1 Bold zebrafish (*danio rerio*) learn faster in an associative learning task

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10 **Abstract**

11 Animals differ in their ability to learn. One potential factor contributing to learning

12 differences is personality types. We investigated the relationship between learning and the bold-

13 shy continuum by comparing performance of bold and shy zebrafish in conditioned place

14 preference (CPP) and 2 choice tasks. Bold fish learned significantly faster than the shy fish but

15 there were no differences in their final performance. When tested in the 2 choice task, we found

16 no clear evidence of learning, however bold fish made more initial choices than shy fish. Overall,

17 our study suggests that bold fish tend to be faster learners when compared to shy fish. The lack

18 of differences in the final change in behavior suggests that the learning difference is due to

19 neophobic tendencies and resulting initial interactions with the learning stimulus.

20 **Keywords:** Personality, cognition, bold, shy, operant, classical, associative learning

27   **Introduction**

28   As animals interact with their environment, how quickly they learn and recall these

29   interactions can vary between individuals (Boogert et al., 2018, Cauchoix et al., 2018). It has

30   been hypothesized that variation in learning between individuals can be explained in part by

31   differing personality types (Dingemanse & Wolf, 2010, Sih & Del Guidice, 2012, Sih et al.,

32   2004). Across many animal taxa, studies demonstrate that one common dimension of personality

33   is the bold-shy continuum (Réale et al., 2007). Bold individuals are characterized by displaying

34   lower neophobic and stress-related behaviors and have higher exploratory activity. In contrast

35   shy individuals tend to have opposing traits (Wilson et al., 1994, Sih et al., 2004, Baker et al,

36   2018).

37   However, studies across taxa find a conflicting relationship between personality and

38   learning. Many studies showed that bold individuals learn faster than shy, in animals such as

39   mammals, birds, to teleost fish (Mazza et al., 2018, Guenther et al., 2014, Dugatkin & Alfieri,

40   2002, DePasquale et al., 2014, Bensky et al., 2017, Daniel & Bhat, 2020, Kareklas, Elwood &

41   Holland, 2017). Fewer studies either found the opposite (e.g. shy learn faster than bold) or no

42   relationship between personality and learning speed (Lermite, Peneaux & Griffin, 2016, Ferron

43   et al., 2015, Sommer-Trembo & Plath, 2018, Baker & Wong, 2019). Inconsistencies across

44   studies suggest that other factors likely influence learning performance beyond personality type.

45   Aspects of the learning assay like the type of task (e.g. operant or classical conditioning) or the

46   context that the animal is tested in could affect the relationship between personality and learning

47   (Poirer et al., 2020, Dingemanse & Wolf, 2010).

48   Individuals of varying personality types likely vary in their interactions with different

49   learning tasks or stimuli, which may influence learning performance (Sih & Guidice, 2012). For

50   example, different training paradigms require that the animal engage with the stimulus in

51   different ways. Some studies found that learning is not correlated across training paradigms

52   (Guillette et al., 2015, Ducatez et al., 2014, Kassai et al., 2022, Poirer et al., 2020) and one found

53   that changing the difficulty of the learning task changed the relationship between personality and

54   learning speed (Chang et al., 2018). Similarly, a meta-analysis in non-human animals found a

55   low correlation between learning ability across cognitive tasks (Poirer et al., 2020). This

56   potential variation across tasks suggests a need for measurements in multiple learning tasks

57   (Griffin et al., 2015). Neophobia, associated with a shy personality, has been seen to affect

58   operant learning of a food reward due to higher latencies to approach (Stöwe et al., 2006). Thus,

59   comparing a passive (classical) task that does not require the animal to approach a novel object

60   to an active (operant) task that does require approach may produce different results.

61   In this study, we investigated the effect of personality type on learning performance

62   across two associative learning paradigms in zebrafish (*Danio rerio*). Using a within-subjects

63   and counter-balanced design we individually trained bold and shy zebrafish to associate a visual

64   stimulus with a food reward in both conditioned place preference and 2 choice tasks. We tested

65   the prediction that bold individuals will be faster learners compared to shy fish because of their

66   decreased neophobia. We also evaluated the prediction that there will be an interaction effect of

67   personality and training paradigm on learning speed. Given that the operant task requires fish to

68   actively make a choice, we expected that bold fish would learn faster in this task than shy fish

69   due to their decreased neophobia.

