-flavored pellet) under the other color of lid (Figure 11.3b). Twelve out of 16 monkeys learned the task and went on to the testing stage. Monkeys were then presented with rectangular blocks of intermediate length and indicated their more-or-less positive judgment about likely reward value by reaching towards either the high reward lid or the low reward lid (Figure 11.3c). The researchers also recorded stereotypical head twirling and pacing. There was a significant negative correlation between rates of stereotypical head twirling and the probability of choosing the lid associated with the preferred reward when the ambiguous intermediate length line was presented. Monkeys who performed more head-twirls were therefore considered to have a more negative judgment bias. No such bias was evident in capuchins who performed more stereotypical pacing, even though head-twirling and pacing were themselves significantly and positively correlated. There was also no relationship between any of the stereotypical behaviors and likelihood to learn the initial discrimination task. The authors interpreted this result as suggesting that some forms of stereotypical behavior may more accurately reflect current negative mood than others and that the judgment bias paradigm may provide a means of distinguishing between these.

Figure 11.3.

e*) Active Choice Task: 'Go-Go' - location*

Schino et al. (2016) applied a spatial version of the 'Go-Go' active choice task with 13 male and female tufted capuchins. In this variant of the task the presence of a preferred or non-preferred reward in one of two differently colored cups placed next to each other (28 cm apart) was indicated by placing a rectangular block next to the rewarded cup. Once monkeys had learned the 'Go-Go' discrimination task for the greater or lesser reward, they were presented with test trials. On test trials, the rectangular block was placed centrally between the two cups. An optimistic choice was indicated by reaching for the cup that had contained the preferred reward during training and a less optimistic choice was indicated by reaching for the cup that had contained the less preferred reward. The researchers also recorded grooming behavior and dominance rank of the monkeys to test the hypothesis that a system of emotional 'bookkeeping' underlies the capacity of group-living animals to reciprocate cooperative interactions. Monkeys who received grooming prior to testing did not, as predicted, show a more optimistic judgment bias for the ambiguously placed rectangle. However, there was evidence for a more optimistic response to the central rectangle in dominant monkeys and those who received more grooming overall.

11.3.4 Advantages and limitations

a*) Advantages*

The handful of judgment bias studies performed with nonhuman primates to date suggest that the judgment bias task is adaptable for use with a range of primate species, across a number of contexts, and is sensitive to both short term emotion and more stable trait characteristics. Enough studies have now been published across taxonomic groups (n=64 in 2015, Bethell 2015) that meta-analyses are becoming viable. Neville et al. (2020) conducted the first meta-analysis of judgment bias studies, focusing only on studies in which a pharmacological manipulation had been used to alter affective state. While none of the 20 articles included in the analysis involved nonhuman primates, trends in task outcomes were identified across taxonomic groups commonly used in research that can be informative for designing and interpreting future primate studies. Further large-scale analyses will speed progression of research applying judgment bias tasks.

b*) Limitations*

There are several caveats around design and application of the judgment bias task. Firstly, operant training usually leads to attrition of subjects; some individuals will fail to learn the task (as occurred in all the studies described above), subordinates may not gain access to the apparatus, and some individuals will lose interest once trained. Active choice tests may be at greater risk of attrition since the distinction between two levels of positive reward is more subtle than the distinction between reward and non-reward. In either case, this results in a self-selected sample in which we may be missing those individuals with poorest welfare. We are aware of several unpublished studies, from our own and others' groups, where researchers have attempted to measure judgment bias in nonhuman primates with inconclusive or variable results (as in Mcguire et al. 2017, discussed above), either because of limitations on the time for initial discrimination training or because of attrition of subjects during the initial training stage (Katie Cronin, personal communication). Are animals failing to learn because they are already in a negative emotion state (Mendl 1999)? The well-documented publishing bias for significant results (Rosenthal 1979) means there may be much unpublished data showing no evidence for a bias, hampering efforts to understand why or under which conditions biases are not seen.

Secondly, judgment bias tests may be prone to habituation and learning effects. For example, Perdue (2017) trained rhesus macaques and tufted capuchin monkeys on a 'Go-Go' judgment bias task. There was no manipulation of emotion state, but over time, rhesus macaques and capuchin monkeys became less likely to respond to the intermediate probes. It is not surprising that over repeated presentations, the ambiguity of probes is lost and learning then influences rate of responding. While the monkeys completed thousands of trials, more than run in most published studies, this paper highlights that the effects of repeated testing certainly need more consideration in judgment bias studies. It is therefore preferable to limit the number of times each probe is presented, for example, by increasing the number of different probes used, or to reduce learning with designs that maintain ambiguity using context-dependent contingencies (as in Mcguire et al. 2017).

