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CONFIDENCE JUDGMENTS IN A SIMULTANEOUS TASK USING SPRAGUE DAWLEY RATS (RATTUS NORVEGICUS)

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CONFIDENCE JUDGMENTS IN A SIMULTANEOUS TASK

USING SPRAGUE DAWLEY RATS (*RATTUS NORVEGICUS*)

By

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Confidence judgments in a simultaneous task using Sprague Dawley Rats (*Rattus Norvegicus*)

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Abstract

In the present experiment, metacognitive confidence judgments were measured in the Sprague-dawley rats using a simultaneous discrimination task. Performance on two types of trials were compared: Forced and Choice. For Forced trials, subjects were required to classify a range of eight tones as either a "long" or "short" tone with the four longest frequency durations comprising the "long" tone category and the four shortest frequency tones comprising the "short" tone duration category. The Choice trials were identical to the Forced trials with the exception that a bailout response was also available, allowing the subject to advance to the next trial without making a discrimination response. For the Forced trials, the subjects performed as expected and made the greatest number of correct discrimination responses for the easy duration tones (e.g. the longest and shortest duration tones) and the greatest number of errors for the difficult duration tones (e.g. the intermediate duration tones). For the Choice trials, the subjects failed to demonstrate greater bailout response use for the difficult duration tones compared to the easy duration tones. The results of the present study suggest that using an auditory test discrimination may be ineffective for determining metacognitive ability in rats.
Keywords: metacognition, uncertainty monitoring, confidence judgment, information processing

Metacognition has been defined in a number of unique ways with an equal number of approaches devised to study metacognition. However, it is agreed that metacognition plays a role in monitoring, and acting on, the individual's knowledge about their knowledge (Hampton, 2009; Smith, Schull, Strote, McGee, Egnor, & Erb, 1995; Smith, Beran, Couchman, Coutinho, 2008; Smith, Beran, Couchman, Coutinho, Boomer, 2009; Terrace & Son, 2009). It is assumed that metacognition is involved in the process of determining how confident the individual is in the accuracy of their knowledge. In comparative studies, metacognitive judgments are measured in terms of confidence judgments. Confidence judgments can be measured by creating discrimination trials with both easy and difficult discriminative tasks and then creating a choice opportunity with an alternative response for declining to participate in the discrimination (a bailout response) (Hampton, 2009).

Comparative metacognitive studies have used three typical approaches as to when the bail-out response is offered; they are known as the prospective task, the simultaneous task, and the retrospective task (Hampton, 2001; Hampton, 2009; Kornell, 2009; Kornell, Son, & Terrace, 2007; Smith, et al, 1995; Terrace & Son, 2009). The prospective task requires making a judgment of confidence before the discrimination task begins (Hampton, 2001). The simultaneous task requires making a judgment of confidence during the discrimination task (Smith et al., 1995). The retrospective task requires making a judgment of confidence after the discrimination task (Kornell, et. al, 2007). Kornell (2009) summed the difference in prospective, simultaneous, and retrospective tasks by using the expressions: "I won't know," "I don't know," and "I didn't know," respectively (p. 14).

During the prospective task, the subject is given the opportunity to proceed with the discrimination trial or choose the bail-out response before the trial begins (Hampton, 2001). The

prospective task can be likened to a gambler drawing his bets before the play is initiated or asking a student how confident they are of their upcoming performance before they take the exam. Hampton (2001) used a prospective task when observing metacognitive responses in rhesus monkeys. The monkeys were given an image that they were then later asked to recall from a selection of four images, in which the original image was shown with three different images. The original image was shown at different time intervals before the task, ranging from 34 s to 38 s. On some of the trials, the choice trials, the monkeys were given the opportunity to make a bailout response or continue on to make a discrimination response (in which they picked the specified item from the four items). The monkeys received peanuts for a correct response, a 15 s time-out for an incorrect response, and a food pellet for a bailout response. The results indicated that the monkeys would chose to bailout for a lesser reward for the more difficult, longer tasks (Hampton, 2001).

` During the simultaneous task, the subject is simultaneously given the opportunity to make a discrimination response or make a bailout response during the trial (Smith et al, 1995). The simultaneous task can be likened to a gambler either choosing “stay” or “draw” during a game or asking a student to answer an item on a test if they are confident or leave a blank response if they are uncertain about their ability to provide an accurate response. Smith et al. (1995) used a simultaneous task when observing metacognitive responses in the dolphin *(Tursiops truncatus)*. The dolphin was simultaneously presented with three paddles during a trial. One paddle represented a discrimination response for a tone below 2100 Hz, one paddle represented a discrimination response for 2100 Hz and higher, and the third paddle represented a bailout response.