70

71   **Methods**

72   *Animals*

73   We used zebrafish from selectively bred lines that exhibit shy (high stationary behavior,

74   HSB) or bold (low stationary behavior, LSB) personality traits (n = 48 per line). Across six

75   different stress and anxiety-like behavioral assays, the HSB line exhibits a greater amount of

76   behaviors consistent with a shy personality type (e.g., freezing, less exploratory, higher cortisol

77   levels) than the LSB line (Wong et al., 2012, Baker & Wong, 2019). Additionally, the

78   exploratory behavior of the lines in an open field test is repeatable and reliable (Baker & Wong,

79   2019). The HSB line also shows faster release of cortisol under stress compared to the LSB line

80   (Wong et al., 2019). For simplicity, we will refer to the HSB and LSB lines as shy and bold

81   personality types, respectively. The fish used in this study were selectively bred for 13

82   generations from wild caught zebrafish. Before testing, we housed the fish together in 40L tanks

83   and fish were fed twice a day with Tetramin Tropical Flakes (Tetra, USA). One week prior to

84   testing we physically isolated fish into 3-liter tanks on a recirculating water system (Pentair

85   Aquatic Eco-Systems or Aquaneering) using UV and solid filtration on a 14:10 L/D cycle at a

86   temperature of 27 °C. Fish had visual and olfactory access to each other. Starting three days

87   before testing we withheld food from the fish to reduce the possibility of satiation while training.
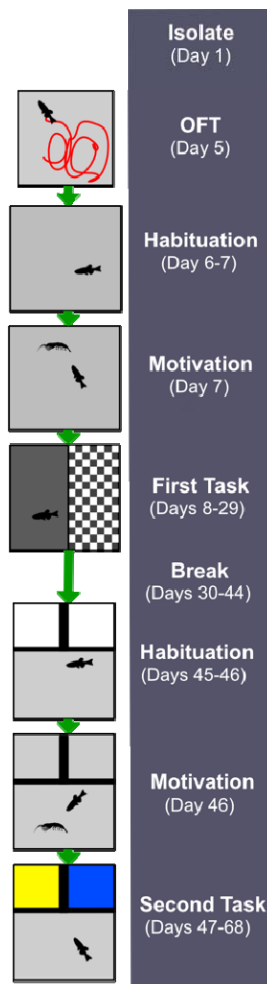
Figure 1. Overview of Experiment Timeline. Fish of all groups started with isolation on the first day then went through an open field test (OFT), habituation, motivation test, and training on the first task (conditioned place preference task in this illustration). After a break fish went through the same for the second task (2 choice discrimination task in this illustration). Our study design was counterbalanced and half of the fish began with the CPP task while the other half began with the 2 choice discrimination task.

Behavioral assays overview

We conducted four behavioral assays on each fish: an open field test (OFT), a test for food motivation, a 2 choice discrimination task (operant conditioning), and a conditioned place preference (CPP, classical conditioning) task. The OFT and food motivation test were performed prior to training. Using a within-subjects design, we tested each fish in both associative learning paradigms and counterbalanced the starting paradigm (Figure 1). We used frozen adult brine shrimp (*Artemia* spp., San Francisco Bay Brand, USA) administered in liquid form as the food reward. Half of the fish received distilled water instead of brine shrimp to serve as controls. We

98   started with four groups of 24 fish (bold control, shy control, bold treatment, and shy treatment).

99   All behavioral assays were performed between 3-8 hours after light onset. After 4 days of

100   isolation, we tested each fish in the open field test to validate behavioral phenotype. We then

101   habituated each fish for two consecutive days in the conditioning tank. We assessed biases in

102   food motivation for the brine shrimp before starting baseline trials of the associative learning

103   assays. Each fish had a 14 day inter-assay testing interval to minimize the influence of the tasks

104   on each other.

105   *Open field test*

106   We individually tested fish in an OFT in a tank that was 31.75cm x 31.75cm x 10cm

107   containing 4L of water. Immediately after placing fish in the tank we video-recorded the

108   individual's behaviors for 5 minutes. We used Ethovision XT 17 (Noldus, Netherlands) to

109   quantify the amount of time that each individual spent frozen during the trial.

110   *Motivation test*

111   This test was performed in the AD and LT models of the Zantiks semi-automated

112   behavioral units (Zantiks, Cambridge, UK). After 30 seconds for acclimation, the food reward

113   was administered 3 times at 30 second intervals. We quantified the time spent in a 9x12 cm

114   rectangle centered around the food administration tube. The time that was being measured started

115   immediately after the first brine shrimp administration until the end of the test to measure the

116   motivation of the fish for the food reward. We performed the test in both Zantiks models but due

117   to the size and height of the tank in the larger LT unit, the food drifted outside the fish tracking

118   zone. Thus, we only used the data from the AD unit to assess motivation.