Thirdly, we have yet to fully test the extent to which the judgment bias paradigm does indeed measure biases in judgment about ambiguity rather than other processes (that are not necessarily mutually exclusive to judgment bias), such as biased attention, risk-taking behavior, and/or arousal. The 'Go-No Go' tasks may be at greatest risk of these confounds since they rely on two types of response. A non-response is interpreted as reflecting a judgment of non-reward when it might instead reflect reduced arousal, distraction, confusion, or lost motivation. In the active choice task, non-responses due to confounds should occur more equally for all trial types and therefore be less likely to skew interpretation in terms of judgments. Potential confounds are sometimes not controlled for in judgment bias studies. It is essential to check for, and report on, any changes in responses to the conditioned stimuli (S+ and S-, or S++ and S+) to identify the likelihood of confounds. For example, Bethell et al. (2012a) found no change in responses on S+ ('Go') and S- ('No Go') trials during testing sessions, adding support to the interpretation of change in responding to the probes in terms of judgments about their ambiguity. By contrast, Harding et al. (2004) found a reduction in 'Go' responses to the S+ during their stress condition, leading to the possibility that the reduction in responding to the probes could have been partially driven by factors not related to ambiguity such as reduced motivation or arousal.

Fourthly, results are reported in categorical terms such as 'optimism' and 'pessimism', yet in the absence of a baseline, we are truly testing relative shifts in tendency to respond. There have not yet been enough studies with nonhuman primates to identify whether there are species-typical ranges of response, for example, or thresholds beyond which we can say an animal's welfare is compromised. Nor have there been enough to fully understand the sensitivity of the paradigm to variation in transient emotions compared with longer term moods, within or between individuals. While the 'Go-No Go' tasks may measure shifts in expectation of both negative and positive outcomes (e.g., Bethell and Koyama 2015 found shifts in response at the two probes closest to the conditioned stimuli but not the central probe), active choice paradigms may only be sensitive to shifts in expectation of reward, lacking sensitivity altogether to expectation of negative events (discussed in Bethell 2015).

In summary, judgment bias tasks are useful tools for testing hypotheses about the influence of emotion on judgments about ambiguous information, the likelihood of positive outcomes following responses, and for identifying differences in optimistic/pessimistic interpretation between individual primates. They may not, however, be the most efficient approach for measuring emotions in real-world settings due to the need for initial training. Nevertheless, in the context of findings from the broader animal literature, the few studies with small numbers of nonhuman primates indicate that the judgment bias task does measure something that maps onto the presumed underlying emotion state. And for now, that is a good start.

11.4 Attention bias

11.4.1 What is it?

'Attention bias' describes how emotion state or mood can influence which cues in the environment individuals attend to (Mogg and Bradley 1999). For example, as noted earlier, in laboratory tests, anxious people are faster at detecting threatening faces in a crowd of neutral faces than are non-anxious people (Gilboa-Schechtman et al. 1999; Mogg and Bradley 1999). This bias for detecting threat is evident even when stimuli are presented subliminally, i.e., outside of awareness (Mogg and Bradley 1999). A characteristic of phobias in humans is an inability to stop attending to the target of the phobia (Gilboa-Schechtman et al. 1999), and this manifests in various coping strategies to avoid phobia-related cues, such as total avoidance (Chen and Clarke 2017). A basis of many meditation and therapeutic practices is the deliberate shifting of attention away from 'negative' and towards 'positive' thoughts, and the field of Positive Psychology is based on the premise that what individuals attend to can influence their sense of psychological wellbeing (Seligman and Csikszentmihalyi 2000).

Our research groups have been exploring the utility of attention bias tasks for assessing emotion in nonhuman primates in free-ranging, zoo and laboratory settings. Attention bias tasks can require less training than judgment bias tasks, and the use of biologically relevant stimuli should reduce the likelihood of habituation and learning effects. In a recent review, Crump et al. (2018) identified 12 studies applying attention bias paradigms to measure emotion in animals, highlighting that this field is at an early stage of development.

11.4.2 Method – the basics

Attention bias tasks, for the purpose of welfare assessment, can be split into two broad categories: those that do not require prior operant training and those that do. The first category comprises a) the attention bias preferential looking task (Calvo and Avero 2005; Garner et al. 2006; Bethell et al. 2012b). This is a simple paradigm in which the subject is shown two pictures that vary in valence (e.g., a negative vs. a neutral picture) side-by-side, and the direction and duration of gaze towards the pictures is filmed or tracked with an eye-tracker. Attention bias is assessed as the difference in looking time towards the emotional compared to the neutral picture. For a recent review of the use of preferential looking attention bias in animal welfare assessment see Crump et al. (2018). The second category includes tasks in which subjects are required to make a manual response, the speed of which is used to assess biases in attention. These are b) dot probe tasks (MacLeod et al. 1986) and c) visual search tasks (Öhman et al. 2001). In both paradigms, participants are instructed (in the case of humans) or rewarded (e.g., in nonhuman primates) for responding accurately and as quickly as possible to a cue when one or more emotional distractor cues have been shown. For a good review of dot-probe studies for assessing animal welfare we recommend van Rooijen et al. (2017).

