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ORIGINAL RESEARCH

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"Micropersonality" traits and their implications for behavioral and movement ecology research

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Abstract

1. Many animal personality traits have implicit movement-based definitions and can directly or indirectly influence ecological and evolutionary processes. It has therefore been proposed that animal movement studies could benefit from acknowledging and studying consistent interindividual differences (personality), and, conversely, animal personality studies could adopt a more quantitative representation of movement patterns.
2. Using high-resolution tracking data of three-spined stickleback fish (*Gasterosteus aculeatus*), we examined the repeatability of four movement parameters commonly used in the analysis of discrete time series movement data (time stationary, step length, turning angle, burst frequency) and four behavioral parameters commonly used in animal personality studies (distance travelled, space use, time in free water, and time near objects).
3. Fish showed repeatable interindividual differences in both movement and behavioral parameters when observed in a simple environment with two, three, or five shelters present. Moreover, individuals that spent less time stationary, took more direct paths, and less commonly burst travelled (movement parameters), were found to travel farther, explored more of the tank, and spent more time in open water (behavioral parameters).
4. Our case study indicates that the two approaches—quantifying movement and behavioral parameters—are broadly equivalent, and we suggest that movement parameters can be viewed as "micropersonality" traits that give rise to broad-scale consistent interindividual differences in behavior. This finding has implications for both personality and movement ecology research areas. For example, the study of movement parameters may provide a robust way to analyze individual personalities in species that are difficult or impossible to study using standardized behavioral assays.

KEYWORDS

animal personality, *Gasterosteus aculeatus*, interindividual differences, stickleback fish, tracking, trajectories

1 | INTRODUCTION

Understanding and predicting animal space use is central to the advancement of ecological research (Kanagaraj et al., 2013; Nathan et al., 2008). Mechanistic models of animal movement tend to assume animal movement is either fixed or else flexible with respect to environmental heterogeneity or uncertainty (Fofana & Hurford, 2017; Grunbaum, 1998; Moorcroft, 2012). Studies supporting flexible movement strategies are growing; animals have the ability to make choices about their environment and respond to stimuli using their various sensory mechanisms (e.g., Ben-Ari & Inbar, 2014; Hopkins, 2016; Lemasson et al., 2009), and movement paths can emerge from interactions with heterogeneous landscapes (e.g., Lima & Zollner, 1996; Sueur et al., 2011). However, to predict population dynamics and the emergence of ecological patterns from individual behavior requires thorough consideration of inter- and intraspecific variation in movement patterns and not only the spatial structure of the landscape (Belgrad & Griffen, 2018; Getz et al., 2018; Morales & Ellner, 2002; Sih et al., 2018; Spiegel et al., 2017).

Variation in movement patterns can be linked to interindividual differences in, for example, exploratory tendency (e.g., Herborn et al., 2010; King et al., 2013) where some individuals explore fast and superficially, while others explore slowly and more thoroughly (e.g., Dingemanse et al., 2002; Guillette et al., 2009), or boldness, where bolder individuals are more likely to move toward (or less likely to retreat from) threat or risk (e.g., Fürtbauer et al., 2015; Williams et al., 2012). Indeed, such "personality traits" have implicit movement-based definitions and can directly or indirectly influence ecological and evolutionary processes (Spiegel et al., 2017; Wolf & Weissing, 2012). It has therefore been proposed that movement studies could benefit from acknowledging and studying consistent interindividual differences, and, conversely, animal personality studies could adopt a more quantitative representation of movement patterns (Spiegel et al., 2017; Webber & Vander Wal, 2018).

Despite the calls for synergy between personality and movement ecology research (e.g., Getz et al., 2018; Spiegel et al., 2017), studies using individual-level data to build data- or theory-driven movement models are rare. However, with advances in tracking technologies allowing researchers to record many individuals' movement simultaneously in the wild (Kays et al., 2015; King et al., 2018) and software enabling the identification and tracking of individuals in the laboratory (Krause et al., 2013; Romero-Ferrero et al., 2019), such work has become possible. For example, during the process of undertaking and writing this study, several works examining individual variation in animal movements using telemetry data have been published (Harris et al., 2020; Harrison et al., 2019; Hertel et al., 2020) and this behavioral type-based approach to study movement ecology allows for better understanding of community and population responses (e.g., Harris et al., 2020; Morales & Ellner, 2002).