During the retrospective task, the subject is not provided a bailout response until after the trial ends (Kornell, Son, & Terrace, 2007). A retrospective task can be likened to asking a gambler how likely of a win is expected after placing a bet or asking the student about their performance after taking the test. Kornell, Son, and Terrace (2007) used a retrospective task when observing metacognitive responses in two rhesus monkeys. The monkeys could make a confidence response or a bailout response. The monkeys could win 3 tokens if the monkey reported high confidence for an accurate response. The monkeys could win 1 token if the monkey chose a low confidence for a after the trial ended. The monkeys would lose 3 tokens if the monkey reported high confidence for an inaccurate response. The monkeys would receive a food reward for each 12 tokens that were obtained (Kornell, Son, & Terrace, 2007)

For the purpose of this study, metacognition will be defined as the internal process of monitoring the self's personal collection of data gained from previous experience and current knowledge which can then direct behavioral responses (Shields, Smith, Guttmannova, & Washburn, 2005). A measurable manifestation of this process can be used by observing confident /uncertain responses. Metacognition has recently been explored by measuring uncertain responses across a variety of species including orangutans, rhesus monkeys, dolphins, dogs, rats, and pigeons as subjects (Foote & Crystal, 2007; Hampton, 2001; Marsh & Macdonald, 2011; McMahon, Macpherson, & Roberts, 2010; Smith, et al, 1995; Zentall & Stagner, 2010). These studies have contributed to our understanding of the decision making process from an evolutionary and neurological perspective.

Hampton (2009) lists key criteria components that must be met when observing uncertain responses of which can be combined into two categories: the discrimination task and the uncertain response. Hampton remarks that it is first necessary to have a discrimination task

which includes hierarchy of tasks ranging from easy to difficult in order to measure accurate and inaccurate responses. Hampton also remarks that is necessary to be able to obtain a measurement of a confidence. One method used for obtaining a confidence rating is by providing a response option to escape or opt-out of making a discrimination response (Smith, et al., 2009). This response leading to an "escape" or "opt out" from a choice response will be referred to as a bailout response. A correct discrimination choice response may result in the delivery of a larger reinforcer than a bailout response. A bailout response typically results in a larger reinforcer than an incorrect discrimination response (Foote & Crystal, 2007; Hampton et al, 2001; Kornell et al, 2007). An incorrect discrimination response often results in a time-out or the lesser reinforcer (Angel, 2011; Foote & Crystal, 2007; Hampton et al, 2001; Kepecs, Uchida, Zariwala, & Mainen, 2008 Kornell et al, 2007; Smith et al, 1995).

The first discrimination task is commonly presented in two distinct types of trials; the Choice trial which provides a minimum of two discriminative responses and also provides a bailout response and the Forced trial which provides only the discriminative responses (Angel, 2011; Foote & Crystal, 2007; Hampton et al, 2001; Smith et al, 1995). Smith, Shields, and Washburn (2003) anticipate that a subject will show a preference to make a discriminative response when the discrimination task is easy and the subject has a high amount of confidence of making a correct response. Likewise, it is assumed that the subject will show a preference for a bailout response when the discrimination is difficult and the subject has a low amount of confidence in making a correct response. Results taken from forced trial performance can be used to support this inference. During a forced trial, it is expected that the number of incorrect discrimination responses will increase with task difficulty. In addition, the sum of errors should be higher for forced trials, especially for the difficult trials in comparison to the sum of errors for

the choice trials. It is inferred that the bailout response provides information about the subject's absolute knowledge (probability of correct answers) and information about the subject's self-confidence/uncertainty in knowledge (probability of escaping making a difficult, discrimination response) (Smith, Shields, & Washburn, 2003).

Smith et al. (1995) pioneered metacognitive research in the comparative field using the bottlenosed dolphin (*Tursiops truncates*). The study included the two prerequisite components: the presentation of a trial with a discrimination response gauged on levels of difficulty and a bail-out response. The dolphin was trained to press a designated paddle for tones that were 2100 Hz or higher tones and another paddle for tones that were lower than 2100 Hz. The task would then become more difficult as the tone played approached 2100 Hz. For example, it would be considered an easy task to discriminate which paddle to push if 1200 Hz was played, but it would be considered a difficult task to decipher which paddle to push if 2099 Hz was played (Smith et al., 1995). If the dolphin pushed the correct paddle, the dolphin would receive a reward of fish. If the dolphin pushed the incorrect paddle, the dolphin received a brief period without a trial, also known as a timeout. The dolphin could avoid a timeout by pressing a third paddle to avoid making any discrimination response, the bailout response. The dolphin did not receive any reward for choosing the bailout paddle but also did not receive any timeout (Smith et al., 1995). The dolphin showed a preference for the bailout option for the difficult trials which may have inspired further comparative research on metacognition.

Recent studies suggest that it might be possible to observe metacognitive ability in the rat (Angel, 2010; Foote & Crystal, 2007; Kepecs, et al, 2008). Foote and Crystal (2007) were the first to publish a metacognitive study using rat as subjects. Foote and Crystal used a prospective task using varying durations of white noise as the stimulus. Kepecs et al. (2008) published paper

observing the uncertain response in Long-Evans hooded rats in a semi-retrospective task using varying concentrations of odor as the stimulus. Angel (2010) used Sprague dawley rats as subjects in a simultaneous task using varying durations of a simple tone as the stimulus.