11.4.3 Examples of Application for Measuring Primate Welfare

a) Preferential looking

Preferential looking tasks have been used to identify cues of interest to nonhuman primates (e.g., Gerald et al. 2009; Parr 2011; Pfefferle et al. 2014; Parr et al. 2016). The first study to apply a preferential looking task to explicitly test emotion-mediated attention bias in a nonhuman primate was conducted with adult male rhesus macaques (Bethell et al. 2012b). Seven monkeys were shown picture pairs of conspecific faces (one ‘threat’ face and one ‘neutral’ face) on two adjacent computer monitors and the direction and duration of looks towards the two face pictures was filmed. As with our test of judgment bias, each monkey was tested at baseline and after the statutory veterinary examination to provide a within-subjects comparison of presumed emotion state.

Monkeys were faster to direct initial gaze towards threat than neutral faces suggesting a general vigilance for threat irrespective of underlying emotion state. This finding is in line with earlier studies demonstrating a general enhanced attention to threatening or agonistic images and scenes in nonhuman primates (Parr and Hopkins 2000; Kano and Tomonaga 2010; Watson et al. 2012). Subsequent looking responses, however, were dependent on condition. During the baseline condition, monkeys continued to look towards the threat face, demonstrating sustained vigilance for threat. However, after the health check those same monkeys rapidly disengaged their gaze from threat faces and spent less time looking towards threat faces overall. We interpreted this as an avoidant attention bias in macaques when stressed. In a later study of juvenile macaques, conducted using the same stimulus pairs, Mandalaywala et al. (2014) found that offspring of protective and dominant mothers had an enhanced attention bias towards threat faces compared to offspring of less protective and more subordinate mothers. The preferential looking paradigm shows great promise as a measure of attention bias as it requires limited training, is relatively simple to execute, and has been widely validated with nonhuman primates to assess the types of stimuli that capture and hold attention (e.g., Waitt et al. 2003; Waitt and Buchanan-Smith 2006; Watson et al. 2012).

b) Dot probe

The dot-probe task provides another means of testing attention bias but requires prior operant training. Two stimuli (one ‘emotional’ and the other ‘neutral’) are presented simultaneously, usually on a touch screen. After a predefined period (which can range between 14ms – 2000ms depending on what point in the attentional time course is of interest) the stimuli are removed from the screen and a probe (e.g., a circle, arrow or other neutral cue) appears in the location of one of two previously shown stimuli. Each subject’s task is to respond to the dot-probe typically either by pressing a key on a keyboard (in the case of humans) or by touching the probe on the screen (in the case of nonhuman primates). Reaction time for detecting the dot-probe will be faster at the attended location than at the unattended location. By comparing response time on trials in which the probe was at the location of the emotional stimulus (congruent trials) with reaction time at the neutral stimulus (incongruent trials), biases in attention towards or away from emotional stimuli can be detected. By manipulating the stimulus duration and the positive or negative value of the emotional stimulus, researchers can distinguish between early attentional capture, dwell, and later avoidance of positive and negative information. Studies with humans have revealed that anxious people are generally faster to detect probes that appear at the location of faces with negative or threatening expression compared with probes that appear at the location of faces with neutral expression (MacLeod et al. 2002; Chen et al.

2002; Mogg et al. 2004; Bar-Haim et al. 2007; Beevers et al. 2007; Carlson et al. 2012; Hommer et al. 2014).

Several published studies have tested for attentional bias to emotional stimuli in nonhuman primates using dot-probe tasks (King et al. 2012; Kret et al. 2016; Wilson and Tomonaga 2018). However, at the time of writing, no published studies have tested an effect of emotion state on attention bias using this paradigm. Here we review the dot probe studies published to date.

Kret et al. (2016) adapted the dot-probe task for use with four bonobos (*Pan paniscus*). Stimuli were pictures of bonobo social scenes or faces rated by four experts as emotional or neutral. In order to begin each trial, bonobos were required to touch a start cue that appeared at the center of a touch screen. A stimulus pair was then shown for 300ms, one image on the left and one on the right of the screen, followed by the dot-probe at the location of one of the two stimuli for 2 seconds. The dot probe was congruent to the location of the emotional stimulus on 50% of trials and occurred at the location of the neutral stimulus in the other 50% of trials. All four bonobos were significantly faster to touch the probe when it followed the location of the emotional stimulus than the neutral stimulus, with fastest responses at the location of high-intensity emotional stimuli. When the authors attempted to categorize the emotional stimuli in terms of valence, the results were less clear; bonobos showed greatest attention bias towards social stimuli containing grooming, sex, and yawning, but not aggression or distress. This study demonstrates that the dot probe task can be adapted for use with bonobos, with further work on categorization of stimuli in terms of emotionality needed.