Here, we study three-spined stickleback fish (*Gasterosteus aculeatus*, Figure 1a), a classic behavioral model species (Bell, 1995) that exhibits interindividual differences in behavior (e.g., Bell, 2005; Dingemanse et al., 2007; King et al., 2013) and flexibility with respect to environmental changes (e.g., Bell & Sih, 2007; Fürtbauer et al., 2015; Hansen et al., 2016). Using high-resolution tracking data, we examined the repeatability of four movement parameters commonly used in the analysis of discrete time series movement data (time stationary, step length, turning angle, burst frequency) and four behavioral parameters commonly used in animal personality studies (distance travelled, space use, time in free water, and time near objects). We chose these movement parameters because they constitute the basis of movement path analyses in movement ecology research (e.g., Ben-Ari & Inbar, 2014; Hopkins, 2016; Kane et al., 2004; Kareiva & Shigesada, 1983; Lemasson et al., 2009; Lima & Zollner, 1996; Sueur et al., 2011). We chose these behavioral parameters as they are commonly studied in this species to investigate activity and exploratory behavior (e.g., Dzieweczynski & Crovo, 2011; Jolles et al., 2018; King et al., 2013; Mamuneas et al., 2015), and such descriptors are repeatable and related to physiological measures in our study population (Fürtbauer et al., 2015).

We expected fish to show consistent interindividual differences in movement and behavioral parameters, across time and context (i.e., in different environments, sampled repeatedly). Furthermore, because consistent interindividual differences in activity and exploration (i.e., personality traits) have implicit movement-based definitions (Spiegel et al., 2017), we hypothesized the two approaches—quantifying movement and behavioral parameters—would be broadly equivalent, whereby interindividual differences in precise movement characteristics give rise to broad-scale interindividual differences in behaviors. If true, we propose that interindividual differences in movement parameters could be usefully viewed as "micropersonality" traits.

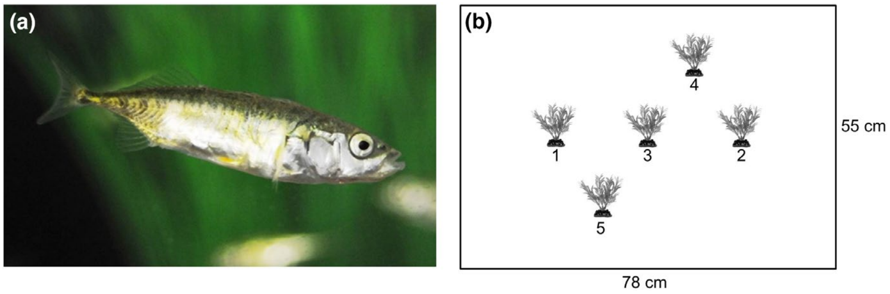

FIGURE 1 (a) Female *Gasterosteus aculeatus*; (b) Set-up. Fish were observed in a 78 × 55 × 16 cm plastic tank, filled to 12 cm with water. The fish were observed with either two shelters (plants 1 and 2), three shelters (plants 1–3), or five shelters (plants 1–5)

2 | METHODS

2.1 | Subjects and housing

Wild three-spined sticklebacks (*Gasterosteus aculeatus*) (Figure 1a) were caught from Swansea University campus pond, UK. Fish were kept in a holding tank (300 × 390 × 1,220 mm) containing gravel substrate, plants, and driftwood for 2 weeks prior to behavioral testing at a consistent temperature of 16°C and with 8 hr:16 hr light:dark photoperiod regime. Fish were fed bloodworms (*Chironomus* sp.) daily. During behavioral testing, fish were kept in individual 2.8 L gravel-lined, aerated tanks, with visual access to neighbors.

2.2 | Fish observations

Fish were filmed using a Panasonic HDC-SD60 HD video camera (Panasonic Corporation of North America) mounted on a custom-built metal frame (1 × 1 × 1.5 m) surrounded by white sheeting (PhotoSEL BK13CW White Screen). Four photographer's lights (each with 4 × 25w 240v 6400K True Day light bulbs) lit the arena from outside the white sheet, dispersing light evenly. Fish were observed for 15 min after being placed in the bottom left-hand corner of an opaque plastic tank, 78 × 55 × 16 cm, which was lined with white gravel and filled with water to 12 cm (and water was changed after each trial). Fish were observed with either two, three, or five plastic plants at fixed positions (Figure 1b) representing increasingly heterogeneous environment and were repeat tested 1 week later in the reverse order ($n = 15$ fish, $n = 6$ trials per fish, total $N = 90$). Data for $n = 1$ fish in week 1 could not be fully tracked from video, resulting in an overall sample of $N = 87$.