Foote and Crystal (2007) used eight durations of white noise that ranged on a scale from 2 s to 8 s (2.00, 2.44, 2.97, 3.62, 4.42, 5.38, 6.56, and 8.00 s) in a prospective discrimination task. Eight Sprague dawley rats were given a discrimination task by pressing one of the two available levers to indicate a long duration of white noise or a short duration of white noise. It was expected that the durations that were closer to 2 s or 8 s would be easily discriminated; however the durations would become increasingly difficult to discriminate as they reached the middle of the scale. During the Forced trials, the subjects were presented with the duration of white noise, activate the only operating nose-poke device which would then make the levers available for a discrimination response on the opposing wall. Rats received six pellets for each correct response and no pellets for an incorrect response. During the Choice trials, the subjects were presented with a duration of white noise, and were presented with two operating nose-poke devices. One nose-poke would make the levers for a discrimination response available on the opposing wall and the other nose-poke acted as a bail-out option. Rats received three pellets for the bailout response, six pellets for a correct response and no pellets for an incorrect response (Foote and Crystal, 2007).

The Foote and Crystal (2007) study could be considered a success in that three rats demonstrated use of the bailout response that is consistent with a metacognitive process. Also, the rats showed a higher preference for the bailout response for specific durations in the Choice trials that resulted in greater incorrect responses when presented in the Forced trials. However, the bailout response was distinctively used more often for the durations that were most difficult

to discriminate, suggesting the possibility of a ceiling effect (Angel, 2010). It should also be noted that only three out of eight rats were able to be used for this study, due to five rats failing to use the bailout response. This may be because the layout of the experimental design was overly difficult because the bailout responses were located on a different panel than the discriminative responses. The prospective task creates an additional learning component that could have made the contingency more difficult for the rats to learn.

Angel (2010) conducted a conceptual replication of Foote and Crystal (2007) examining metacognition in the rat using eight tone durations that ranged on a scale from 2 s to 8 s (2.00, 2.63, 3.17, 3.82 , 4.19, 5.04, 6.06, and 8.00) using a simultaneous discrimination task. Two Sprague dawley rats were presented with a discrimination task in which a tone of a specific duration was presented. The subjects pressed one of two available levers to categorize the tone as either a long or short duration. During the Forced trials, the rats were presented with a duration tone followed by the presentation of two levers and received one sucrose pellet for each correct response and no pellets/20 s time-out for an incorrect response. During the Choice trials, the rats were presented with a duration tone followed by the presentation of two levers and illumination of a nose-poke device and received one sucrose pellet for each bailout response, one sucrose pellet for each correct response and no pellets/20 s time-out for an incorrect response.

Some of the possible complications in the Foote and Crystal (2007) study were addressed in the Angel (2010) study. First, the discrimination scale was created so that the differences in the length of the duration tones were lessened in order to avoid the ceiling effect. Second, the chamber's discrimination and response devices were located on the same panel of the chamber which minimized the amount of distance between performing discrimination and a bail-out

response. Third, a simultaneous task was used. The simultaneous task may be the easiest of the three possible approaches for the bailout response.

The present experiment will be a conceptual replication of the Foote & Crystal (2007) study and the Angel (2010) study. Two changes will be the focus in the present study. First, a simultaneous discriminative task will be used because it is a simpler task compared to a prospective or a retrospective discriminative task. Second, the apparatus for the bailout response will be salient.

Methods

Subjects

Twelve Sprague-Dawley rats were used. All rats were 97 days old, weighing an average of 309 grams, when the experiment began. Rats were housed, in pairs, in polycarbonate boxes (480 mm x 270 mm x 220 mm) with ad lib access to water. These procedures were approved by the University of Montana's institutional animal care and use committee (IACUC).Daily food supplements were provided 1 hour after the completion of each experimental session and rationed so that rats would maintain 85% of their *ad-libitum* weights.

Apparatus

Four Standard Modular Test Chambers (Med Associates, Inc., ENV-008) were used. Each test chamber was enclosed in a sound-attenuated box with constant ventilation. Each test chamber was equipped with two nose-pokes, one retractable lever (Lafayette, model number ENV-112CM), a pellet feeder, and a speaker. All response devices, the nose-pokes and the lever, were installed on the same wall. The two nose-pokes were located 80 mm above the chamber floor and positioned (30 mm) from the center of the panel. A signal light was located

above each nose-poke and was only lit when the nose-poke below was functioning. A nose-poke response was recorded when the photo-beam, located inside of the nose-poke device, is broken. The lever was located, equidistant between the two nose-pokes, 100 mm above the chamber floor. A lever response was recorded after a 3 mm depression with a force of 0.20 N. The pellet feeder was located on the wall opposite the response devices. The pellet feeder was used to deliver 45 mg (Dustless Precision pellets, Bio-Serv, Frenchtown, NJ) sucrose pellets. The pellets were dispensed to a food cup located 80 mm above the box floor, centered from the sides of the panel. The speaker was located on the wall directly opposite the response devices.

Procedure

Magazine training

Magazine training consisted of the delivery of 25 pellets per session using a VT-30 sec schedule. Magazine training continued until subjects were reliably consuming a minimum of 85% of the pellets. Magazine training was completed within five sessions.