Wilson and Tomonaga (2018) trained eight chimpanzees (*Pan troglodytes*) on a dot-probe task. Stimuli were grey scale pictures of chimpanzee threat faces of high intensity (scream face) and lower intensity (bared teeth), paired either with chimpanzee faces with neutral expressions, or face images that had been scrambled so that they were no longer recognizable as faces but contained the same color information as the original pictures. Stimuli were shown on a touch screen monitor. To start a trial the chimpanzee had to touch a start cue presented just below the center of the screen. Two stimuli were then shown for 150ms, one stimulus at each of the left and right screen locations. Stimulus pairs were a threat face paired with a neutral face, or a threat face paired with a scrambled image. After 150ms the two stimuli disappeared from the screen and the dot probe appeared, congruent to the emotional stimulus on 50% of trials. Attention bias was determined as faster responses to the probe when it appeared at the location where the emotional face had previously been shown. No attention bias was evident for the threat-neutral face pairs. Chimpanzees were as fast to touch the probe when it appeared at the location of the neutral face as when it appeared at the location of the threat face. However, an attention bias was evident when threat faces were paired with scrambled images. Chimpanzees were faster to touch probes appearing at the location of the threat face than the scrambled face, indicating that they were looking towards the location of the threat faces when the probe appeared.

c) Visual search

The visual search task has been widely applied to measure attention bias to threat in humans (Gilboa-Schechtman et al. 1999; Yiend 2010). Participants are asked to detect, as quickly as possible, the location of one ‘target’ picture (e.g., a frowning face) in an array of other pictures (e.g., neutral faces). The speed with which the target picture is detected reveals how quickly and strongly the target pictured captured the viewer’s attention. Anxious people are faster to detect a negative face in an array of neutral faces than are non-anxious controls (Gilboa-Schechtman et al. 1999; Yiend 2010).

The visual search task has been adapted for use with nonhuman primates (Öhman and Mineka 2003; Kawai and Koda 2016; Kawai et al. 2016), although it has never been applied to assess emotional states. These studies reveal that monkeys are faster to detect snakes in arrays of flowers, herbivorous mammals and spiders than vice versa (Shibasaki and Kawai 2009; Kawai and Koda 2016), and to detect conspecific threat faces amongst an array of neutral faces (Kawai et al. 2016).

Shibasaki and Kawai (2009) trained three Japanese macaques (*Macaca fuscata*) on a visual search task using a touch screen. Monkeys were first trained with color patches in which they learned to touch the ‘odd one out’ in order to receive a small food reward. Stimulus arrays were either 2 x 2 or 3 x 3. Once the basic task was learned, pictures of snakes and flowers were introduced to test for differential ability to locate a fear-relevant stimulus in an array of non-fear stimuli and vice versa. Monkeys were required to touch a rectangular white start cue at the center of the screen to start each trial. After 500ms an array of four or nine pictures appeared and stayed on the screen until the monkey touched one of the pictures. A correct touch to the odd-one-out resulted in a small food reward. Overall monkeys were faster to find snakes in flower arrays than vice versa, both for pictures in color and greyscale. This effect was seen only when snakes were the fear-relevant stimulus and not when pictures of spiders were used (Kawai and Koda 2016). The same research group later tested another three Japanese macaques on a visual search task using conspecific threat and neutral faces (Kawai et al. 2016). Macaques were faster to find the threat face in the neutral array than vice versa. These results suggest that fear-relevant stimuli, like snakes and aggressive faces, capture attention in nonhuman primates. The extent to which this is mediated by emotion state, as it does in humans, remains to be tested.

11.4.4 Advantages and Limitations

a*) Advantages*

Advantages of attention bias tasks are simpler training protocols and fewer trials overall compared to the judgment bias task, due to the use of biologically relevant stimuli. The preferential looking task requires no training beyond that required to habituate animals to the researcher and apparatus. For example, Mandalaywala et al. (2013) recorded attention bias for threat-neutral face pictures in free-ranging monkeys at the Cayo Santiago field station simply by approaching animals that were resting and presenting the pictures while filming which pictures the macaque looked at. An advantage of the dot-probe task is that the actual dot probe has nothing to do with the preceding emotional stimuli that are used to induce attention bias. Further, it can provide information about the time-course of attention. Adjustment of duration for which stimuli are shown on the screen can be used to assess attention bias at earlier stages of attention (e.g., to subliminally presented stimuli) separate from later stages of attention (e.g., maintenance or disengagement of attention). Attention bias tasks can be less at risk of attrition of subjects, learning effects, confounding factors, such as arousal, or interpretation in terms of categories of emotion (since responses are relative time looking at either stimulus in the preferential looking task), compared with judgment bias tasks.

b*) Limitations*

There have been a limited number of published studies of attention bias, and the sample sizes are small. For the preferential looking paradigm, our experience is that monkeys show the most pronounced looking on the first trial, and steadily lose interest in subsequent trials. Therefore, running only one trial at a time may work best (e.g., Mandalaywala et al. 2014). By contrast, the dot-probe task, due to the need to make responses to receive rewards, is more engaging and therefore suitable for repeated trials within a session. Coding trials from video can be time consuming, while eye-trackers are expensive, often difficult to calibrate, and are only available in a few primate facilities. Dot-probe tasks require automated systems which are available in a limited number of facilities being that they are relatively expensive to set up and maintain.