2.3 | Fish trajectory data

Video recordings were processed using IDTracker (Perez-Escudero et al., 2014) to generate *x*, *y* coordinates for fish, frame by frame (25 Hz recording). Movement was therefore considered to be formed by a discrete step-turn process. Data were then manually checked, and a value of 5 mm/s was chosen as a threshold to determine movement, which represented movement across frames of less than a pixel (Duteil et al., 2016). A subsampling rate of 2.5 Hz was used to prevent false large turns which can occur due to the processing of the video recording (Delcourt et al., 2013). The movement threshold and subsampling rates are in essence arbitrary values but were chosen to retain as much information about the movement path, while minimizing any causal effects such smoothing can have on characteristics of movement trajectories (Bailey et al., 2020; Benhamou, 2014; Bovet & Benhamou, 1988; Codling & Hill, 2005; Gurarie & Ovaskainen, 2011); different combinations of thresholds and subsampling did not affect our findings (Figures S2–S10).

2.4 | Movement and behavioral parameters

For each fish and for each trial, we calculated the following movement parameters: (a) Time Stationary (% of trial), (b) Step Length (mean across trial, mm), (c) Turning Angle (mean cosine turn angle, ϴ), and (d) Burst Frequency (the relative frequency of periods of movement with a speed above 3 *SD*'s of the mean step length of the fish when moving) (Kane et al., 2004), and the following behavioral parameters: (e) Distance Travelled (total distance travelled during trial) (f) Space Use (proportion of tank two-dimensional space explored), (g) Time Near Objects (% of time "near" an object during the trial), and (h) Time in Free Water (% time away from tank edges and shelters) (Figure 2). Near (or away) from objects was considered as

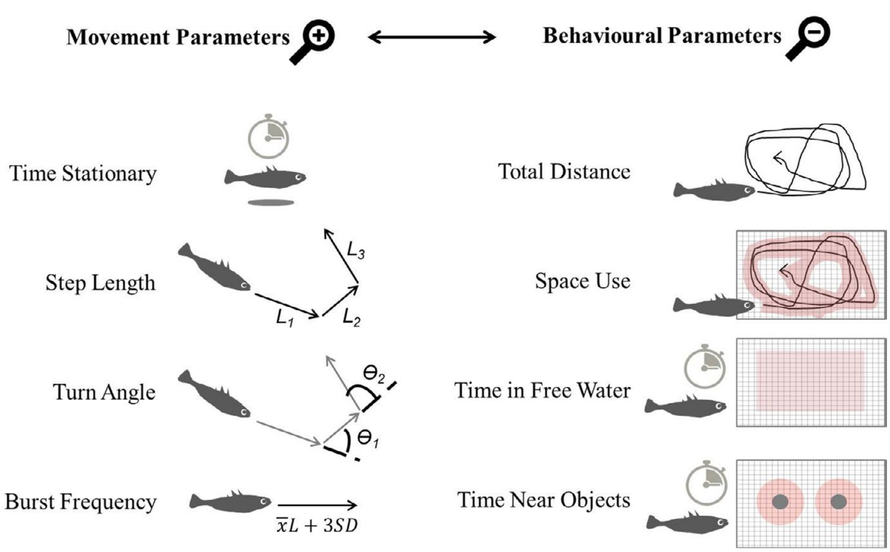

FIGURE 2 Using high-resolution tracking data of three-spined stickleback fish (*Gasterosteus aculeatus*), we examined the repeatability of four movement parameters commonly used in the analysis of discrete time series movement data and four behavioral parameters commonly used in animal personality studies. Movement parameters shown quantify precise characteristics of fish trajectories, while behavioral parameters indicate overall patterns of activity and space use

within 7 cm (larger than fish body length which is on average 5.3 cm in a sample from our study population; Fürtbauer et al., 2015); other distances were considered from 2 to 15 cm, but results were quantitatively similar.

2.5 | Statistical analyses

All statistical analyses were carried out using R software v3.5.1 (R Core Team, 2018). To assess repeatability in movement and behavioral parameters at the individual level, agreement repeatability was calculated across the six observations per fish (equivalent to the intraclass correlation coefficient (Nakagawa & Schielzeth, 2010; Roche et al., 2016) by fitting a univariate linear mixed model for each parameter using the lme4 package in R (Bates et al., 2015) with only the fish identity (ID) as a random factor (Dingemanse & Dochtermann, 2013; Houslay & Wilson, 2017; Nakagawa & Schielzeth, 2010; Roche et al., 2016). Adjusted repeatability controlling for fixed effects (trial number and environment), was then calculated using the rptR package in R (Nakagawa & Schielzeth, 2013; Stoffel et al., 2017).

