

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 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 among-individual, environment, avatar, and within-individual variance-covariance matrixes. We extracted the among- (individual, avatar, environment) 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 :

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

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

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

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

30 where the diagonals represent the random effect variances for each hunting trait, and the lower off-diagonals  
 31 the covariance between the random effect intercepts for each combination of hunting traits (travel speed, the  
 32 rate of space covered, the proportion of time spent ambushing, and the time before first capture).

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

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#### *Parametrization of the bayesian mixed-models for hunting success*

40 We used a Gaussian prior with mean of 0 and standard deviation of 5 for all the models’ fixed effects. We vi-  
 41 sually inspected trace plots, effective sample sizes, and residuals to assess convergence and stability. We also  
 42 evaluated the models’ prediction accuracies using posterior predictive checks. We computed random inter-  
 43 cepts for the individual player ID and the game environment. We also included an observation-level random  
 44 effect to account for overdispersion. We calculated the ICC estimates using the function `posterior_samples()`

45 in the “brms” package, by dividing each random effect variance sample value by the total variance. We could  
 46 thus compute the mean of the samples to obtain the ICC value for each random effect, and HDP intervals to  
 47 obtain their corresponding 95% credible intervals.

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

$$\begin{aligned}
 \text{logit}(P_{ij}) = & (\beta_0 + id_{0i} + env_{0i} + \varepsilon_{0,ij}) \\
 & + \beta_{1,pred} speed_i \\
 & + \beta_{2,pred} space_i \\
 & + \beta_{3,pred} time\ in\ ambush_i \\
 & + \beta_{4,pred} time\ I^{st}\ capture_i
 \end{aligned} \tag{S5}$$

51 We included prey behaviour in the second model and kept the same structure as equation S5. For this model,  
 52 we ran four chains using 153 000 iterations by sampling every 100 intervals (thinning), and used the first  
 53 3000 iterations for warmup. The model was parametrized as :

$$\begin{aligned}
 \text{logit}(P_{ij}) = & (\beta_0 + id_{0i} + env_{0i} + \varepsilon_{0,ij}) \\
 & + \beta_{1,pred} speed_i \\
 & + \beta_{2,pred} space_i \\
 & + \beta_{3,pred} time\ in\ ambush_i \\
 & + \beta_{4,pred} time\ I^{st}\ capture_i \\
 & + \beta_{5,prey} speed'_i \\
 & + \beta_{6,prey} space'_i
 \end{aligned} \tag{S6}$$

54 In the third model, we were interested in investigating nonlinear relationships between hunting success and  
 55 predator behaviour exclusively. We thus added quadratic effects for each hunting trait. We also investigated  
 56 how predator behaviours interact to affect huntin success. The model was run for 103 000 iterations by

57 sampling every 100 intervals and using the first 3000 iterations as warmups. This model was computed as :

$$\begin{aligned}
\text{logit}(P_{ij}) = & (\beta_0 + id_{0i} + env_{0i} + \varepsilon_{0,ij}) \\
& + \beta_{1,pred} speed_i + \beta_{2,pred} space_i + \beta_{3,pred} time \text{ in ambush}_i + \beta_{4,pred} time I^{st} capture_i \\
& + \frac{1}{2} \gamma_{1,pred} speed_i^2 + \frac{1}{2} \gamma_{2,pred} space_i^2 + \frac{1}{2} \gamma_{3,pred} time \text{ in ambush}_i^2 + \frac{1}{2} \gamma_{4,pred} time I^{st} capture_i^2 \\
& + \gamma_{1,pred} speed_i \times space_i + \gamma_{2,pred} speed_i \times time \text{ in ambush}_i \\
& + \gamma_{3,pred} speed_i \times time I^{st} capture_i + \gamma_{4,pred} space_i \times time \text{ in ambush}_i \\
& + \gamma_{5,pred} space_i \times time I^{st} capture_i + \gamma_{6,pred} time \text{ in ambush}_i \times time I^{st} capture_i
\end{aligned} \tag{S7}$$