There are well-documented visual field (hemispheric laterality) effects for processing emotional information in both humans (Sato and Aoki 2006) and nonhuman primates (Lindell 2013). We recommend including location as a control variable when analyzing data so potential laterality effects can be accounted for. For the dot-probe task, it is essential to counterbalance the side on which the emotional face is shown, as well as congruency of the subsequent probe location.

A challenge is to accurately categorize the emotional content of stimuli and acknowledge that the perception of emotional content may vary between individuals. In a recent study (Bethell et al. 2019b) we tested the influence of fearful temperament on reaction times to touch different categories of stimuli in adult male rhesus macaques. Stimuli were categorized as those we predicted to be negative in meaning (conspecific male faces with direct stare, pictures of husbandry items including a veterinary glove, brush and net, and pictures of a human wearing a mask). Monkeys with the most fearful temperament showed the slowest responses to the conspecific faces. There was some limited slowing of response to pictures of husbandry items and no slowing of response to the masked human. It is important to understand how individual monkeys perceive the stimuli that we classify as threatening.

Creating adequate stimulus sets can be time consuming and challenging. Obtaining clear face pictures of the same individual nonhuman primate displaying different facial expressions is difficult. Stimuli must be equated for properties such as color, luminance and contrast energy (Waitt and Buchanan-Smith 2006). This is more easily done with pictures in greyscale than color, but color information is then lost, which may reduce salience. Open access online resources like the Macaque Stimulus Set (Witham and Bethell 2019) and the Facial Stimuli – Macaques Sets (Pfefferle 2020) provide a platform for researchers across fields to share stimuli, as well as to download stimuli used in published studies. For example, the stimuli used in Bethell et al. (Bethell et al. 2012b, 2016, 2019a), Mandalaywala et al. (2013) and Pfefferle et al. (2014) can be downloaded from this online resources. Shared resources enhance quality of science by allowing for more concise replication of studies across contexts.

Adequate controls are essential for interpreting results. The dot-probe study by Wilson and Tomonaga (2018) is a good example of how adequate controls are needed to interpret results. In that study, Wilson and Tomonaga (2018) found no evidence for an attention bias to chimpanzee threat faces that were paired with neutral chimpanzee faces but did find an attention bias for threat faces paired with a scrambled stimulus. Without a neutral-scrambled pair comparison, it is not clear from the results whether the attention bias seen in threat-scramble trials was driven by the threat value of the face or the presence of social information. In control trials that took place during the same study, the chimpanzees were also faster to detect probes following a picture of a chair when paired with a scrambled stimulus. The latter is an example of a good control insofar as it provides information about how to interpret data. In this case, chimpanzees showed an attention bias for threat faces and chairs, relative to scrambled images. We cannot interpret the bias for threat faces solely in terms of attention bias for threat without also considering the chimpanzees found chairs threatening; it is as likely that pictures of faces and objects are simply more interesting to look at than abstract scrambled images. The lack of attention bias for threat faces when paired with neutral faces could indicate the absence of an attention bias for threat faces in those chimpanzees, or the use of stimuli not perceived by the chimpanzees to vary significantly in their threatening or neutral value to elicit a bias in looking. Without adequate controls, we are limited in what we can conclude from any data set.

11.5 Take Home and Considerations for Study Design

We encourage facilities housing nonhuman primates to consider how they can incorporate cognitive bias testing into their welfare assessment protocols. There is not a one size fits all design for measuring cognitive bias, but all designs must be fit for purpose with adequate controls and consideration around interpretation of results.

1. Can all or most animals be trained on an operant task? If not, simpler attention bias tasks may be best.

2. What discrimination tasks can they learn? Ability to discriminate between two stimuli is required for judgments bias tasks (‘Go-No Go’ and ‘Go-Go’ tasks). If not, simpler attention bias tasks require learning to touch one stimulus (as in dot-probe tests) and ‘the odd one out’ in visual search.
3. What stimuli to use? Stimuli need to be species appropriate and, where they are intended to be valenced, to be perceived as such by subjects.
4. What controls are needed? Do you have a baseline against which to compare responses? In the judgment bias task, check for any change in ‘Go’ or ‘No Go’ responses to the conditioned stimuli. In attention bias tasks, control for visual field and basic stimulus characteristics such as color, luminance, and contrast energy that might bias looking.
5. How many trials to run? For judgment bias tasks limit presentations of the probes to maintain ambiguity (for example by having multiple probe forms presented at low frequency among presentations of the conditioned stimuli). In the preferential looking task, macaques have been shown to lose interest in face images after the first trial. In dot-probe and visual search tasks, nonhuman primates will perform many more trials due to rewards, but initial training is required.
6. What reward contingency to use? In the judgment bias task, using a variable reward ratio (e.g., 40% in Bethell et al. 2012a) may reduce the likelihood, or speed, of learning that probe trials are not rewarded. Consider that using punishers in ‘Go-No Go’ designs may confound the effects of any positive mood manipulations. In this case a ‘Go-Go’ task may be more suitable. For attention bias tasks, use any reward contingency that keeps subjects working.
7. How to interpret data? With caution and in consideration with other measures of welfare. Currently there is no categorical measure of emotional valence (e.g. optimist/pessimist, stressed/unstressed) that can be extracted from cognitive bias data. However, building up pictures of individual profiles can help identify changes in animals over time, or distinguish between more- vs. less optimistic individuals in a group. As with many health measures, changes may be more informative than absolute values.

