

1 Online supporting information for

2 Analysing individual variation in predator hunting mode and the
3 effect of predator and prey behavior on hunting success using an
4 online multiplayer videogame

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Supporting Information: Materials and methods

Principal component analysis

We computed the PCA using packages “FactoMineR” (Lê et al. 2008) and “factoextra” (Kassambara and Mundt 2020) in the R software version 4.0.4 (R Core Team, 2021), under a Windows 10 computer OS. The “PCA” function in “FactoMineR” uses singular value decomposition. Before running the PCA, we divided each variable (except travel speed) by the match duration to account for differences in duration among matches. All variables were standardized to mean and unit variance (Z scores) before running the PCA. We ranked variables based on their contribution (in %) to a given principal component axis. To do so, for each variable, we used the ratio between their cos2 multiplied by 100 and the cos2 of the principal component. The PCA was computed on a sample of 70 831 matches from 2 171 players.

Parametrization of the bayesian multivariate mixed-model

We used a weakly informative LKJ prior with a shape parameter (n) set to 2 for the random effects variance-covariance matrixes, and a gaussian prior with mean 0 and standard deviation of 5 for the fixed effects (i.e. prey travel speed x_1 and rate of space covered x_2) of all the submodels (i.e. for each response variable). We ran four chains using 43 000 iterations, and sampled every 40 intervals (thinning). We used the first 3000 iterations for warmup. We visually inspected trace plots, effective sample sizes, and residuals to assess convergence and stability. We also evaluated the model’s prediction accuracy using posterior predictive checks. We computed a variance-covariance matrix (Ω_k) for each random effect (k). We extracted the among-environment, avatar, individual, and within- individual behavioural correlations using the function `posterior_samples()` in the “brms” package. We could thus compute the mean of the correlation sample values, and the HDP intervals to obtain the 95% credible intervals for each correlation. The variance-covariance matrixes were parametrized as :

$$\begin{bmatrix} en_{0y1,g} \\ en_{0y2,g} \\ en_{0y3,g} \\ en_{0y4,g} \end{bmatrix} = MVN(0, \Omega_{en}) : \text{where } \Omega_{en} = \begin{bmatrix} V_{en_{0y1}} & & & \\ Cov_{en_{0y1}en_{0y2}} & V_{en_{0y2}} & & \\ Cov_{en_{0y1}en_{0y3}} & Cov_{en_{0y1}en_{0y4}} & V_{en_{0y3}} & \\ Cov_{en_{0y2}en_{0y3}} & Cov_{en_{0y2}en_{0y4}} & Cov_{en_{0y3}en_{0y4}} & V_{en_{0y4}} \end{bmatrix} \quad (S1)$$

$$\begin{bmatrix} av_{0y1,h} \\ av_{0y2,h} \\ av_{0y3,h} \\ av_{0y4,h} \end{bmatrix} = MVN(0, \Omega_{av}) : \text{ where } \Omega_{av} = \begin{bmatrix} V_{av_{0y1}} & & & \\ Cov_{av_{0y1}av_{0y2}} & V_{av_{0y2}} & & \\ Cov_{av_{0y1}av_{0y3}} & Cov_{av_{0y1}av_{0y4}} & V_{av_{0y3}} & \\ Cov_{av_{0y2}av_{0y3}} & Cov_{av_{0y2}av_{0y4}} & Cov_{av_{0y3}av_{0y4}} & V_{av_{0y4}} \end{bmatrix} \quad (S2)$$

$$\begin{bmatrix} id_{0y1,i} \\ id_{0y2,i} \\ id_{0y3,i} \\ id_{0y4,i} \end{bmatrix} = MVN(0, \Omega_{id}) : \text{ where } \Omega_{id} = \begin{bmatrix} V_{id_{0y1}} & & & \\ Cov_{id_{0y1}id_{0y2}} & V_{id_{0y2}} & & \\ Cov_{id_{0y1}id_{0y3}} & Cov_{id_{0y1}id_{0y4}} & V_{id_{0y3}} & \\ Cov_{id_{0y2}id_{0y3}} & Cov_{id_{0y2}id_{0y4}} & Cov_{id_{0y3}id_{0y4}} & V_{id_{0y4}} \end{bmatrix} \quad (S3)$$