To determine whether parameters were correlated between individuals (Hertel et al., 2019), while also testing for the effect of fish identity, and the environment (Houslay & Wilson, 2017; Roche et al., 2016) we fitted a series of mixed models. We fitted each parameter as the response variable (scaled: mean = 0, *SD* = 1), week (1, 2), and environment (two, three, five plants) as fixed effects, and fish ID as a random effect. To compare variation (V) attributed to repeatable interindividual differences (ID) and the environment (Env), we modeled ID and ID × Env as random effects (Dingemanse et al., 2010) allowing us to calculate V_{ID}/V_{Env}, values close to 0 indicating when V_{ID} is negligible compared to the effect of the environment. We also performed an eigendecomposition on the between-individual covariance matrix to see whether a major axis of among-individual variation existed (Houslay et al., 2018) indicative of a single latent behavior (Hertel et al., 2019; White et al., 2019).

The mixed model approach described above was fitted using the MCMCglmm package (Hadfield, 2010) and followed the process outlined in Houslay and Wilson (2017) to avoid the anticonservative estimations of best linear unbiased predictors (Hertel et al., 2019; Houslay & Wilson, 2017; Tan & Tan, 2019). We used the MCMCglmm default prior for the fixed effects and an inverse-gamma prior for the residuals ($V = 1, \nu = 0.002$). For the random effects an uninformative, parameter-expanded prior was used with ($V = 1$, $\nu = 0.002$, $\alpha\mu = 0$, $\alpha V = 25^2$) (Hertel et al., 2019; Houslay & Wilson, 2017). Posterior distributions were visibly inspected to determine the validity of the algorithms and to ensure convergence, and trace plots (Figure S1) confirmed mixing of chains and absence of autocorrelation between posterior samples (using coda package in R: Plummer et al., 2006). An eigendecomposition on the between-individual covariance matrix was performed with 95% CIs estimated from 5,000 bootstrapped replicates of the MCMC chain by modifying the bootstrap code provided by Houslay et al. (2018).

3 | RESULTS

3.1 | Repeatability of movement and behavioral parameters

Univariate models (Table S1) and mixed effects models (Table S2) revealed consistent interindividual differences in both movement and behavioral parameters, with the exception of Time Near Objects (Table 1). Moreover, the variance explained by fish identity was greater than that explained by changes in the environment, for all parameters except Time in Free Water and Time near Objects (Table 1).

3.2 | Correlations between movement and behavioral parameters

We found significant between-individual correlations among a number of movement parameters and behavioral parameters (Table 2; Figure 3). Time Stationary and Step Length (movement parameters) correlated with Distance Travelled and Space Use (behavioral parameters). Burst Frequency (movement parameter) was correlated with Space Use and Time in Free Water (behavioral parameters). Turning angle (movement parameter) was correlated with Time in Free Water (behavioral parameter).

3.3 | Major axis of between-individual variation

Eigendecomposition revealed a major axis of between-individual variation (Eigenvector 1 = 59.8%, Table S3) representing fish activity/

TABLE 1 Agreement repeatability estimates (*R*), with 95% confidence intervals (CI) and corresponding *p* value, estimates using the rptR package in R (Stoffel et al., 2017). Variation (V) attributed to repeatable interindividual differences (ID) and the environment (Env), are also provided

Parameter	*R*	95% CI	*p*	V_{ID}/V_{Env}
Time stationary	0.43	0.16. 0.62	<.001	0.56
Step length	0.75	0.51, 0.87	<.001	0.74
Turn angle	0.27	0.04. 0.49	.003	0.36
Burst frequency	0.25	0.02, 0.46	.003	0.41
Distance travelled	0.44	0.17, 0.64	<.001	0.91
Space use	0.58	0.30, 0.76	<.001	0.66
Time in free water	0.28	0.04, 0.49	.001	0.01
Time near objects	0.11	0.00, 0.30	.100	0.01

Note: All parameters except for Time Near Objects were repeatable. Comparison of variation (V) attributed to repeatable interindividual differences (ID) and the environment (Env) based on output of fitting ID and ID × Env as random effects (Dingemanse et al., 2010) and calculated V_{ID}/V_{Env} are also shown; values close to 0 indicate when V_{ID} is negligible. Values imply V_{ID} is not negligible compared to V_{Env} for all parameters except Time in Free Water and Time near Objects.