119

120   *Conditioned place preference*

121   We used a modified conditioned place preference protocol (Lau et al., 2006) in the

122   Zantiks LT unit. The testing tank (36 cm x 27 cm x 30 cm) was filled with 5.8 L of water. We

123   tested each fish in the CPP task for three weeks that consisted of 2 days of habituation, 1 day of

124   baseline testing, 11 days of conditioning, and 3 days of probe trials (Figure S1a). To habituate

125   each fish to the assay we placed the fish in the tank for 10 minutes with no training stimulus

126   lights. After habituation we determined the baseline preference for the light stimuli (gray or

127   checkered pattern) for each fish. Fish swam freely for 10 minutes in the tank where one half was

128   illuminated from the bottom with a gray screen and the other half a checkered screen. We

129   determined the conditioned and non-conditioned stimuli as the stimulus where the fish spent the

130   least and most amount of time, respectively. During conditioning days, we sequentially presented

131   each stimulus for 5 minutes to each fish. The non-conditioned stimulus was presented for the

132   first five minutes followed by the conditioned stimulus. One hundred microliters of brine shrimp

133   or distilled water was administered every minute during presentation of the conditioning and

134   non-conditioning stimulus, respectively. Food reward consisted of 11.4 grams of frozen brine

135   shrimp in 30 mL of distilled water. We fed control fish an equivalent amount of brine shrimp

136   after each conditioning trial. Probe trials were administered the day after a conditioning trial.

137   Probe trials were conducted after 3 days, 7 days, and 11 days after the first day of conditioning

138   with a total of 3 probe trials. Probe trial methods were the same as those used in the baseline

139   preference step where we quantified the time spent in each stimulus for each fish. The order of

140   stimulus presentation was consistent within a fish but random across fish for probe and baseline

141   trials.

142

143   *2 choice discrimination task*

144   We used a modified 2 choice discrimination task from an established protocol (Bilotta et

145   al., 2006). We used the AD model Zantiks unit (Zantiks, Cambridge, UK) with a 14cm x 20cm x

146   15cm tank filled with 2.5 L of water (Figure S1b). We habituated each fish for 20 minutes a day

147   for two consecutive days with white lights on in the wells as shown in Figure S1b. We tested

148   each fish every other day for a total of 10 testing days. Fish were fasted on non-testing days. In

149   this task the fish were presented with two 6.5 cm x 5.1 cm light stimuli (blue and yellow) from

150   below at one end of the tank. Prior studies show that with appetitive learning in zebrafish there is

151   a bias towards red compared to other colors such as blue and yellow (Spence & Smith, 2008,

152   Kim et al., 2017). For each fish, a color was randomly chosen at the start of testing to be the

153   reinforced stimulus where a food reward (brine shrimp) was administered at the other end of the

154   tank when the fish swam into the designated reinforced color. The food reward consisted of 5.7

155   grams of frozen brine shrimp suspended in 30 mL of distilled water. Each trial began with an

156   acclimation period of two minutes with white lights in the two wells. After two minutes blue and

157   yellow lights were presented for 30 seconds. Swimming into the designated correct choice

158   resulted in the correct colored light staying on for an additional 30 seconds and we

159   simultaneously administered 25 µl of the food reward. An incorrect choice resulted in all lights

160   turning off for 30 seconds. This sequence ran for a total of 20 trials each day for each fish (i.e.,

161   one session consists of 20 trials). The position of the yellow and blue lights (e.g., left or right)

162   was randomly set for each trial. There was an intertrial interval of 10 seconds. Control fish

163   underwent the same protocol with distilled water administered instead of brine shrimp and were

164   fed brine shrimp after each testing day. We compared the number of correct choices and the total

165   number of choices across sessions to assess learning.

166

167

168   *Statistical analysis*

169   We performed all statistical tests using R statistical software(R 4.2.2 GUI 1.79 Big Sur

170   ARM build) and Rstudio version 2022.12.0+353 (R Core Team, 2021). Due to fish mortality

171   during the experiment, the sample sizes for statistical analyses between the conditioned place

172   preference (bold control (n = 20), shy control (n = 20), bold treatment (n = 19), and shy treatment

173   (n = 19)) and 2 choice (bold control (n = 20), shy control (n = 17), bold treatment (n = 19), and

174   shy treatment (n = 20)) tasks differed. We conducted post-hoc tests using the emmeans (Lenth et

175   al., 2022) package and normality and assumptions were checked using base R. The lme4 package

176   (Bates et al., 2022) was used to test negative binomial linear mixed effect models. We obtained

177   simple statistics for all measures using the psych package (Revelle, 2022) (Table 1). Sex was

178   included in all models but was not significant and therefore removed. Model assumptions,

179   including normality were inspected in R.