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Figure legends

Figure 11.1: A visual analogue of the classic ‘Go-NoGo’ judgment bias task, adapted for use with nonhuman primates. a) The experimental procedure for S+ (‘Go’) trials, showing the long line as S+ and outcomes following a response (correct), and no response (incorrect). b) The experimental procedure for ‘NoGo’ control trials, showing the short line as the S- and outcomes following a response (incorrect), and no response (correct). c) The experimental procedure for ambiguous probe trials, showing a line of intermediate length to the S+ and S, and outcomes following a response and no response (neither response rewarded nor punished). Figure adapted with permission from Bethell (2010).

Figure 11.2: Example of stimulus pair combinations used in the ambiguous cue paradigm. In this example the red square is the rewarded stimulus (‘Go’) when paired with the blue circle (NA pair), but it becomes the non-rewarded (‘NoGo’) stimulus when paired with the orange triangle (PA pair). On test trials, the red square is shown paired with previously unseen (i.e. ambiguous) colored shapes. Figure reproduced with permission from McGuire et al. 2017.

Figure 11.3: Example of a ‘Go-Go’ version of the judgment bias task. a) The long rectangular block indicates a high value reward (S++) under the dark lid, shown here on the left. b) The short rectangular block indicates a lower value reward (S+) under the light lid, shown here on the right. c) The block of intermediate length represents an ambiguous cue. Figure reproduced with permission from Pomerantz et al 2012.

