Statistical Analyses

All analyses were carried out in R (v 3.3.0, R Development Core Team 2010). In all models, treatment (social and control) was coded as two level factors. Batch ID was included in all models as a covariate. We used generalised linear models (GLM) to model the mean trials taken to learn each task with a negative binomial error distribution in the ‘lme4’ package (Bates et al. 2015). Similarly, the number of errors during the learning phase for the association task was also modelled using a GLM with a negative binomial error distribution.

[Survival analysis]

Bayesian generalised linear mixed effects models (GLMM) from the ‘MCMCglmm’ package (Hadfield 2010) were used to analyse the probability of making a correct choice and the probability of flipping the correct lid *only* with binomial errors (logit link). We included as interaction term between treatment and trial and modelled the change in probability between the treatment groups across trials. Default uniform priors were used for fixed effects. The residual variance was fixed at one, as this is what the ‘logit’ family assumes. Lizard ID was fitted as random intercept and trial number as a random slope. We specified the prior variance-covariance matrix of the random effects as V = with nu = 0.002. We ran 2,000,000 iterations, with a thinning interval of 1000 and a burn-in of 15,000. The trace plots were visually inspected to ensure the samples were mixing well. We performed Geweke and Heidelberg diagnostics to ensure our samples were not strongly correlated. Posterior modes and 95% credible intervals are reported. When interaction terms were not significant, they were removed and the models were rerun, thus main effect estimates are therefore derived from models with non-significant interaction terms excluded.

We also considered potential motivational differences between treatment groups in attempting trials by checking whether observer lizards attempted at least 80% of their trials. All lizards attempted at least 80% of their trials, thus motivation should not have confounded our results.

The robustness of our learning criterion for the association task was assessed using a subset of lizards that had more than eight trials after the trial they learnt the task (n = 27). We tallied the number of lizards that retained a significant binomial choice of choosing the correct dish after reaching the learning criterion. In the association task 17/27 (63%) lizards retained a significant tally, suggesting our learning criterion was relatively weak at categorizing learners and non-learners. Data for this study can be accessed at: [FIG SHARE]

Results

*Instrumental task*

Twenty-six out of 28 lizards (93%) learnt the task. Fifteen out of 15 (100%) lizards from the social group and 11/13 (84%) lizards from the control group, reached the learning criterion for instrumental task. The mean number of trials taking to learn the task did not differ significant between the social and control group (Fig. 1b, Table 1a).

*Association task*

All lizards (100%) from both treatments reached the learning criterion for association task. Social lizards learnt the task, on average, in significantly fewer trials compared to the control group (Fig. 1b, Table 1b). Moreover, social lizards made, on average, significantly fewer errors compared to the control group (Fig. 1c, Table 2). Interestingly, we found a significant treatment by trial interaction effect for the probability of making a correct choice (Table 3a). Social lizards had a much higher intercept for the probability of making a correct choice compared to control lizards (Fig. 2d). However, as trials progressed, the probability of making a correct choice for social lizards decreased across trials, while it slowly increased for control lizards (Fig. 2d). There was no effect of treatment group on the probability of flipping the correct lid only (Table. 3b).

References

Bates D, Mächler M, Bolker B, Walker S (2015) Fitting linear mixed-effects models using lme4. J Stat Softw arXiv preprint arXiv:1406.5823

Hadfield JD (2010) MCMC methods for multi-response generalized linear mixed models: the MCMCglmm R package. J Stat Softw 33:1-22

R Development Core Team (2010) R: A language and environment for statistical computing. In. R Foundation for Statistical Computing, Vienna, Austria

Figure legends

Fig. 1a – Proportion of lizards across trials in the social (n = 15) and control (n = 13) group that learnt the instrumental task. Solid circles, solid lines represent the social group, open circles, dashed lines represent the control group

Fig. 1b – Predicted means of numbers of trials taken to learn for lizards in the social (n = 15) and control (n = 13) group in the instrumental task from a GLM (Table 1a). Batch number was set to 1. White bars represent the control group, grey bars represent the social group. Error bars represent the standard error

Fig. 2a – Proportion of lizards across trials in the social (n = 15) and control (n = 13) group that learnt the association task. Solid circles, solid lines represent the social group, open circles, dashed lines represent the control group

Fig. 2b – Predicted means of numbers of trials taken to learn for lizards in the social (n = 15) and control (n = 13) group in the association task from a GLM (Table 1b). Batch number was set to 1. White bars represent the control group, grey bars represent the social group. Error bars represent the standard error.

Fig. 2c – The predicted mean number of errors made by lizards in the social (n = 15) and control (n = 13) group in the association task from a GLM (Table 2). Batch number was set to 1. White bars represent the control group, grey bars represent the social group. Error bars represent the standard error.

Fig. 2d– Predicted probability to making a correct choice across trials for lizards in the social (n = 15) and control (n = 13) group in the association task from a GLMM (Table 3). Batch number was set to 1. Solid circles, solid lines represent the social group, open circles, dashed lines represent the control group. Grey and white area represents the 95% credible interval for the social and the control group, respectively.

Figures

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Fig. 1

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Tables

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| Table 1- Estimates and standard errors (SE) from a generalized linear model (GLM) examining the effects of a lizard’s treatment group (social or control) on the mean number of trials it took for a lizard to learn the a) instrumental task (N = 28), b) association task (N = 28). Bolded estimates are significant. Note that batch number was included as a covariate but not presented in the table for simplicity. | | | | |
|  | **a) Instrumental Task** | | **b) Association Task** | |
|  | **Estimate** | **SE** | **Estimate** | **SE** |
| Intercept | 1.92 | 0.29 | 2.42 | 0.12 |
| Treatment (SOCIAL) | -0.05 | 0.16 | **-0.3** | **0.13** |
| Batch (2) | -0.06 | 0.17 | **0.28** | **0.13** |

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| Table 2- Estimates and standard errors (SE) from a generalized linear model (GLM) examining the effects of a lizard’s treatment group (social or control) on the mean number of errors made by lizard during the learning phase in the association task (N = 28). Bolded estimates are significant. Note that batch number was included as a covariate but not presented in the table for simplicity. | | |
|  | **Estimate** | **SE** |
| Intercept | 0.87 | 0.29 |
| Treatment (SOCIAL) | **-1.02** | **0.34** |
| Batch (2) | **0.67** | **0.32** |

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| Table 3 - Posterior modes and 95% credible intervals from a Bayesian Markov chain Monte Carlo generalized linear mixed effects model (GLMM) examining the effects of a lizard’s treatment group (social or control) and trial number on the log odds of making a correct choice, the log odds of choosing the correct dish only. Italicised estimates are significant. Main effects are presented from a model without the interaction, when the interaction was not significant. Note that batch number was included as a covariate but not presented in the table for simplicity. | | | | | | |
|  | **a) Log odds of making of a correct choice** | | | **b) Log odds of flipping the correct lid only** | | |
|  | **Estimate** | **L** | **U** | **Estimate** | **L** | **U** |
| Intercept | 1.34 | 0.56 | 2.02 | -1.06 | -2.13 | -0.06 |
| Treatment (SOCIAL) | **1.77** | **0.72** | **2.67** | -0.03 | -0.92 | 0.9 |
| Trial | **0.06** | **0.01** | **0.1** | -0.04 | -0.09 | 0.01 |
| Batch (2) | **-0.63** | **-1.35** | **-0.07** | **-3.81** | **-5.54** | **-2.42** |
| Treatment (SOCIAL) Trial | **-0.13** | **-0.2** | **-0.06** | -0.04 | -0.13 | 0.07 |