180

181   *Open field test and motivation*

182   We tested for differences between the bold and shy groups in the OFT and motivation

183   test using a Welch two-sample t-test. This test was used due to unequal variances between bold

184   and shy groups. We compared the duration of time frozen in the OFT between the bold and shy

185   personality types. To investigate difference in food motivation, we compared the duration of

186   time spent around the food administration tube between the bold and shy personality types using

187   the same test.

188

189   *Conditioned place preference*

190   We modeled the duration of time spent in the conditioned stimulus for the last half (5

191   minutes) of the baseline and probe trials to test for a change in preference for the conditioned

192   stimulus across the task within the different groups. We did not include the first half (5 minutes)

193   in the analysis to minimize the influence of handling on fish behavior. We performed a repeated

194   measures ANOVA to investigate the effects of treatment, personality type, and conditioning day

195   on the time spent in the conditioned stimulus with a linear mixed effects model with individual

196   as the random effect. We included all interactions in the model and used type II sums of squares.

197   We used Tukey post-hoc tests to evaluate differences in the response variables across trials for

198   each group and within trials between groups.

199

200   *2 choice discrimination task*

201   We modeled the number of correct choices over the conditioning days to examine

202   changes in correct choices over time within groups. We performed a negative binomial mixed

203   effect regression on the number of correct choices with treatment, personality type and session as

204   the fixed effects and ID as the random effect. Simple slopes were obtained to test for increases in

205   correct choices within each group using the interactions package in R and plotted using the same

206   package. Additionally, we performed a negative binomial mixed effect regression on the total

207   number of choices with treatment, personality type and session as the fixed effects and ID as the

208   random effect. We also obtained simple slopes for this model.

209

210   **Results**

211   *Shy fish freeze more but had equal motivation to eat*

212   There was a significant effect of personality type on freezing time in the open field test

213   (Figure 2a). Shy fish spent significantly more time frozen than bold fish (t =-3.55, df = 90, p =

214    $6.4*10^{-4}$). There were no significant differences between personality types (t = -0.19, df = 82, p =

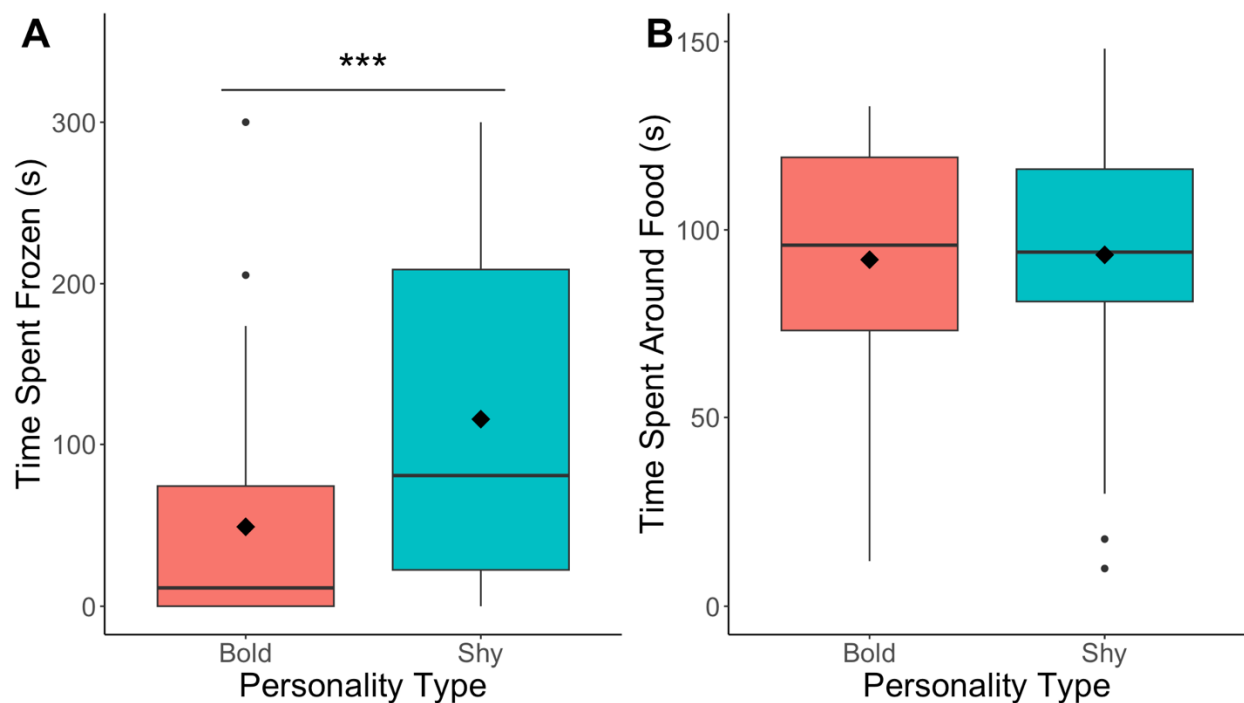215   .85) in the amount of time spent around the food in the motivation task (Figure 2b).