$$\begin{bmatrix} \varepsilon_{0y1,ghij} \\ \varepsilon_{0y2,ghij} \\ \varepsilon_{0y3,ghij} \\ \varepsilon_{0y4,ghij} \end{bmatrix} = MVN(0, \Omega_{\varepsilon}) : \text{ where } \Omega_{\varepsilon} = \begin{bmatrix} V_{\varepsilon_{0y1}} & & & \\ Cov_{\varepsilon_{0y1}\varepsilon_{0y2}} & V_{\varepsilon_{0y2}} & & \\ Cov_{\varepsilon_{0y1}\varepsilon_{0y3}} & Cov_{\varepsilon_{0y1}\varepsilon_{0y4}} & V_{\varepsilon_{0y3}} & \\ Cov_{\varepsilon_{0y2}\varepsilon_{0y3}} & Cov_{\varepsilon_{0y2}\varepsilon_{0y4}} & Cov_{\varepsilon_{0y3}\varepsilon_{0y4}} & V_{\varepsilon_{0y4}} \end{bmatrix} \quad (S4)$$

where the diagonals represent the random effect (k) variance ($V_{k_{0y_n}}$) for each hunting trait (y_n), and the lower off-diagonals the covariance between the random effect intercepts for each combination of hunting traits (travel speed ($y1$), the rate of space covered ($y2$), the proportion of time spent ambushing ($y3$), and the time before first capture ($y4$)).

We ran a separate multivariate mixed-model after observing that game environments did not explain a high percentage of variation in predator behavior (see the “discussion” in the main text). We did so to test the hypothesis that prey might instead respond to the environment, which may then indirectly affect predator behavior. We thus computed the same multivariate model, and excluded prey travel speed and rate of space covered as the linear fixed effects. Results for environmental variation in predator behavior are presented below in the results section of the supporting information.

We used a Gaussian prior with mean of 0 and standard deviation of 5 for all the models' fixed effects. We visually inspected trace plots, effective sample sizes, and residuals to assess convergence and stability. We also evaluated the models' prediction accuracies using posterior predictive checks. We calculated the ICC_k estimate for each random effect (k) using the function `posterior_samples()` in the "brms" package, by dividing each random effect variance sample value by the total variance. We could then compute the mean of the samples to obtain the ICC value for each random effect, and HDP intervals to obtain their corresponding 95% credible intervals.

For the first model, we aimed at investigating the relationship between hunting success and predator behaviour exclusively. For this model, we ran four chains using 103 000 iterations by sampling every 100 intervals (thinning), and used the first 3000 iterations for warmup. The model was parametrized as :

$$\begin{aligned}
 \text{logit}(P_{hij}) = & (\beta_0 + env_{0,h} + id_{0,i} + \varepsilon_{0,hij}) \\
 & + \beta_{1,pred} speed_{hi} \\
 & + \beta_{2,pred} space_{hi} \\
 & + \beta_{3,pred} ambush\ time_{hi} \\
 & + \beta_{4,pred} time\ I^{st} capture_{hi}
 \end{aligned} \tag{S5}$$

49 We included prey behaviour in the second model and kept the same structure as equation S5. For this model,
50 we ran four chains using 153 000 iterations by sampling every 100 intervals (thinning), and used the first
51 3000 iterations for warmup. The model was parametrized as :

$$\begin{aligned}
\text{logit}(P_{hij}) = & (\beta_0 + env_{0h} + id_{0i} + \varepsilon_{0,hij}) \\
& + \beta_{1,pred} speed_{hi} \\
& + \beta_{2,pred} space_{hi} \\
& + \beta_{3,pred} ambush\ time_{hi} \\
& + \beta_{4,pred} time\ I^{st} capture_{hi} \\
& + \beta_{5,prey} speed'_{hi} \\
& + \beta_{6,prey} space'_{hi}
\end{aligned} \tag{S6}$$

52 In the third model, we were interested in investigating nonlinear relationships between hunting success and
 53 predator behaviour exclusively. We thus added quadratic effects for each hunting trait. We also investigated
 54 how predator behaviours interact to affect huntin success. The model was run for 103 000 iterations by
 55 sampling every 100 intervals and using the first 3000 iterations as warmups. This model was computed as :

$$\begin{aligned}
 \text{logit}(P_{hij}) = & (\beta_0 + env_{0h} + id_{0i} + \varepsilon_{0,hij}) \\
 & + \beta_{1,pred} \text{speed}_{hi} + \beta_{2,pred} \text{space}_{hi} \\
 & + \beta_{3,pred} \text{ambush time}_{hi} + \beta_{4,pred} \text{time } I^{st} \text{capture}_{hi} \\
 & + \frac{1}{2} \gamma_{1,pred} \text{speed}_{hi}^2 + \frac{1}{2} \gamma_{2,pred} \text{space}_{hi}^2 \\
 & + \frac{1}{2} \gamma_{3,pred} \text{ambush time}_{hi}^2 + \frac{1}{2} \gamma_{4,pred} \text{time } I^{st} \text{capture}_{hi}^2 \\
 & + \gamma_{1,pred} \text{speed}_{hi} \times \text{space}_{hi} \\
 & + \gamma_{2,pred} \text{speed}_{hi} \times \text{ambush time}_{hi} \\
 & + \gamma_{3,pred} \text{speed}_{hi} \times \text{time } I^{st} \text{capture}_{hi} \\
 & + \gamma_{4,pred} \text{space}_{hi} \times \text{ambush time}_{hi} \\
 & + \gamma_{5,pred} \text{space}_{hi} \times \text{time } I^{st} \text{capture}_{hi} \\
 & + \gamma_{6,pred} \text{ambush time}_{hi} \times \text{time } I^{st} \text{capture}_{hi}
 \end{aligned} \tag{S7}$$