TABLE 2 Adjusted repeatability values (i.e., repeatability values calculated conditioned on the fixed effects) and 95% CIs (in brackets) given in italics across the main diagonal

	Time stationary	Step length	Turn angle	Burst frequency	Distance travelled	Space use	Time in free water
Time stationary	*0.50 (0.23, 0.77)*	−0.08 (−0.68, 0.56)	**−0.65 (−1.00, −0.14)**	**0.67 (0.14, 1.00)**	**−0.66 (−0.97, 0.21)**	**−0.73 (−0.97, −0.36)**	<u>−0.57 (−1.00, 0.02)</u>
Step length		*0.80 (0.66, 0.94)*	0.07 (−0.60, 0.72)	−0.31 (−0.90, 0.34)	**0.50 (0.00, 0.92)**	**0.57 (0.12, 0.94)**	0.32 (−0.32, 0.86)
Turn angle			*0.37 (0.08, 0.65)*	**−0.86 (−1.00, −0.53)**	0.39 (−0.27, 0.96)	0.42 (−0.19, 0.92)	**0.70 (0.16, 1.00)**
Burst frequency				*0.34 (0.07, 0.62)*	−0.53 (−1.00, 0.11)	<u>−0.57 (−0.99, −0.02)</u>	**−0.75 (−1.00, −0.23)**
Distance travelled					*0.53 (0.21, 0.86)*	**0.89 (0.68, 1.00)**	**0.69 (0.18, 1.00)**
Space use						*0.62 (0.39, 0.87)*	**0.64 (0.13, 1.00)**
Time in free water							*0.34 (0.07, 0.64)*

Note: Correlations between parameters along with 95% CI are given above the diagonal. Values are calculated by sampling 4,000 models from the MCMC chain at 1,000-generation intervals (Hertel et al., 2019). Due to the Bayesian nature of calculating the correlation, values were considered significant if the CIs did not cross 0, and these are shown in bold. Where CIs were close to crossing 0 are underlined.

exploration (Eigenvector 1) with behavioral parameters (Distance Travelled, Space Use, Time in Free Water) loading in the same direction as two movement parameters (Turning Angle, Step Length), however the CIs for the movement parameters either straddled or were close to 0 (Table 3). Time Stationary (behavioral parameter) and Burst Frequency (movement parameter) loaded mainly in the opposite direction (Table 3), although the CIs also straddled or were close to 0. Eigenvector 2 was almost entirely loaded by Step Length, and all parameters CIs straddled 0, and hence, no clear conclusions can be made about EV2 (Table 3).

4 | DISCUSSION

We find that stickleback fish show consistent interindividual differences in movement parameters (commonly used in the analysis of discrete movement data) and behavioral parameters (commonly used in animal personality studies), when observed repeatedly across different environments. While our observations of $n = 15$ individuals observed six times is a low sample size (Dingemanse & Dochtermann, 2013), previous studies on this species have shown such behavioral parameters to be repeatable (e.g., Fürtbauer et al., 2015; Jolles et al., 2016, 2018, 2019; King et al., 2013), and movement parameters are repeatable in other fish species (e.g., mosquitofish, *Gambusia holbrooki*: Herbert-Read et al., 2013). By combining movement and behavioral parameters to quantify the structure of behavioral variation in our study population (White et al., 2019), we show these two approaches—quantifying movement and behavioral parameters—are broadly equivalent.

We demonstrate that movement and behavioral parameters capture similar interindividual variation via correlations among parameters (Figure 3). Furthermore, comparison of the variance accounted for by fish ID and the environment (Table 1) indicates fish ID explains more variation than the environment, for all parameters except for Time in Free Water and Time near Objects which are determined by the environment directly, and not by fish behavior/movement. Eigendecomposition on the between-individual covariance also suggests a single axis of between-individual variation representing activity/exploration (Table 3). Specifically, we find that fish that spent less time stationary, tookmore direct paths, and less commonly burst travelled (movement parameters), were also observed to travel farther, explore more of the tank, and spend more time in open water (behavioral parameters). However, the CIs for the loading of movement parameters are larger than those of behavioral parameters (Table 3) suggesting movement parameters may be less reliable measures of this activity/exploration axis. Studies investigating correlations among movement and behavioral parameters in other species and contexts are therefore needed. Nevertheless, we expect the consistent interindividual differences in movement parameters and their correlation with behavioral parameters to represent a general phenomenon (Spiegel et al., 2017) with implications for personality and movement ecology research (Nathan et al., 2008; Schick et al., 2008; Spiegel et al., 2017) as discussed below.

Laboratory studies of animal personality make observations of individuals over many minutes or hours (e.g., studies of fish or insects) and often disregard data from an arbitrarily defined period at the start of observations to allow subjects to acclimatize to the test arena or circumstances. Our findings indicate that researchers may be able to use movement parameters (e.g., time spent stationary and burst frequency) to not only quantitatively determine acclimatization periods, but also assay personality types using minimal trajectory data. In the case of determining acclimatization periods, moving average calculations and change-point tests (Picard, 1985) will allow researchers to define periods during which movement parameters