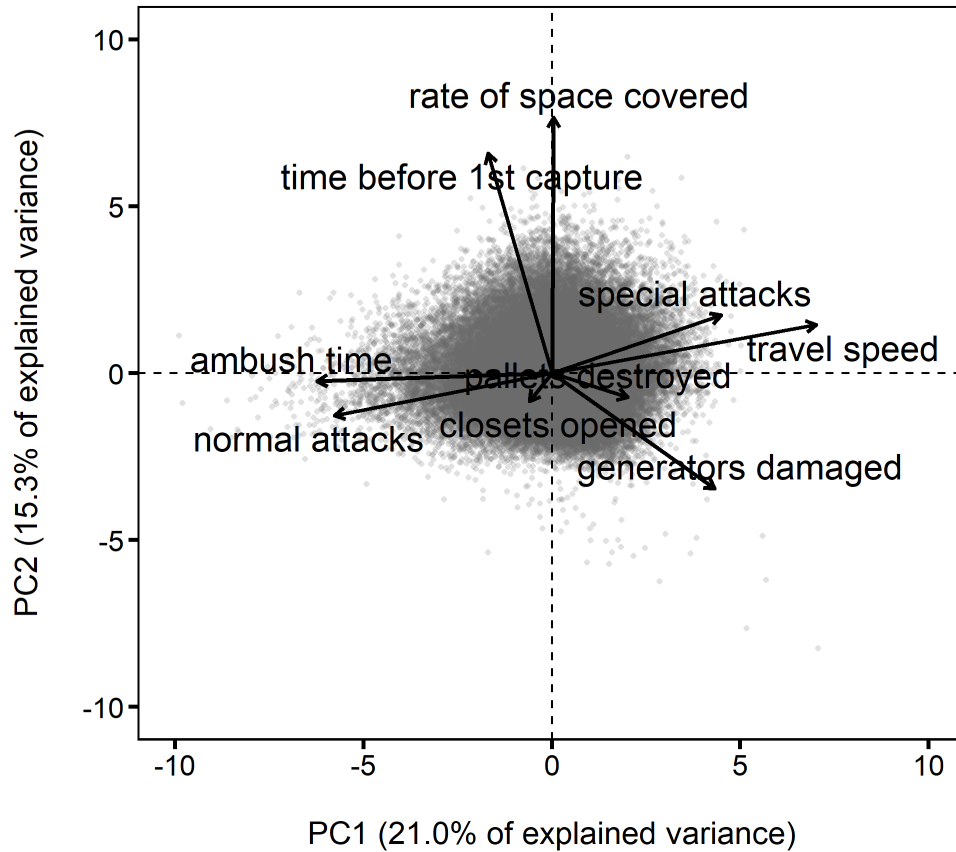
58 The fourth and final model included prey behaviours with their quadratic effects. We also included inter-  
59 actions between predator and prey behaviours to investigate how they jointly affect hunting success. The  
60 model was run for 103 000 iterations by sampling every 100 intervals and using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

$$\begin{aligned}
\text{logit}(P_{ij}) = & (\beta_0 + id_{0i} + env_{0i} + \varepsilon_{0,ij}) \\
& + \beta_{1,pred} speed_i + \beta_{2,pred} space_i + \beta_{3,pred} time \text{ in ambush}_i + \beta_{4,pred} time I^{st} capture_i \\
& + \frac{1}{2} \gamma_{1,pred} speed_i^2 + \frac{1}{2} \gamma_{2,pred} space_i^2 + \frac{1}{2} \gamma_{3,pred} time \text{ in ambush}_i^2 + \frac{1}{2} \gamma_{4,pred} time I^{st} capture_i^2 \\
& + \gamma_{1,pred} speed_i \times space_i + \gamma_{2,pred} speed_i \times time \text{ in ambush}_i \\
& + \gamma_{3,pred} speed_i \times time I^{st} capture_i + \gamma_{4,pred} space_i \times time \text{ in ambush}_i \\
& + \gamma_{5,pred} space_i \times time I^{st} capture_i + \gamma_{6,pred} time \text{ in ambush}_i \times time I^{st} capture_i \\
& + \beta_{5,prey} speed'_i + \beta_{6,prey} space'_i \\
& + \frac{1}{2} \gamma_{5,prey} speed'^2_i + \frac{1}{2} \gamma_{6,prey} space'^2_i \\
& + \gamma_{7,pred \text{ prey}} speed_i \times speed'_i + \gamma_{8,pred \text{ prey}} speed_i \times space'_i + \gamma_{9,pred \text{ prey}} space_i \times speed'_i \\
& + \gamma_{10,pred \text{ prey}} space_i \times space'_i + \gamma_{11,pred \text{ prey}} time \text{ in ambush}_i \times speed'_i \\
& + \gamma_{12,pred \text{ prey}} time \text{ in ambush}_i \times space'_i + \gamma_{13,pred \text{ prey}} time I^{st} capture_i \times speed'_i \\
& + \gamma_{14,pred \text{ prey}} time I^{st} capture_i \times space'_i
\end{aligned} \tag{S8}$$

## 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

*Differences among environments in predator behavior without the effect of prey*

After removing prey behavior as linear fixed effects, the percentage of explained variance by the game environments remained almost the same compared to the first model for predator travel speed (0.0021 [0.0010, 0.0035]), the proportion of time spent ambushing (0.0014 [0.0006, 0.0023]), and the proportion of time required to capture the first prey (0.0019 [0.0009, 0.0033]). Thus, variation in these three behaviors was not explained by differences among game environments. However, there was considerable variation among game environments in the rate of space covered (0.2752 [0.1733, 0.3977]).

**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

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