56 The fourth and final model included prey behaviours with their quadratic effects. We also included inter-
 57 actions between predator and prey behaviours to investigate how they jointly affect hunting success. The
 58 model was run for 103 000 iterations by sampling every 100 intervals and using the first 3000 iterations as
 59 warmups. The model is described as :

$$\begin{aligned}
 \text{logit}(P_{hij}) = & (\beta_0 + env_{0h} + id_{0i} + \varepsilon_{0,hij}) \\
 & + \beta_{1,pred} speed_{hi} + \beta_{2,pred} space_{hi} \\
 & + \beta_{3,pred} ambush\ time_{hi} + \beta_{4,pred} time\ I^{st} capture_{hi} \\
 & + \beta_{5,prey} speed'_{hi} + \beta_{6,prey} space'_{hi} \\
 & + \frac{1}{2} \gamma_{1,pred} speed_{hi}^2 + \frac{1}{2} \gamma_{2,pred} space_{hi}^2 \\
 & + \frac{1}{2} \gamma_{3,pred} ambush\ time_{hi}^2 + \frac{1}{2} \gamma_{4,pred} time\ I^{st} capture_{hi}^2 \\
 & + \frac{1}{2} \gamma_{5,prey} speed'^2_{hi} + \frac{1}{2} \gamma_{6,prey} space'^2_{hi} \\
 & + \gamma_{1,pred} speed_{hi} \times space_{hi} \\
 & + \gamma_{2,pred} speed_{hi} \times ambush\ time_{hi} \\
 & + \gamma_{3,pred} speed_{hi} \times time\ I^{st} capture_{hi} \\
 & + \gamma_{4,pred} space_{hi} \times ambush\ time_{hi} \\
 & + \gamma_{5,pred} space_{hi} \times time\ I^{st} capture_{hi} \\
 & + \gamma_{6,pred} ambush\ time_{hi} \times time\ I^{st} capture_{hi} \\
 & + \gamma_{7,pred\ prey} speed_{hi} \times speed'_{hi} \\
 & + \gamma_{8,pred\ prey} speed_{hi} \times space'_{hi} \\
 & + \gamma_{9,pred\ prey} space_{hi} \times speed'_{hi} \\
 & + \gamma_{10,pred\ prey} space_{hi} \times space'_{hi} \\
 & + \gamma_{11,pred\ prey} ambush\ time_{hi} \times speed'_{hi} \\
 & + \gamma_{12,pred\ prey} ambush\ time_{hi} \times space'_{hi} \\
 & + \gamma_{13,pred\ prey} time\ I^{st} capture_{hi} \times speed'_{hi} \\
 & + \gamma_{14,pred\ prey} time\ I^{st} capture_{hi} \times space'_{hi}
 \end{aligned} \tag{S8}$$

Supporting Information: Results

Principal component analysis

The first principal component (PC1) explained 20% of the total variation, and the second principal component (PC2) explained 15.3% of the total variation (figure S1). We found that travel speed and time spent ambushing had the highest contribution (23.19% and 29.38% respectively) to the first principal component (table SI), while the rate of space covered and the time before first capture had the highest contribution (48.12% and 35.55%) to the second principal component (table SI). The time spent ambushing is negatively correlated with travel speed (figure S1), which may indicate the presence of structured tactics where individuals that are fast do not ambush, and individuals who ambush prey are slower travelers.