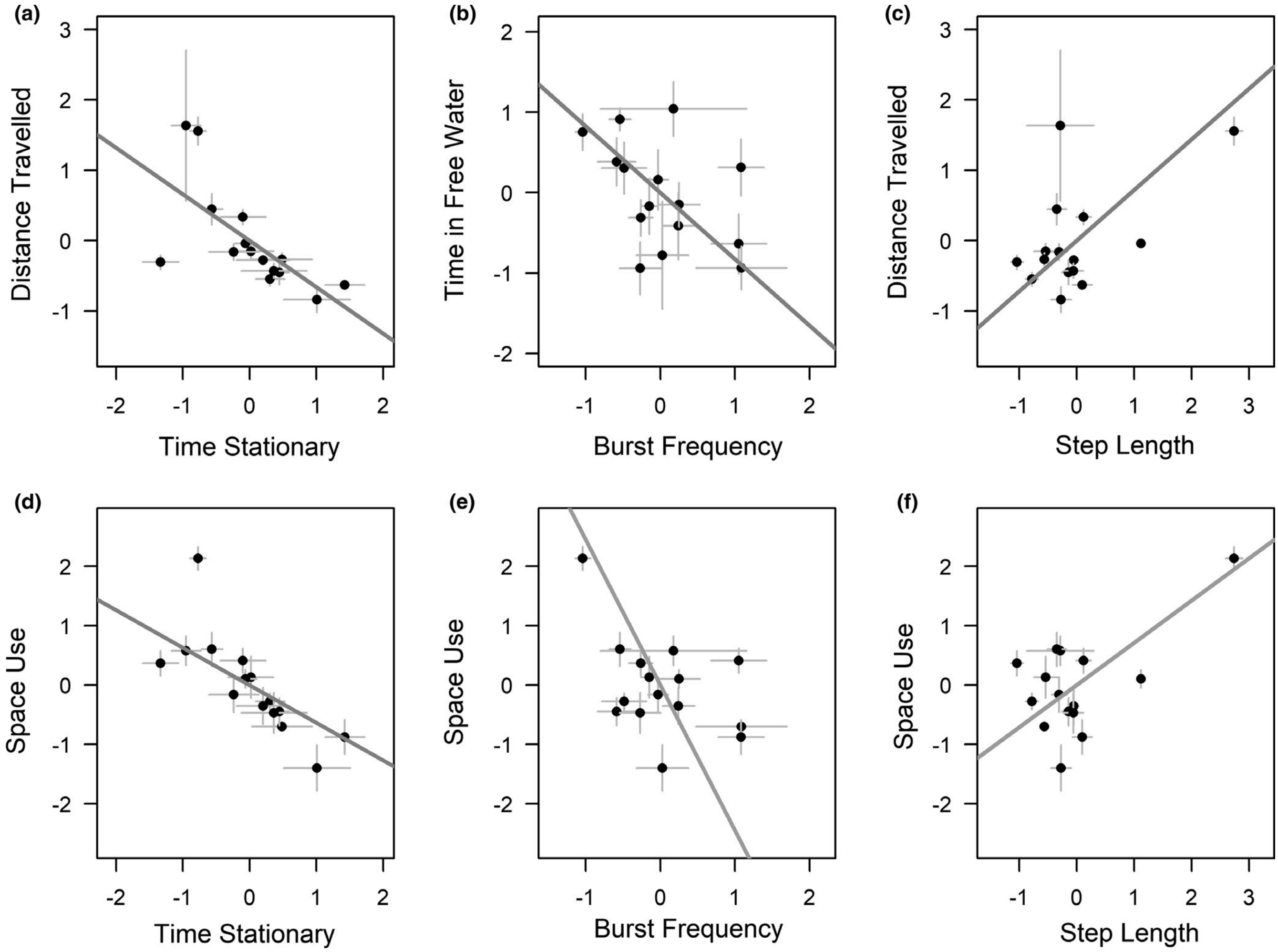

FIGURE 3 Statistically significant between-individual correlations among movement parameters and behavioral parameters (Table 2). Parameters are scaled (mean = 0, *SD* = 1) with the dots and error bars representing individual mean averages ± standard error (taken from the posteriors of the random effects from the multivariate MCMCglmm model; Table S2). Regression lines fitted to data are estimated by dividing the covariance of the traits by the variance of the trait on the *x*-axis (Hertel et al., 2019; Houslay & Wilson, 2017)

are consistent. In practice, this will likely differentiate time periods at the start of trials from the rest of the observation. Data over seconds during identified stable periods may also be sufficient to assay an individual's personality type (sensu David et al., 2012; MacKay et al., 2013). Furthermore, if this process could be automated by a tracking system (e.g., Alarcon-Nieto et al., 2018; Dell et al., 2014; Matthews et al., 2017; Strömbom & King, 2018), it would open the possibility for generating large and robust datasets affording studies linking individual differences in behavior to evolutionary processes (e.g., Alarcon-Nieto et al., 2018; Gernat et al., 2018; King et al., 2018; Rudolf et al., 2019; Sabol et al., 2018; Valletta et al., 2017), or animal welfare and management (e.g., Fehlmann et al., 2017; Henry et al., 2018; Matthews et al., 2017). Note, however, the discussion above would only be applicable to relatively fast-moving species and not be applicable to, for example, studies of personality in gastropods (e.g., Ahlgren et al., 2015).