216

217   **Figure 2.** A. Boxplot of time spent frozen in the open field test and B. boxplot of time spent around the food in the

218   motivation task. Bold fish are in red and shy fish are in teal. The diamond indicates the mean and the line is at the

219   median.*p<.05, ** p <.01 ***p<.001

220
221   *Bold fish change their behavior before shy fish*

222   Treatment fish increased time spent in the conditioned stimulus in the CPP task, with

223   bold fish increasing time spent in the conditioned stimulus earlier in the task than shy fish

224   (Figure 3). In the full model (Table S1) the interaction effect between treatment and probe trial

225   was approaching significance ($F(3, 292) = 4.09$, *p* = .09). A Tukey post hoc test (Table S2)

226   revealed that there were no significant differences in the duration of time in the conditioned

227   stimulus between trials for the control groups for either personality type ($p > .05$). In the bold

228   treatment group there was a significant difference between baseline and probe 1 (i.e., after 3 days

229   of conditioning; t = -2.64, df = 296 , p = .03), probe 2 (i.e., after 7 days of conditioning; t = -3.55,

230   df = 296 , p = $2.8*10^{-3}$), and probe 3 (i.e., after 11 days of conditioning; t = -3.35, df = 296 , p =

231    $4.7*10^{-3}$). In the shy treatment group there was no significant difference in time spent in the

232   conditioned stimulus between baseline and probe 1 (t = -1.27, df = 296, p = .45) but there was a

233   trend for a difference between baseline and probe 2 (t = -2.42, df = 296 , p = .07) and at probe 3

234   shy treatment group spent significantly more time in the CS compared to baseline (t = -2.67, df =

235   296 , p = .04). No significant differences in duration of time in the CS between probe 1, 2, or 3

236   were detected in any of the groups ($p > .05$). There were no differences in time spent in the

237   conditioned zone at any of the time points between personality types ($p > .05$). Additionally,

238   there was no significant correlation between learning speed (change in CS time from baseline

239   after 3 days of conditioning) and final time spent in the conditioned stimulus in the CPP task for

240   the bold fish (ρ = .19, p = .44) or for the shy fish (ρ = .22, p = .35).
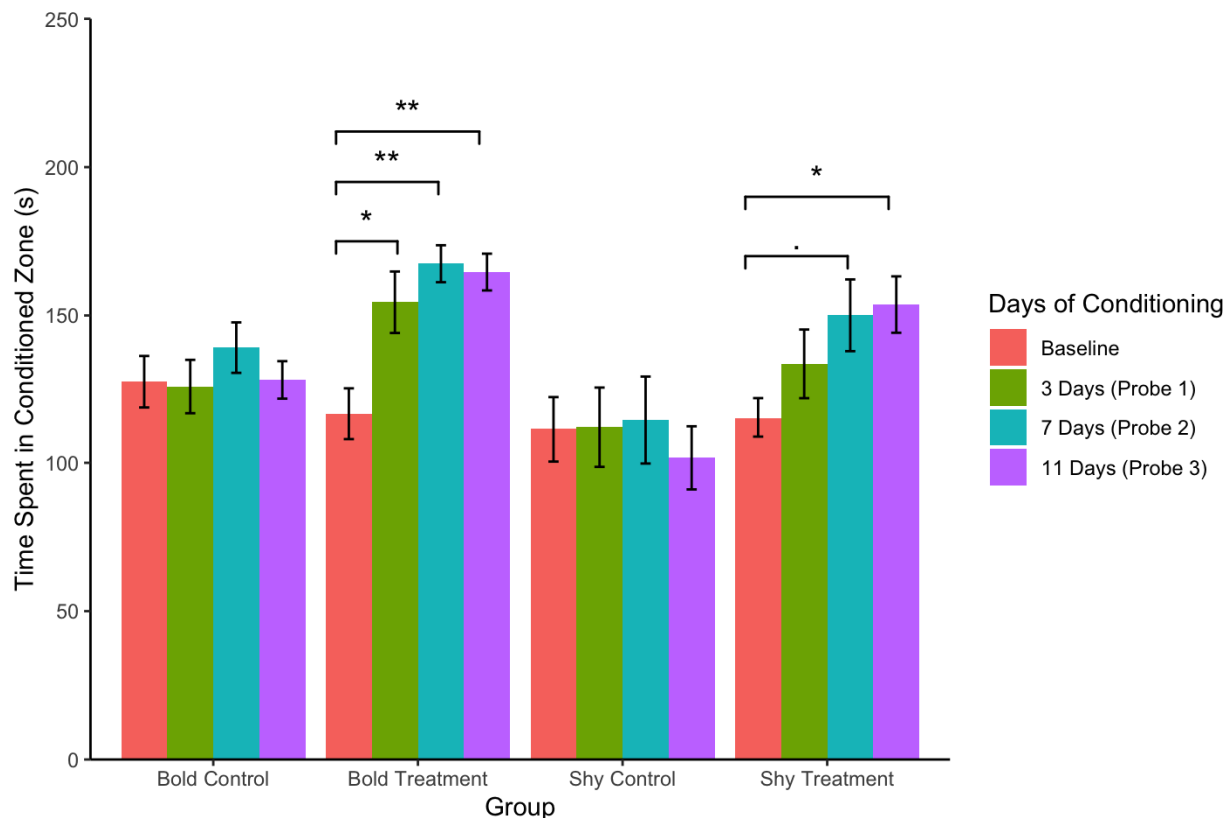
Fig. 3 Time spent in the conditioned zone by group and day of conditioning in the CPP. Pink bars are at baseline, green bars are after 3 days of conditioning (Probe 1), blue bars are after 7 days (Probe 2) and purple bars are after 11 days of conditioning (Probe 3). Error bars indicate standard error. $^{.}p < .1$, $^{*}p < .05$, $^{**}p < .01$.