Response training

Nose-poke training consisted of daily sessions during which subjects were shaped to respond on each nose-poke. Upon completion of nose-poke shaping, single nose-pokes were reinforced with a single sucrose pellet. Upon completion of single nose-poke training, signaled (using a signal light located above the nose-poke) nose-poke training began. Signaled, nose-pokes were presented individually in a pseudo-random order such that no nose-poke was presented more than three consecutive times and rats were required to respond on the signaled nose-poke for the reward to be delivered. Nose-poke training continued until each subject was

reliably obtaining 90 pellets during a 60 minute session. Nose-poke training was completed within eleven sessions.

Lever press training began following the completion of nose-poke response training. Lever press training consisted of daily sessions during which subjects were shaped to respond on the lever. Upon completion of lever press shaping, lever presses were rewarded with a single sucrose pellet. Lever press training continued until each subject was reliably obtaining 90 pellets within a 60 minute session. This phase was completed within three sessions.

All Response (AR) training began following the completion of lever press training. AR training consisted of daily sessions during which a nose-poke or a lever was presented individually in a pseudo-random order such that no nose-poke response or lever response was presented more than three consecutive times. Each response option was presented 40 times per session and rewarded with a single sucrose pellet. AR training continued until each subject was reliably obtaining 120 pellets during a 60 minute session. AR training was completed within six sessions.

Discrimination training

Discrimination training began upon completion of AR training. Subjects were presented with either a short anchor tone (2 ms) or a long anchor tone (8 ms). Immediately after the presentation of the tone, both nose-pokes were made available, associated signal light was turned on, for responding. A correct classification of an anchor tone resulted in the delivery of three pellets. An incorrect classification of an anchor tone resulted in the delivery of no pellets and a 20 s time-out. An inter-trial interval (ITI) of 10 s began after the reward/time-out period was

complete. During the ITI the nose-poke signal lights were turned off and the lever was retracted. A new trial began upon completion of the ITI.

Tone classification was counterbalanced across subjects such that a long anchor tone classification was indicated by a left nose-poke response for half the subjects and a right nose-poke response for the remaining subjects. Each anchor tone was presented pseudo-randomly, with no more than three of each tone presented consecutively. Discrimination training continued until subjects correctly met the classification accuracy criteria of 75% or higher.

Testing

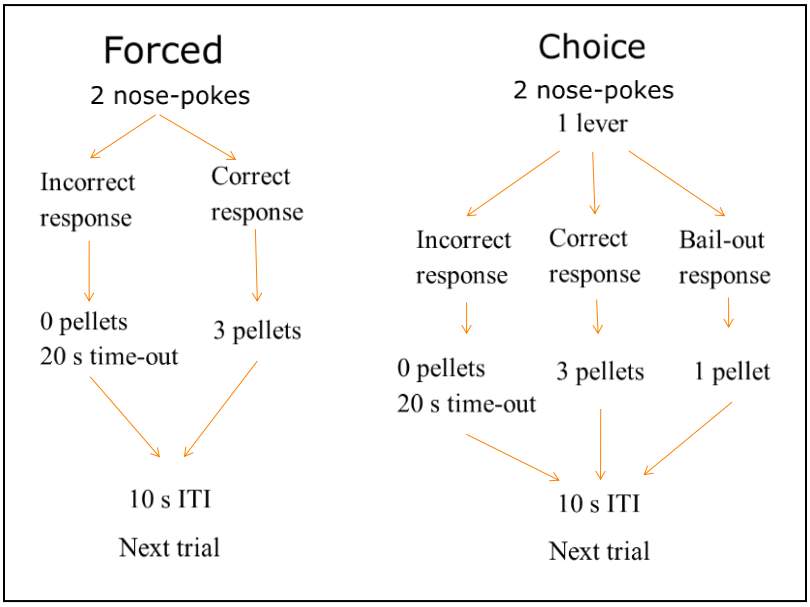
Testing trials began upon completion of Discrimination training. A total of eight duration tones were used for the testing phase. The duration tones were divided into two categories; four tones were classified as short tones (2.00 s, 2.63 s, 3.17 s, and 3.82 s) and the remaining tones were classified as long tones (4.19 s, 5.04 s, 6.06 s, and 8.00 s). Each daily session consisted of three continuous cycles of 8 Forced trials followed by 16 Choice trials for a total of 72 trials per session, The nose-poke indicating a short or long categorization was counterbalanced across subjects such that a short duration classification was indicated by a left nose-poke response for half the subjects and a right nose-poke response for the remaining subjects. The lever, representing the bailout response, only functioned during the Choice trials

During the Forced trial phase all eight duration tones were presented in a random without replacement order. Forced trials began with a presentation of a tone. Upon termination of the tone both nose-pokes were made available, associated signal light was turned on, for responding. When the subject made a classification response, by triggering a nose-poke, both nose-pokes were made unavailable and the appropriate reward/time-out was delivered. A correct

classification resulted in the delivery of 3 pellets. An incorrect classification resulted in a 20 s time-out, during which the lever was retracted and the lights above both nose-pokes were not lit. An ITI of 10 s began after the reward/time-out period was complete. A new trial began upon completion of the ITI until each of the eight duration tones had been played once.