TABLE 3 Eigendecomposition on the between-individual covariance matrix to investigate major axis of among-individual variation (following Houslay & Wilson, 2017) indicative of a single latent behavior (Hertel et al., 2019; White et al., 2019)

Parameter	EV1	EV2
Time stationary	0.35 (0.01, 0.64)	0.41 (−0.33, 0.78)
Step length	−0.43 (−0.88, −0.01)	0.79 (−0.10, 0.90)
Turn angle	−0.23 (−0.48, 0.05)	−0.36 (−0.75, 0.36)
Burst frequency	0.26 (−0.01, 0.47)	0.20 (−0.44, 0.65)
Distance travelled	−0.45 (−0.67, −0.11)	−0.04 (−0.62, 0.56)
Space use	−0.52 (−0.74, −0.17)	0.01 (−0.62, 0.58)
Time in free water	−0.30 (−0.51, −0.02)	−0.17 (−0.64, 0.43)
Time near objects	0.07 (−0.07, 0.18)	−0.06 (−0.31, 0.25)

With the increasing availability of telemetry data (Kranstauber et al., 2011; Krause et al., 2013), movement parameters may also provide a robust way to analyze personality traits for species that are difficult or impossible to study using standardized behavioral assays (Carter et al., 2013), allowing further integration of movement ecology with other fields of behavioral ecology (Hertel et al., 2020). For example, an advantage of such in situ movement data is that researchers can examine changes in movement parameters at an individual to quantify flexibility in personality (e.g., Betini & Norris, 2012; Briffa et al., 2008; Carere et al., 2005; Carter et al., 2013; Dingemanse et al., 2010; Frost et al., 2007; Kralj-Fiser & Schneider, 2012; Quinn & Cresswell, 2005). Statistically, this involves testing individuals' plasticity or "reaction norms" to different environments or contexts (Araya-Ajoy, Mathot, & Dingemanse, 2015; Cornwell, McCarthy, Snyder, & Biro, 2019; Dingemanse & Dochtermann, 2013). While this requires large sample sizes (numbers of individuals), tracking the movements of many individuals simultaneously is now possible in the wild (King et al., 2018). Future work can therefore adopt a behavioral type-based approach to understand the consequences of fixed or flexible behaviors at the individual level for population dynamics and the emergence of complex ecological patterns (e.g., Getz et al., 2018; Spiegel et al., 2017). There is increasing evidence for personality-dependent space use (e.g., Schirmer et al., 2019), and experiments with *Tribolium confusum* beetles, for example, found that conventional correlated random walk models, which do not incorporate interindividual differences in movement, were unable to account for the authors' data in a series of landscape experiments (Morales & Ellner, 2002).

Our case study supports a proposal for movement studies to acknowledge and study consistent individual differences, and, conversely, animal personality studies to adopt a more quantitative representation of movement patterns (e.g., Getz et al., 2018; Spiegel et al., 2017). Indeed, for researchers interested in "higher order" group- and population-level behaviors, it is necessary to incorporate such individual-level variation into their studies (King et al., 2018). However, where individual-level data are collected in isolation (i.e., solitary individuals) we urge caution using these data to build data- or theory-driven movement models, since variation in the social environment can profoundly alter the expression of movement and behavior (e.g., Fürtbauer & Fry, 2018; Herbert-Read et al., 2013; King et al., 2015; Zhang et al., 2020), and this poses a new challenge for researchers in both areas. In short, the two research areas should continue to collaborate to advance their respective and combined fields of research.

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CONFLICT OF INTEREST

None declared.

AUTHOR CONTRIBUTION

Joseph D. Bailey: Data curation (equal); Formal analysis (lead); Visualization (lead); Writing-review & editing (supporting). **Andrew J. King:** Conceptualization (supporting); Data curation (supporting); Formal analysis (supporting); Funding acquisition (equal); Investigation (supporting); Methodology (supporting); Project administration (supporting); Resources (equal); Supervision (lead); Writing-original draft (lead). **Edward A. Codling:** Formal analysis (supporting); Project administration (supporting); Writing-review & editing (supporting). **Ashley M. Short:** Data curation (equal); Investigation (equal); Methodology (equal). **Gemma I. Johns:** Data curation (equal); Investigation (equal); Methodology (equal). **Ines Fürtbauer:** Conceptualization (lead); Data curation (supporting); Funding acquisition (equal); Investigation (equal); Project administration (equal); Resources (equal); Supervision (supporting); Writing-original draft (supporting); Writing-review & editing (supporting).