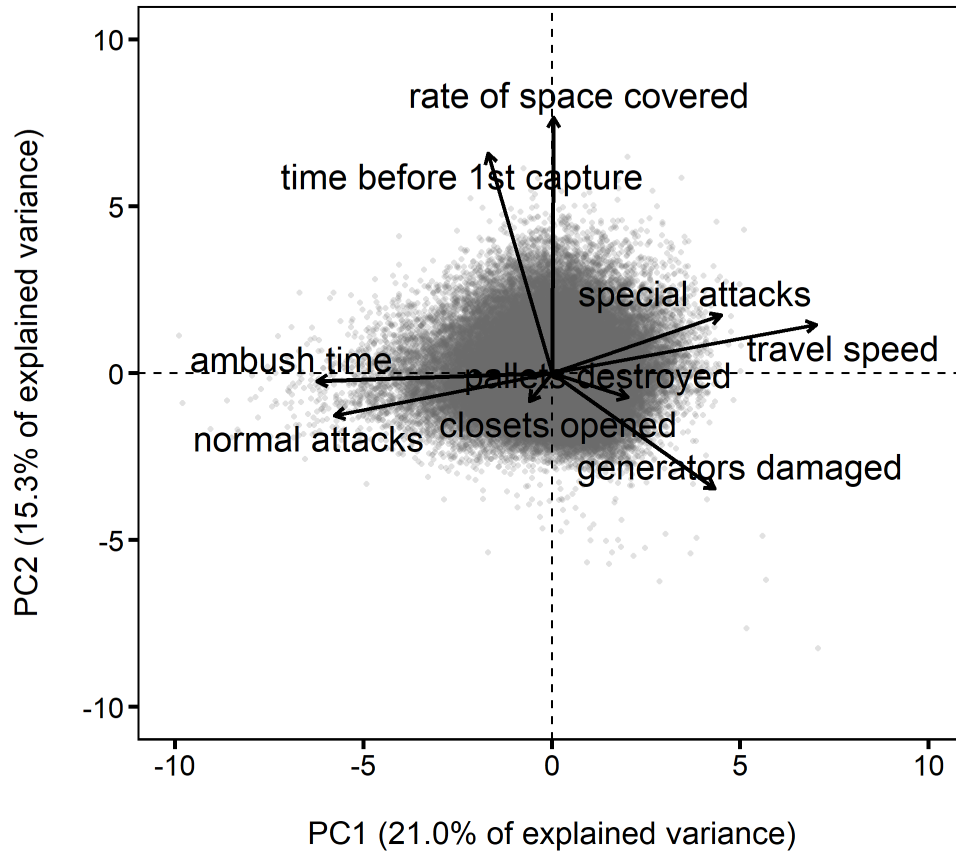


Figure S 1: Biplot of the principal component analysis on predator hunting variables. We extracted correlations and the percentages of explained variance on the first and second PC axes to select variables for the subsequent analyses.

Table SI: Principal component loadings for all the predator behavioural traits.

	PC1 (% variance = 21.0)		PC2 (% variance = 15.3)	
	Correlation	% variance	Correlation	% variance
ambush time	-0.66	23.19	-0.03	0.05
travel speed	0.75	29.38	0.15	1.73
rate of space covered	0.00	0.00	0.82	48.12
closets opened	-0.06	0.21	-0.09	0.56
pallets destroyed	0.21	2.42	-0.08	0.43
generators damaged	0.46	11.17	-0.37	9.79
normal attacks	-0.61	19.89	-0.13	1.31
special attacks	0.48	12.02	0.18	2.47
time before 1st capture	-0.18	1.72	0.70	35.55

70 After removing prey behavior as linear fixed effects, the percentage of explained variance by the game
 71 environments remained almost the same compared to the first model for predator travel speed, the proportion
 72 of time spent ambushing, and the proportion of time required to capture the first prey (table SII). Thus,
 73 variation in these three behaviors was not explained by differences among game environments. However,
 74 there was considerable variation among game environments in the rate of space covered (table SII).

Table SII: ICC estimates for the model without prey fixed effects.

Behavior	Random effect	ICC (95% CI)
travel speed	player ID	0.29 (0.26, 0.31)
	game environment	0.00 (0.00, 0.00)
	avatar	0.10 (0.04, 0.16)
	residuals	0.62 (0.57, 0.66)
space covered	player ID	0.04 (0.03, 0.05)
	game environment	0.28 (0.17, 0.40)
	avatar	0.01 (0.01, 0.03)
	residuals	0.67 (0.56, 0.77)
ambush time	player ID	0.32 (0.30, 0.35)
	game environment	0.00 (0.00, 0.00)
	avatar	0.04 (0.01, 0.07)
	residuals	0.64 (0.61, 0.66)
time 1st capture	player ID	0.13 (0.12, 0.14)
	game environment	0.00 (0.00, 0.00)
	avatar	0.02 (0.01, 0.04)
	residuals	0.85 (0.83, 0.86)

Literature Cited

- 76 Kassambara, A., and F. Mundt. 2020. Factoextra: Extract and Visualize the Results of Multivariate Data
77 Analyses. Comprehensive R Archive Network (CRAN).
- 78 Lê, S., J. Josse, and F. Husson. 2008. FactoMineR: An R Package for Multivariate Analysis. *Journal of*
79 *Statistical Software* 25:1–18.