During the Choice trial phase all eight duration tones were presented twice in a random without replacement order. Choice trials began with a presentation of a tone. Upon termination of the tone, the associated signal light above both nose-pokes was lit and the lever press extended. When the subject made a classification response or a bailout response, triggering a nose-poke or a lever press respectively, both signal lights above nose-pokes were turned off, the lever press retracted, and the appropriate reward/time-out was delivered. A correct nose-poke classification was rewarded with 3 food pellets. An incorrect nose-poke classification resulted in a 20s time-out. A lever press, a bailout response, was rewarded with 1 food pellet. An ITI of 10 s began after the reward/time-out period was complete. A new trial began upon completion of the ITI until all each of the eight tones had been played twice. Figure 1 is a diagram of the possible behaviors and consequences for the Forced trials and the Choice trials.

Figure 1



Results

The eight duration tones were collapsed by trial type difficulty (TD). The easiest trial type difficulty (TD1) represented the anchor tones, which were the shortest duration tone (2.00 s) and longest duration tone (8.00 s). It was expected that response accuracy would be highest for TD1 tones. The most challenging trial type difficulty (TD4) represented the duration tones that were most similar (3.82 s and 4.19 s). It was expected that response accuracy would be at chance performance for the TD4 tones. Table 1 shows the number of discrimination choices and for each subject during the Forced phase of the experiment.

Only subjects that made a discrimination response, classified the tone duration as either short or long, for a minimum of 50% of the Choice trials were included in the data analysis. Only four subjects (S01, S03, S06, and S07) met this criterion. Specifically, S01, S03, and S06 made a discrimination response for a minimum of 90% of the Choice trials and S07 made a discrimination response for 51% of the Choice trials. The remaining subjects made a

discrimination response for a maximum of 2% of the Choice trials, except for S02 who made a choice for 17% of the Choice trials. The following data analysis is based on the four subjects that met the criterion-S01, S03, S06, and S07.

Hypothesis 1

It was hypothesized that subjects would demonstrate greater accuracy for the easiest TD level and accuracy would incrementally decrease as the TD level increased during the Forced Trials. The number of correct discrimination responses for each subject at each level of TD is shown in Table 1. A Chi-square test of independence demonstrated a significant difference in the number of correct discrimination responses across the TD levels, $X2$ (3, N = 4) = 25.179, p < .0001. As predicted, discrimination accuracy declined as TD increased, with the highest TD level resulting in chance performance.

Table 1

Frequency and Proportion of Correct Responses by Trial Type Difficulty (TD) in Forced Trials.

Subject	Trial Type Difficulty			
	TD 1	TD 2	TD 3	TD 4
S01	63	61	54	46
	75%	73%	64%	55%
S03	69	59	59	44
	82%	70%	70%	52%
S06	71	63	59	44
	85%	75%	70%	52%
S07	78	69	58	42
	93%	82%	69%	50%
total	281	252	230	176
	84%	75%	68%	52%

Note. The accuracy performance of subject 01 (s01), subject 03 (s03), subject 06 (s06), and subject 07 (s07)
is arranged by the frequency of accurate responses in the shaded row and the proportion of accurate
responses in the unshaded rows. The combined frequency/proportion of the four subjects (total) shows the

highest amount/proportion of accurate performances during the easy TD trials and the lowest amount/proportion of accurate performances during the hard TD trials.

Hypothesis 2

It was hypothesized that subjects would incrementally increase the use of the bailout option as the TD level increased. The number of bailout responses for each subject at each level of TD is shown in Table 2. A Chi-square test of independence failed to demonstrate a significant difference between bailout responses across the TD levels, $X2$ (3, N = 4) = 0.958, $p < 0.812$. There was little variation in bailout response across the TD levels as each subject demonstrated a similar number of bailout responses for the easiest TD level compared to the intermediate or most difficult TD level. These data could not confirm a strategic use of the bailout response.

Table 2

Frequency of Bailout Responses by Trial Type Difficulty (TD) in Choice Trials

Subject	Trial Type Difficulty			
	TD 1	TD 2	TD 3	TD 4
S01	15	10	7	6
S03	12	12	17	11
S06	6	8	8	8
S07	88	86	92	85
Total	121	116	124	110

Note. There is little variation in frequency of the use of the bailout response across the TD levels.

