
Extended Materials and Methods

Study animal and husbandry

The Eastern Water Skink (Eulamprus quoyii) is a ground-dwelling lizard found throughout much of southeastern Australia. Males of this species defend territories and adopt alternative reproductive tactics and have been suggested to form dominance hierarchies [1, 2]. As such, males tend to be visible to one another in the landscape but do not form groups. They are capable of rapid spatial learning and do well in captivity [3]. We used E. quoyii from our captive colony that was originally maintained in large semi-natural enclosures as part of a mating experiment conducted in 2010 [2, 4]; young lizards were born in 2011. Heat cable was placed under part of each lizard’s enclosure to provide a thermal gradient. Enclosures were lined with mulch substrate and each lizard was provided with a single refuge, a water bowl, and thermoregulatory opportunities. Lizards were housed in these enclosures two days prior to the beginning of the habituation stage and remained there for the duration of the experiment (except for a few demonstrators; see below).

Social demonstration experiments

For logistical reasons we tested six ‘old’ and six ‘young’ lizards at a time (i.e. a single batch) for a total of three batches. We randomly allocated lizards to treatments and balanced the number of young and old lizards. In all experiments we conducted two trials per day, in the morning (0900-1100h) and the afternoon (1300-1500h) with a minimum interval between trials of 1.5 h (1.5-3 h). Trials were run every day for the duration of the experiment. Before commencing experiments demonstrators were trained to remove the lid independently of experimental lizards and we ensured that demonstrators were consistently removing lids
before commencing experiments. During this period, experimental lizards continued the
habituation stage I. If, during the experiment, the demonstrator lizard was not motivated to do
the task, we did not count the trial and we switched this demonstrator with a demonstrator
from a lizard in the control treatment (n = 3).

Stage I. Habituation – feeding from a dish

We placed a single petri dish on a block of wood and secured it in place using putty
(Bluetak®). Black, opaque electrical tape was wrapped around the sides of the dish so that
lizards could not use visual cues during the experiment. A single mealworm was placed in an
uncovered dish during each trial. Lizards had to eat from the open dish at least 6 times in a
row to move to the next stage. Mealworms were approximately 3 cm in length.

Stage II. Instrumental task

All trials were video recorded using a CCTV system (Avermedia with Sony 1/3” high
resolution color cameras) that enabled us to record the latency until the lid was displaced.
Lizards could either learn how to manipulate this lid from demonstrators in order to gain
access to the food reward, or learn by themselves. All trial videos were scored by a single
observer, however, it was not possible to score trials ‘blind’ because the camera captured
multiple lizards in the same frame. Given the lack of ambiguity of our variables (lizards
either displaced the lid or not) and because all trials were conducted without observer
interference, we doubt this confounded the results in any way.

Stage III. Training – experimental lizards trained to manipulate lid

Not all lizards learnt to displace the lid in the instrumental task. Therefore, prior to the
association task, lizards were trained to open the lid covering the dish in the instrumental
task. We used the same habituation procedures demonstrators experienced, except that we switched to a two-dish habituation procedure, where one of the two dishes was three-quarters covered and the second dish was fully covered. This expedited training of the instrumental task, particularly for those lizards that were unsuccessful. One mealworm was placed in each of the two dishes. A lizard was considered to have learnt how to shift the lid when it ate from both dishes 5/6 times.

Stage IV. Association task

The association task required that lizards (n = 36) learnt to associate the food reward with a dish covered by a blue lid. We randomized and counter-balanced the position of the blue dish (right or left placement) to account for possible lateralization biases and then kept it in the same position for every trial. We were therefore not able to test whether lizards used spatial or colour cues to learn the task. We did this deliberately to expedite learning since our goal was not to understand what cues lizards were using to learn tasks, but to determine whether lizards were capable of social learning. To ensure that demonstrators were presenting unambiguous information to experimental lizards in the social treatment we firmly attached the white lid to prevent removal.