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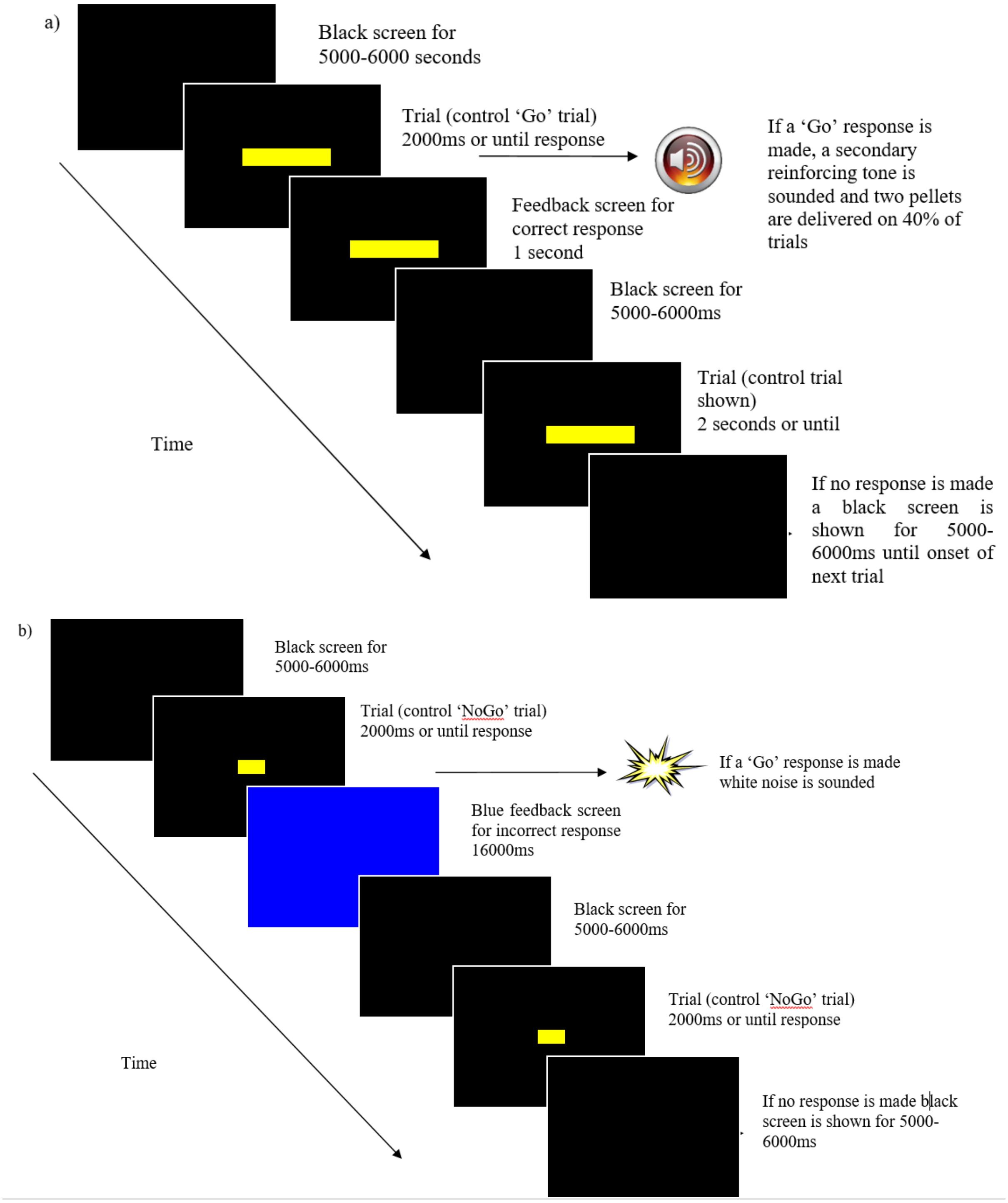
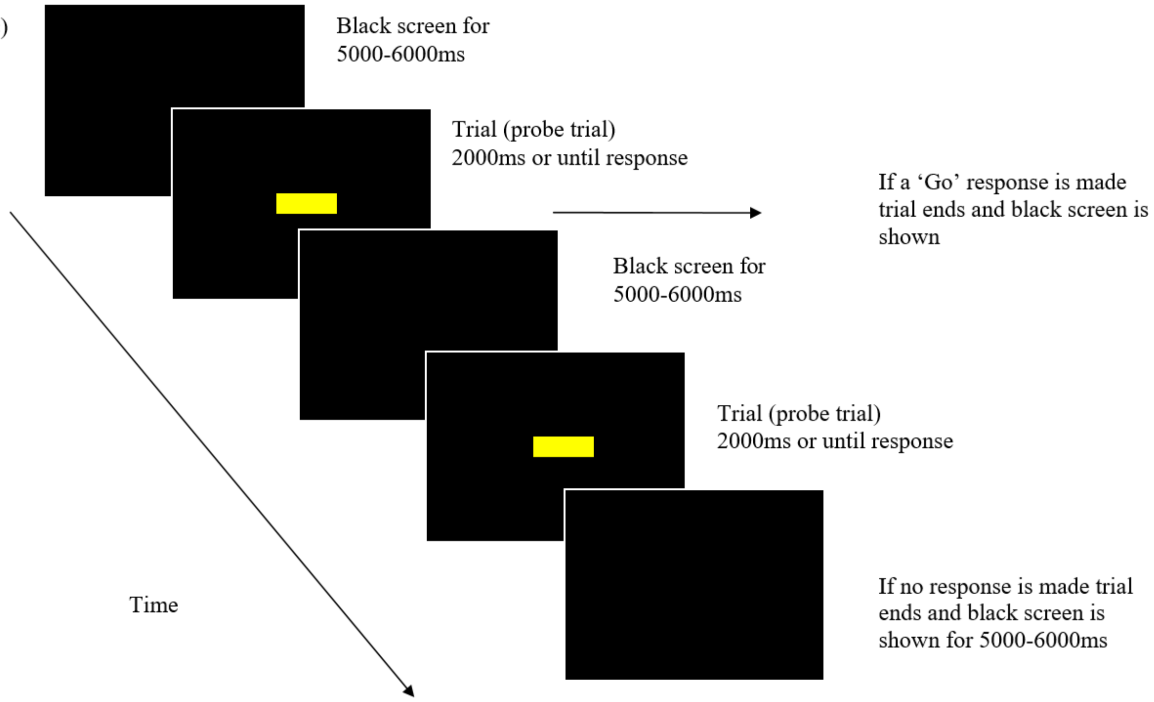
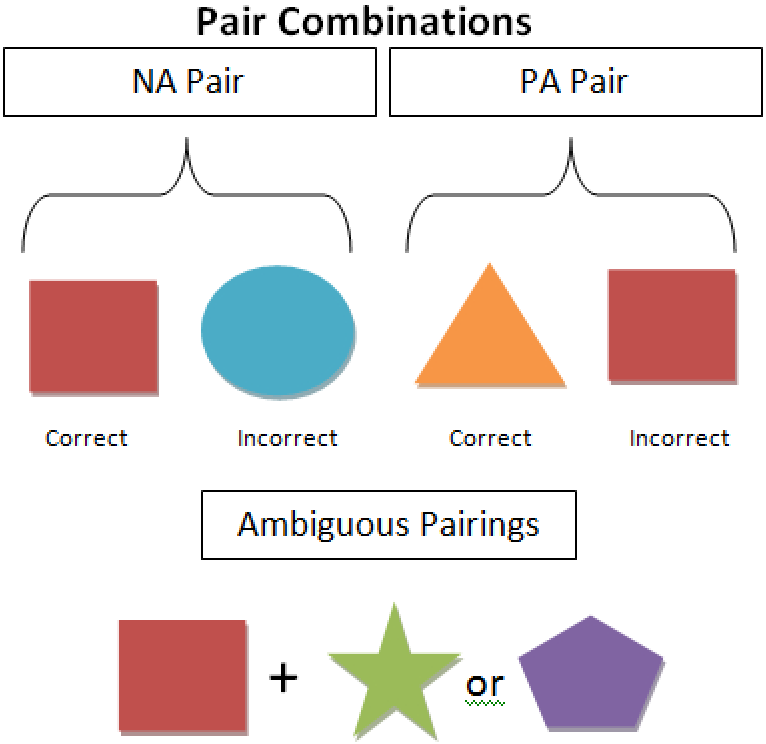
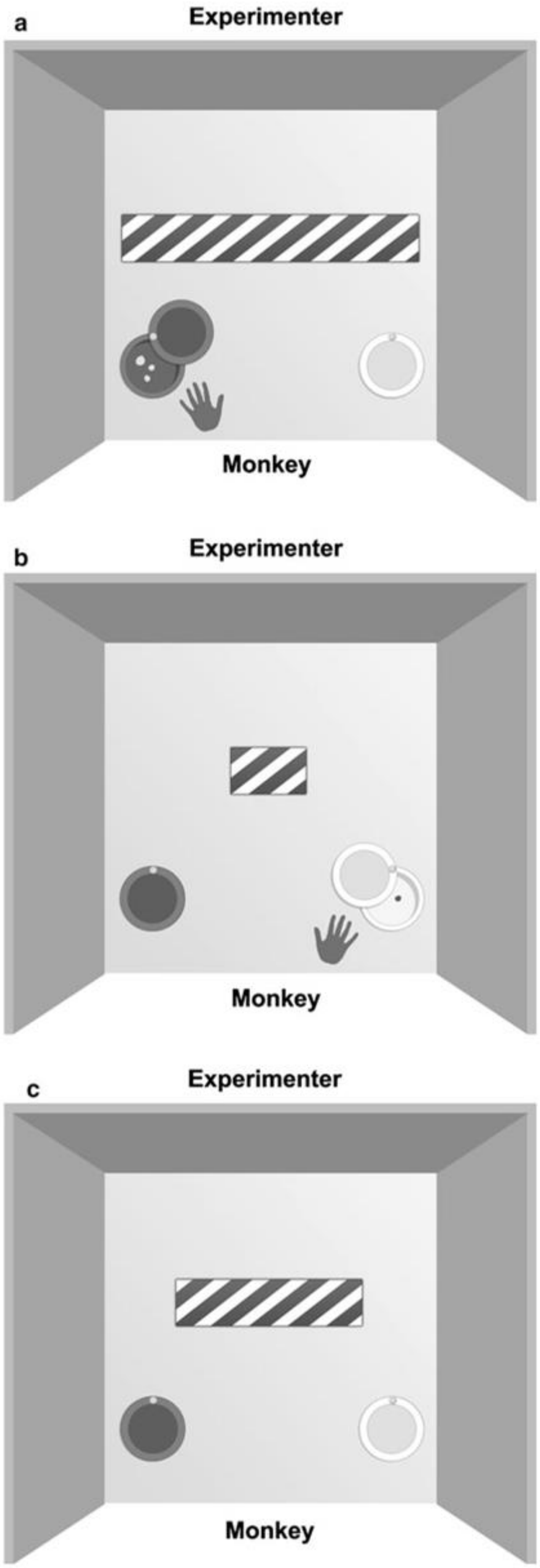