No evidence of learning in 2 choice discrimination task with correct choices

In the 2 choice discrimination task there was no significant difference in number of correct choices between control and treatment fish (Table S3). There was only a significant main effect of personality type such that bold fish made more correct choice compared to shy fish ($b = -.49$, $t = -2.84$, $p = .01$) and a significant interaction between personality type and session ($b = 0.03$, $t = 2.601$, $p = .01$). Testing for the simple slopes (Table S4, Figure S2), both shy control ($m = 0.03$, $t = 3.15$, $p = 2.2*10^{-5}$) and shy treatment ($m = 0.04$, $t = 4.24$ $p = 4.4*10^{-6}$) groups had a

253   significant positive slope while bold control (m = 0, t = -0.26, p = .79) and bold treatment (m =

254   0.01, t = 0.98, p = .33) have no significant relationship.

255

256   *Difference across treatment and control only in total number of choices in 2 choice*

257   *discrimination task*

258   For the total number of choices, there was a significant difference between control and

259   treatment fish (Figure 4, Table S5). There was a main effect of personality type on total number

260   of choices (b = -.34, t = -2.07, p = .04) where bold fish had higher total number of choices than

261   shy. The interaction between session and treatment is approaching significance (b = 0.15, t =

262   1.69, p = .09). Testing for the simple slopes, shy control (m = 0.01, t = 1.22, p = .22), and bold

263   control (m = 0, t = -0.44, p = .66) did not have a significant relationship (Figure 4a). Only shy

264   treatment (m = 0.03, t = 4.59, p = .4.4*10-6) had a significant positive slope (Figure 4b, Table