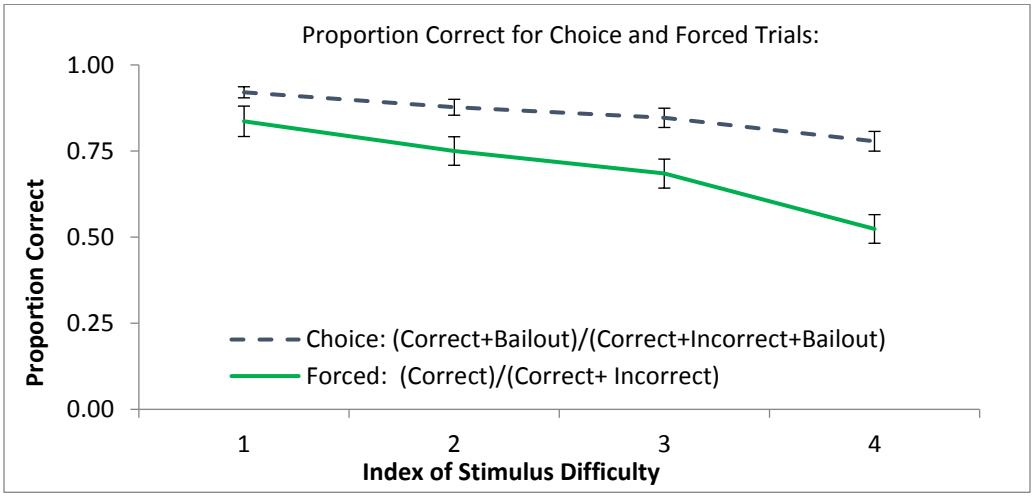
Hypothesis 3

It was hypothesized that subjects would demonstrate a greater mean number of correct discrimination responses during the Choice phase (compared to the Forced phase). It was expected that subjects would show greater use of the bailout response when uncertain, resulting

in an increase in the number of overall correct discrimination responses. There were a greater number of Choice trials (2:1) so the frequency of accurate responses was greater for the Choice phase. However, as there was no strategic use of the bailout response, there was minimal difference in the mean number of correct discrimination responses between the Choice phase and the Forced phase. Surprisingly, subjects were negligibly less likely to make an accurate response during Choice trials across all TD levels. For example, subjects had an overall probability of 84% for the TD1 level during the Forced phase, but an overall accuracy of 78% for the TD level during the Choice phase. Response accuracy was at chance performance for the most difficult TD levels for both Choice (48%) and the Forced phases (52%).

Figure 2 shows the average of combined correct discrimination responses for the Forced and the Choice phase (an average of discrimination responses combined with bailout response). There is an overall increase of correct average responses when the bailout response is included with the discrimination response, but there is a minimal change in accurate responses as the level of TD increased.

Figure 2



Note. Figure 1 shows a linear decline in accurate responses as the TD increases from easy to hard in the Forced trials. The difference in accurate responses in the Choice trials between correct

responses scored when making a correct discrimination response and correct discrimination responses scored when including the bailout as a discrimination response are included. The figure does not show an increase accurate responses as the TD increases to harder trials during Choice trials, regardless of whether the bailout response is included in the calculation of correct responses.

Discussion

This study was designed after observing that previous metacognitive research using rats reported minimal use of a bailout response. The primary objective of the present study was to create an operant procedure that included a highly salient bailout response. It was predicted that rats would be more likely to demonstrate metacognitive processing if the bailout response was a more salient option. The results clearly demonstrated the efficacy of the task difficulty manipulation as evidenced by the incremental decrease in response accuracy as task difficulty increased. However, while the frequency of the bailout responding was higher than reported in previous studies, the overall use of the bailout was inconsistent with what was expected of metacognitive processing. The remainder of the discussion will explore possible reasons for the present results.

Task difficulty is a key manipulation used in previous research examining metacognitive ability in rats and other animals. For example, when Smith et al. (1995) pioneered the study of metacognitive processing in comparative research, it was predicted that trials that included a level of difficulty continuum ranging from easy to difficult would create a cognitive state of knowing during the easy trials that would incrementally change into a state of uncertainty during the difficult trials. This was needed for two reasons: 1) to determine the psychophysical threshold of the subject and 2) to create a cognitive state of uncertainty (Smith et al., 2010). Smith et al. (1995) confirmed the psychophysical threshold of the dolphin. The proportion of accurate responses was greatest during the easiest trials when the dolphin was forced to make a

discrimination response and the proportion of accurate responses gradually decreased to near chance performance during the most difficult trials. Additionally, Smith et al. (1995) found that the dolphin performed as predicted if experiencing a cognitive state of uncertainty when an option to escape the discrimination task was available by using a bailout response. The use of the bailout response increased as the trial difficulty increased, indicating metacognitive processing. Put another way, less frequent use of the bailout response during the easier trials indicated greater confidence in the discrimination response while greater use of the bailout response during the more difficult trials indicated less confidence in the discrimination response (Smith et al., 2010).

The results of the present study confirmed the psychophysical threshold for rat via the intended trial difficulty (TD) manipulation. The percentage of correct responses for the Forced trials demonstrated a clear linear decline from greater than 90% accuracy from the easiest TD level to near chance performance for the hardest TD level. While the present study is consistent with other studies using rats, the results from the Foote and Crystal (2007) study did not reflect this pattern of performance across TD levels. In the study by Foote and Crystal (2007), the mean accuracy of three subjects was above 75%, for both of the intermediate TD levels and accuracy noticeably declined to chance performance only at the hardest TD level. This unexpectedly high proportion of accurate responses across the TD levels could suggest a ceiling effect (Angel, 2010).

The differing accuracy due to the TD manipulation in the Foote and Crystal (2007) study may be partially explained by the specific design that was used. Like Angel (2010), the present study used a simultaneous design, whereas Foote & Crystal (2007) used a prospective design. In a simultaneous design, the device used for the bailout response is available concurrently with

device used for the discrimination response. In a prospective design, the device used for the bailout response is made available before the device used for the discrimination response becomes available. The prospective design adds temporal distance between the bailout response and the discrimination response so that the intended discrimination response may be forgotten before it is available (Angel, 2010).