a)
Black screen for
5000-6000 seconds
Trial (control 'Go' trial)
2000ms or until response
If a 'Go' response is made, a secondary reinforcing tone is sounded and two pellets are delivered on 40% of trials
Feedback screen for correct response
1 second
Black screen for
5000-6000ms
Trial (control trial shown)
2 seconds or until
If no response is made a black screen is shown for 5000-6000ms until onset of next trial
Time
b)
Black screen for
5000-6000ms
Trial (control 'NoGo' trial)
2000ms or until response
If a 'Go' response is made white noise is sounded
Blue feedback screen for incorrect response
16000ms
Black screen for
5000-6000ms
Trial (control 'NoGo' trial)
2000ms or until response
If no response is made black screen is shown for 5000-6000ms
Time

c)


Black screen for 5000-6000ms
Trial (probe trial) 2000ms or until response
If a ‘Go’ response is made trial ends and black screen is shown
Black screen for 5000-6000ms
Trial (probe trial) 2000ms or until response
If no response is made trial ends and black screen is shown for 5000-6000ms
Time


Pair Combinations
NA Pair
PA Pair
Correct
Incorrect
Correct
Incorrect
Ambiguous Pairings
+
or


a
Experimenter
Monkey
b
Experimenter
Monkey
c
Experimenter
Monkey