265   S6). In contrast, bold treatment had a slope approaching significance (m = 0.01, t = 1.90, p = .06)
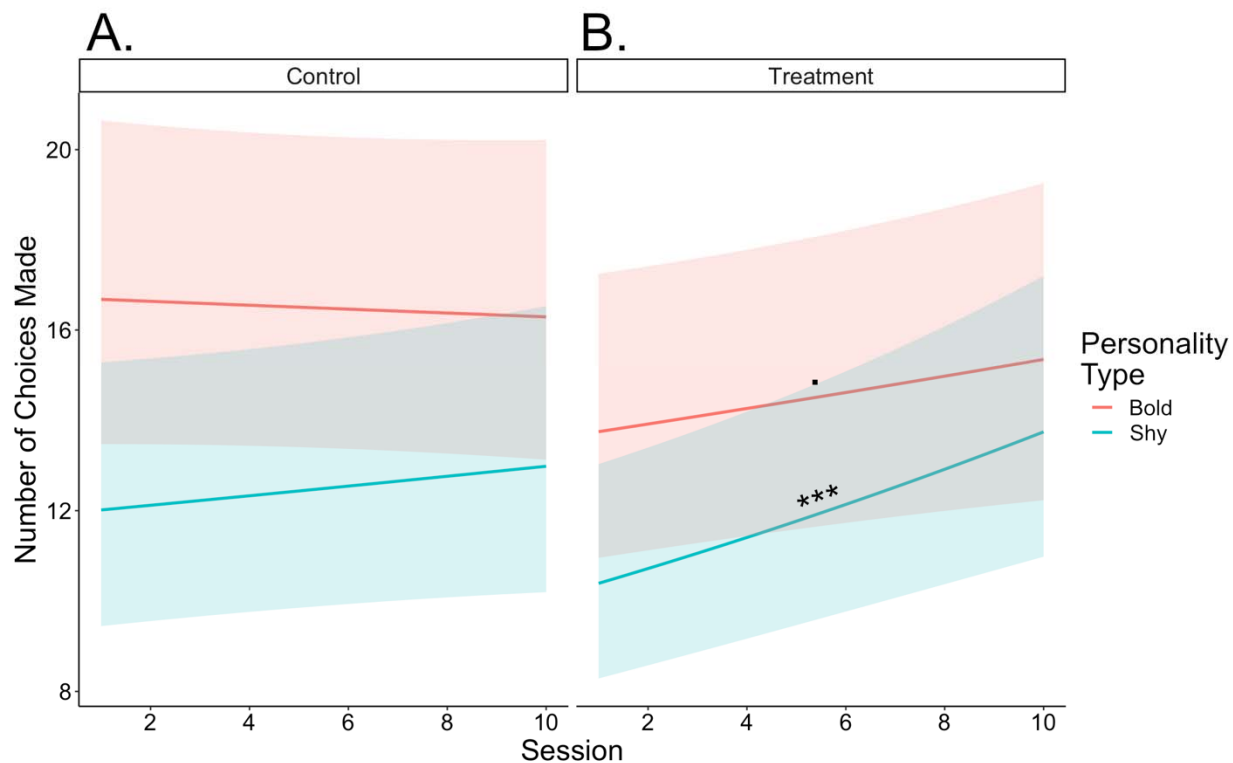
266   (Figure 4b).

Figure 4. Regression lines of the number of choices made by personality type and treatment. 4A. shows the regression lines for control fish and 4B. shows regression lines for treatment fish. The bold group is in red and the shy group is in blue. Shaded regions indicate a 95% confidence interval. The simple slopes significance is indicated. $\cdot p < .1, *p < .05, **p < .01, ***p < .001$.

Discussion

Variation in learning performance can be due to complex interactions between intrinsic (e.g., personality type) and extrinsic (e.g. learning task) factors (Sih & Guidice, 2012). We investigated the effects of personality type and learning task by testing zebrafish of differing personalities across two different associative learning assays. Overall, we found that learning performance in one of the tasks was influenced by an animal's personality type.

Bold fish increased time spent in the conditioned stimulus earlier than shy fish in the conditioned place preference task, which suggests that bold fish learned faster in this task. The bold fish showed a significant increase in time spent in the conditioned stimulus after just 3

280 conditioning days whereas shy fish took an additional 8 days of conditioning to show a

281 significant change from baseline (Figure 3). These results are consistent with other studies

282 demonstrating that individuals with bold personality types learn faster than shy individuals

283 (Mazza et al., 2018, Guenther et al., 2014, Dugatkin & Alfieri, 2002, DePasquale et al., 2014,

284 Bensky et al., 2017, Daniel & Bhat, 2020, Kareklas, Elwood & Holland, 2017). Differences in

285 learning speed between personality types in this task may be due to differences in behavior such

286 as stress reactivity, exploration, and neophobia (Sih & Guidice, 2012, Sommer-Trembo & Plath,

287 2018). Our observed differences in learning speeds between personality types cannot be

288 explained by differences in motivation for the food reward (Figure 2). Interestingly, there were

289 no differences in the amount of time spent in the conditioned stimulus between the personality

290 types after 11 days of conditioning, suggesting that individuals approach an asymptotic level of

291 performance. This suggests that both personality types are capable of changing their behavior

292 (e.g. learn) to similar extents and therefore differences in cognitive ability between personality

293 types is an unlikely explanation for differences in learning speed.