Additionally, the differing accuracy due to the TD manipulation in the Foote and Crystal (2007) may be partially explained by the variation in the physical layout of the operant chambers. Like Angel (2010), the present study was designed so that the device used for bailout response was located on the same panel as the device used for the discrimination response. Foote and Crystal (2007) used a design where the device used for the bailout response was located on a panel opposite the panel used for the discrimination task. Thus, the physical distance between the two types of devices used for the bailout response and the discrimination response also resulted in a temporal distance between the bailout response and the discrimination response which may be used to explain why there was a disjointed relationship between the confidence response and task difficulty.

As noted by Smith (2010), the key to interpreting confidence judgments in comparative metacognitive research is comparing the frequency of bailout responding with trial difficulty. Confidence is expected to be high when a correct response is likely and a bailout response is expected when a correct response is uncertain. The percentage of bailout responses in the present study was unrelated to TD.

It was especially difficult to interpret the confidence judgments in previous rat studies using an auditory discrimination task because of minimal use of a bailout response (Angel, 2010, Foote

and Crystal, 2007). Although the rats in previous studies showed minimal use of the bailout response, there was a slight indication that a relationship between the bailout response and the TD may exist. The only subject from the Angel (2010) study that used the bailout response displayed an increased use of the bailout response (from just below 60% to just above 70%) as task difficulty increased, however this was not a statistically significant increase. The three subjects from the Foote and Crystal (2007) study that used the bailout response displayed an increase use of the bailout response (from roughly 20% to just below 50%), as TD increased, however, the overall use of the bailout response was minimal.

A key purpose of the present study was to determine whether increasing the use of the bailout response would demonstrate a more strategic, metacognitive use of the bailout response in the rat. As Angel (2010) predicted, increasing the saliency of the response device used for the bailout response was effective in increasing the bailout response. In the Angel (2010) study, a nosepoke was chosen as the device for the bailout response. The nosepoke was centered between the two levers that were used for the discrimination task. The availability of the bailout response was signaled by a light, meaning there was only a visual indication of its availability. Consistent with other metacognitive studies involving rats, use of the bailout response in the Angel (2010) study was minimal/nonexistent. In contrast, the lever was used for the bailout response in the present study. The lever was centered between the two nosepokes that were used for the discrimination task. The lever was decided to be the most salient device because it protruded from the wall when it became available, meaning there was a dimensional, visual, and auditory indication of its availability. Unlike the subjects in other studies, two-thirds of the rats in the present study showed a strong preference for the bailout response when it was available. Seven of the subjects consistently used the bailout response for more than 97% of the Choice Trials.

However, the observed frequent use of the bailout response in the present study did not conform to a pattern of responding consistent with metacognitive processing.

In other metacognitive comparative studies, dogs, monkeys, orangutans, and chimps demonstrated increased use of the bailout response as TD increased. It was surprising that the rats in the present study failed to demonstrate an increased use of the bailout response as TD increased, given the overall increase in use of the bailout response. One explanation for this discrepancy may be how we interpreted the relationship between performance, TD, and the bailout response (Terrace and Son, 2009; Smith 2009; Angel, 2010). The original explanation for human-like metacognitive performance in animal research by Smith et al (1995) posed that a measurement of the psychophysical threshold of the subject could be measured by an incremental decrease in performance as TD increased. Smith suggested that as TD increased, uncertainty increased and the bailout response was most likely to be used as an escape from a stimulus that created uncertainty. The dolphin used in the Smith study was more likely to make a discrimination response for the set of stimuli that was easy and use a bailout response for the set of stimuli that was more difficult (1995). Although the psychophysical threshold was created, the results from the present study failed to show an increase in bailout response during the hard TD levels as Smith (2010) predicted.

Terrace & Son (2009) provided an alternative explanation of the dolphin's performance. It was noted that there was a greater amount of easy TD trials than high TD trials. The dolphin may have been using the bailout response as an efficient strategy to get to the easier trials. The bailout response acted as a prompt for a bypass through the higher TD levels, as another stimulus, and may not have been used as an escape for any internal uncertainty (Terrace & Son, 2009). Smith (2009) noted that ending each trial with reinforcement may also encourage behaviors based on

the reward. Additionally, as noted by Angel (2010), only the easiest TD trials were used during the pretraining for the discrimination response in the Forced trials. The intermediate TD trials are not introduced until testing, when the bailout response is available during Choice trials, which may influence how the tones are categorized. The intermediate tones may be categorized as an association with the bailout response, not categorized as an association with the internal state of uncertainty.

The rats in the present study were unique from rats in other metacognitive studies because of the high use of a bailout response. The results of the majority of the rats in the present study were excluded because of a near exclusive use of the bailout response whereas the rats in the other studies were excluded because there was minimal/non-existent use of the bailout response. Moreover, from the responses of the four subjects that were included in present study, the results did not demonstrate that the use of the bailout response was associated with any TD level. This behavior is not consistent with the stimulus-reinforcement explanation (Angel, 2010; Smith 2009; Terrace and Son, 2009). Nakumara (2011) suggested that there may be a theoretical difference in the way other mammals use metacognitive abilities from pigeons and the same may be said for rodents.