To test whether our learning criteria correctly categorized learners, we ran a subset of lizards (n = 21) for five or more trials beyond their learning trial. We then tallied their overall learning score to see whether it was significant according to a binomial choice test. In total 20/21 (95%) lizards with five or more trials beyond their learning trial (11-32 trials in total per lizard; mean = 19.81 ± 1.40) retained a significant tally of choosing the blue lid in the first try, strongly suggesting that our learning criterion was sufficient.
Statistical analysis

Data used for all analyses are located in the Dryad Digital Repository, http://datadryad.org/resource/doi:10.5061/dryad.6rj28 [5]. We analyzed the probability of learning the instrumental task using generalized linear models (GLMs) with a binomial error distribution (‘logit’ link). We included treatment and age as two-level categorical variables along with an interaction between age and treatment because we hypothesized that there may be differences in the use of social information between young and old lizards. We included ‘batch’ in our models to control for batch effects. Latency to open the dish and choose the blue dish was first log transformed prior to analysis to ensure normality of residuals and modeled using a Gaussian error distribution (identity link) using a GLM. To supplement these analyses we also ran generalized linear mixed models (GLMMs) using all available trial data for each individual. We treated correct and incorrect choices (‘1’ or ‘0’) as coming from a binomial probability distribution (i.e. binomial error – logit link) and included treatment, age and a treatment by age interaction in the model. We also estimated a fixed effect for trial to account for the fact that the probability of making a correct choice should increase across trials for individual lizards because lizards were not rewarded for opening the white dish. In all models we controlled for batch effects and included lizard ID as a random effect to account for non-independence in measurements from the same lizard. To better account for the correlation between residuals across trials within lizards, given the difficulty in estimating random slopes, we re-ran our model using generalized estimating equations (GEEs) and included an AR1 correlation structure to test whether temporal correlation affected our estimates. This gave similar results to our GLMMs and thus we present results from our random intercept model. Latency to choose the correct dish was modeled using a GLMM with a Gaussian error distribution. In all cases models were simplified using likelihood ratio tests by dropping each term from the full model and computing the $\chi^2$ test statistics (binomial
or Poisson models) or F- statistics (Gaussian and quasipoisson/binomial) and their corresponding p-values are presented for each predictor variable dropped from the final model. Interactions were dropped first and then models were refitted and each term excluded one at a time from the main effects model. In Poisson and binomial GLMs and GLMMs we tested whether inferences were affected by over-dispersion (variance estimate deviates from the mean) by re-running our top-supported models using either a quasipoisson/binomial error distributions (GLMs) or including an observation level random effect (GLMMs). All analyses were run using ‘lme4’ in R [6].

Assessing motivation

We considered whether lizards from the different treatments might have differed in their levels of motivation because of a range of factors including age, mass and body size. First, animals were completely randomized to each of the groups. Age is strongly related to both mass and body size, as is the case in most lizards, and thus these variables were not included in the final models. Although younger animals were smaller and lighter than older males, we are confident that this did not lead to differences in motivation between groups. In the association task, lizards did not eat in 9/797 (1.13%) trials based on all the lizards (young and old) in the study. Furthermore, these ‘no eat’ trials were spread out across the groups (young-social: 2; old-social: 5; young-control: 1; old-control: 1) and were not counted towards the learning tally or in the models. In the instrumental task, which was much more difficult to learn, we are also confident that motivation was not a driver in whether lizards removed the lid or not. In the 12 trials prior to the start of the instrumental task (habituation to eating from the dish and the 6 trials viewing prior to start of the task) only 3/36 lizards did not eat during all of their trials. These lizards (1 young and 2 old) did achieve the learning criterion and also ate very consistently in the association task. This is not what we would predict if there were
differences in motivation driving our effects, but rather we would expect to see older lizards having far more trials where they did not eat, which was not the case. Based on these data we are convinced that motivation was not an issue for our tasks.

Results

Given the age*treatment interaction, we have further analysed our data and tested for significant differences between old lizards and young lizards in the control and social demonstration experiments. As expected, old lizards in the social treatment were significantly different (took more trials to learn) compared to young lizards in the social treatment ($t = -2.8$, $df = 11.2$, $p = 0.02$), while old lizards in the control treatment and young lizards in the social treatment were not significantly ($t = -1.64$, $df = 13$, $p = 0.13$) different.

Fig S1 – Predicted probability of choosing only the blue lid (solid lines) and 95% confidence intervals (dashed lines) for a) ‘Old’ lizards in the social demonstration (‘black’) and control (‘gray’) treatments; b) ‘Young’ lizards in the social demonstration (‘black’) and control (‘gray’) treatments.