294 When testing the same fish in the 2 choice discrimination assay, there was no significant

295 difference in the number of correct choices between treatment and control groups, which

296 suggests the fish did not learn the stimulus-reward association in this task (Figure 4). However,

297 there were differences across personality types in which both shy treatment and control increased

298 the number of correct choices while the bold groups did not. The positive slope for the shy

299 groups is likely due to an overall increase in total choices with repeated exposure. When looking

300 at the total number of choices made over sessions, the control groups did not change over time

301 while the treatment groups increased the total number of choices made over sessions. This

302 suggests that the treatment fish did not learn the color association but may instead have learned

303 to go into the wells. Animals can attend to several cues in discrimination learning and sometimes

304 attend to unintentional or general cues (Mackintosh, N., J., 1965). We also cannot rule out that

305 rewarding the fish in a different location than the stimuli may have decreased the strength of

306 pairing between action and reward (Murphy & Miller, 1958). While in the 2 choice

307 discrimination task fish did not learn the color association, the bold fish made more choices than

308 shy fish in the first session. This is likely due to decreased neophobia and increased exploration

309 in the bold fish as demonstrated in the open-field test (Sih et al., 2004, Wong et al., 2012).

310   Differences in neophobia (e.g. latency to approach novel objects) classically distinguish

311 bold and shy personality types (Carter et al., 2012, Sih et al., 2004, Wilson et al., 1994). In the

312 current study one potential explanation for bold fish learning quicker in the conditioned place

313 preference and making more initial choices in the 2 choice discrimination task relative to shy fish

314 are differences in neophobia between the personality types. The shy fish could have found the

315 colored lights in the 2 choice discrimination task initially aversive and increased their choices as

316 they habituated to the novel stimuli. Shy individuals tend to have increased neophobia and

317 habituate slower, which would result in the shy fish taking longer to make active choices (Carter

318 et al., 2012). The two days of habituation in the 2 choice discrimination task only allowed the

319 fish to experience the tank and lighted wells but at start of conditioning they were naïve to the

320 color of the lights and the changing stimuli. A similar effect was seen in *Gallus gallus* where

321 individuals that were less exploratory (i.e., shy) habituated slower to a loud sound than those that

322 were more exploratory (Dissegna et al., 2022). Neophobia may also explain shy fish learning

323 slower in the CPP task, as shy fish could have experienced more stress than the bold fish at the

324 start of the task even after habituation and so learned the positive association slower. Mollies

325 (*Poecilia mexicana*) that were desensitized to the lights and sounds used in the task showed no

326 differences in learning related to personality type (Sommer-Trembo & Plath, 2018). Increasing

327 familiarity with the task environment and stimuli could explain why shy fish were slower to

328 increase their preference for the conditioned stimulus but ultimately reached a level of

329 performance similar to bold fish after 11 days of conditioning. Bold individuals tend to make

330 associations faster likely because they are less neophobic and in a simple conditioned place

331 preference task, this leads to them learning faster but does not change the plateau of performance

332 (Dugatkin & Alfieri, 2002, DePasquale et al., 2014, Daniel & Bhat, 2020).

333   The relationship between more rapid learning and bold personality type is not consistent

334 across all studies (Ferron et al., 2015, Lermite, Peneaux & Griffin, 2016). Potential explanations

335 are that the relationship between speed of learning and personality can depend on aspects of the

336 task such as learning stimulus valence or task complexity. Shy zebrafish trained in a contextual

337 fear learning paradigm showed faster learning than bold zebrafish (Baker et al., 2019). As shy

338 zebrafish have a faster glucocorticoid response to a novelty stressor than bold fish, this may

339 facilitate quicker learning of aversive stimuli (Wong et al., 2019, Rau et al., 2005, Riggenbach et

340 al., 2019) but inhibit learning of appetitive stimuli seen in current study. For task complexity, a

341 study looking at learning accuracy found that aggressive spiders (e.g. bold personality type) were

342 more accurate in a simple task but not in a more complex task (Chang et al., 2018). Future work

343 may consider testing whether the same trend holds in a more complex classical conditioning

344 task. In a more complex task, bold fish may make incorrect associations and not learn as quickly

345 as shy fish.

346   Overall, we found support for differences between bold and shy individuals in how they

347 interact with two different learning tasks. These differences in performance could be explained

348 by varying neophobia between bold and shy individuals. In a 2 choice task requiring an active

349   behavioral response, we found differences in initial number of choices made between personality

350   types, suggesting that the personality types naively interacted with the stimulus differently. In the

351   conditioned place preference task, the bold fish learned faster than the shy fish. Differences in

352   performance between bold and shy individuals in both tasks could be explained by variation in

353   neophobia related to personality type. Additionally, the bold and shy fish reached a similar level

354   of performance. We encourage future studies to test the performance of bold and shy individuals

355   across different tasks to compare their behavior both within and across tasks. Future work should

356   also consider explicitly measuring how individuals interact with the task environment, perhaps

357   measuring neophobia and motivation for the task.

358

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