It could be argued that using sound for the discrimination task is an insufficient modality to use when observing rats. Kepecs et. al (2008) were interested in the association with activity in the orbitofrontal cortex and confidence and created a discrimination task using varying concentrations of a scent mixture. Two odorants were used to create categories ranging from a pure concentration of the odorant to an even binary concentration of each of the odorants. As anticipated, that there were a greater number of accurate discrimination responses between the pure odors and the discrimination responses became less accurate as the concentration became

more binary. A measurement was taken of the neuron activity in the orbitofrontal cortex (OFC) and, as expected, neurons in this area were more likely to fire, and fire more vigorously, as the concentration become more binary. These results could be used to suggest a neural measurement of confidence that was contingent on the ease of the task. Contradictory activity of a smaller percentage of OFC neurons when the concentration was pure makes these results difficult to interpret. A similar discrimination task using varying concentrations of scents may be useful.

A spatial task has also been shown to be a successful design for observing the possibility of metacognitive ability in the rat. Kirk et. al (2014) used two variations of a maze to observe information-seeking behavior. In the first experiment, three different groups of twelve rats were placed in a T-maze that ended with one of the alleyways containing food. All rats were trained to push a lever at the end of the maze, centered at the T, between the two alleyways. Pushing the lever was reinforced by the delivery of sucrose pellets. The first group of rats were also trained that pushing a lever was contingent on illuminating the correct alleyway containing the food. Each of the subjects in the other two groups were yoked to a subject in the first group for the experiment. The second group of rats only found a reward at the end of the alleyway if their yoked partner had received a reward, regardless of whether the alleyway was lit. The third group of rats were forced to go down the same alleyway choice as their yoked partner and only received a reward in the lit alleyways. The rats in the first group were most accurate when the pushed the lever and the alleyway containing the alleyway was illuminated. The likelihood of the rats in the first group going down the alleyway with the reward dropped to chance probability if the rats did not push the lever and the alleyway was not illuminated. Extinction was successful for rats in second group and the third group when pushing a lever was no longer reinforced by delivery of sucrose pellets and only resulted in correct alleyway being illuminated. However, rats

from the first group continued to use the lever when it was no longer immediately reinforced but could be used as a cue for the correct alleyway. By using comparison groups, Kirk et. al not only demonstrated that the first group would using the lever as prompt for information. Kirk et al. (2014) ran a second spatial experiment using ten rats in an eight-arm radial maze, increasing the number of non-reinforced alleys. For some of the trials using the eight-arm radial maze, the alleyway containing food was illuminated if the rat pushed a lever in the middle of an eight-arm radial maze and for the remainder of the trials the food remained in the same alleyway. As they anticipated, the rats were less likely to push the lever if that request for further information was unnecessary.

The results from present study, and other studies using an auditory discrimination task, suggest that rats do not have metacognitive ability. However, other studies using the olfactory discrimination task and spatial discrimination task have been more successful in finding qualities that appear to be metacognitive. The results from the Kepecs et. al (2008) study indicated that the rats experience tensions in reward expectation based on current knowledge during an olfactory discrimination task. The results from the Kirk et al. (2014) study indicated that rats will request for further information when their confidence is low during a spatial discrimination task. Further research using the designs that match the evolutionary preparedness of the rat may be used to better understand the possibility that metacognitive ability in the rat.

It would be interesting to expand on the findings from Kirk et al. (2104) and see how rats request for further information in different types of mazes. The Morris water maze, where subjects are placed in a pool to find a platform to escape from water, is a spatial task that could be used to test information-seeking behavior in the rat. Shettleworth (1998) noted how rats use physical landmarks above the water as a guide to find the platform. The location of the starting

position of entering maze and location of a hidden platform in the Morris water maze can be changed for each trial so that a changing physical landmark, a cue, would be a more effective tool than an egocentric cognitive map to use to find the hidden platform.

One possible way to use the Morris water maze would be to design a similar t-maze used by Kirk et al. (2014). For example, a rat could swim down an alley way that dissects into two different rooms. One room is marked by a checkered flag the other room is marked by a white flag. There is a checkered flag above the hidden platform if the rat swims into the room with the checkered flag. There is no flag to be used a landmark for the hidden platform if the rat swims into the room with the white flag.

The Morris water maze could also be used so that the subject would have to swim to a certain location in order to view the landmark above the platform. This would be difficult because rats have a large field of vision. One possible solution would be to mask the available field of vision directly behind the rat. The rat would have to swim to the center of pool and reorient themselves back to the starting gate, where there would be a landmark above the hidden platform. Another possible solution would be to have a rat swim to a flag on the side of the pool which would prompt a landmark flag above the hidden platform to be raised. Either of these trials could be compared against other trials where there is a platform in the back of the pool, always in the same location, but without any landmark flag.

The performance of the rats in the Morris water maze could be used to gauge whether rats will seek for further information when needed. It would be expected that the rats would alter their behavior so that they would quickly gain visual access to the landmark above the ever-changing hidden platform rather than depend on any ineffective cognitive map. The results from

these studies would likely support the findings from Kirk et al. (2014) and may be used to launch a variety of similar confidence judgments tasks using spatial tasks.

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