ETHICAL APPROVAL

This work was approved by Swansea University institutional Animal Welfare and Ethical Review Body (AWERB) REF-IP-1213-3.

DATA AVAILABILITY STATEMENT

All data needed to perform analyses uploaded as supplementary material.

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REFERENCES

Ahlgren, J., Chapman, B. B., Nilsson, P. A., & Brönmark, C. (2015). Individual boldness is linked to protective shell shape in aquatic snails. *Biology Letters*, *11*(4), 20150029. https://doi.org/10.1098/rsbl.2015.0029

Alarcon-Nieto, G., Graving, J. M., Klarevas-Irby, J. A., Maldonado-Chaparro, A. A., Mueller, I., & Farine, D. R. (2018). An automated barcode tracking system for behavioural studies in birds. *Methods in Ecology and Evolution*, *9*, 1536–1547. https://doi.org/10.1111/2041-210X.13005

Araya-Ajoy, Y. G., Mathot, K. J., & Dingemanse, N. J. (2015). An approach to estimate short-term, long-term and reaction norm repeatability. *Methods in Ecology and Evolution*, *6*, 1462–1473. https://doi.org/10.1111/2041-210X.12430

Bailey, J., Benefer, C., Blackshaw, R., & Codling, E. (2020). Walking behaviour in the ground beetle, *Poecilus cupreus*: Dispersal potential, intermittency and individual variation. *Bulletin of Entomological Research*, 1–10. https://doi.org/10.1017/S0007485320000565

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*, 48.

Belgrad, B. A., & Griffen, B. D. (2018). Personality interacts with habitat quality to govern individual mortality and dispersal patterns. *Ecology and Evolution*, *8*, 7216–7227. https://doi.org/10.1002/ece3.4257

Bell, M. A. (1995). Intraspecific Systematics of Gasterosteus Aculeatus Populations: Implications for Behavioral Ecology. *Behaviour*, *132*(15–16), 1131–1152. https://doi.org/10.1163/156853995X00496

Bell, A. (2005). Behavioural differences between individuals and two populations of stickleback (Gasterosteus aculeatus). *Journal of Evolutionary Biology*, *18*, 464–473. https://doi.org/10.1111/j.1420-9101.2004.00817.x

Bell, A. M., & Sih, A. (2007). Exposure to predation generates personality in threespined sticklebacks (Gasterosteus aculeatus). *Ecology Letters*, *10*(9), 828–834. https://doi.org/10.1111/j.1461-0248.2007.01081.x

Ben-Ari, M., & Inbar, M. (2014). Aphids link different sensory modalities to accurately interpret ambiguous cues. *Behavioral Ecology*, *25*, 627–632. https://doi.org/10.1093/beheco/aru033

Benhamou, S. (2014). Of scales and stationarity in animal movements. *Ecology Letters*, *17*(3), 261–272. https://doi.org/10.1111/ele.12225

Betini, G. S., & Norris, D. R. (2012). The relationship between personality and plasticity in tree swallow aggression and the consequences for reproductive success. *Animal Behaviour*, *83*, 137–143. https://doi.org/10.1016/j.anbehav.2011.10.018

Bovet, P., & Benhamou, S. (1988). Spatial analysis of animals' movements using a correlated random walk model. *Journal of Theoretical Biology*, *131*(4), 419–433. https://doi.org/10.1016/S0022-5193(88)80038-9

Briffa, M., Rundle, S. D., & Fryer, A. (2008). Comparing the strength of behavioural plasticity and consistency across situations: Animal personalities in the hermit crab *Pagurus bernhardus*. *Proceedings of the Royal Society B-Biological Sciences*, *275*, 1305–1311.

Carere, C., Drent, P. J., Privitera, L., Koolhaas, J. M., & Groothuis, T. G. G. (2005). Personalities in great tits, *Parus major*: Stability and consistency. *Animal Behaviour*, *70*, 795–805. https://doi.org/10.1016/j.anbehav.2005.01.003

Carter, A. J., Feeney, W. E., Marshall, H. H., Cowlishaw, G., & Heinsohn, R. (2013). Animal personality: What are behavioural ecologists measuring? *Biological Reviews*, *88*, 465–475. https://doi.org/10.1111/brv.12007

Codling, E. A., & Hill, N. A. (2005). Sampling rate effects on measurements of correlated and biased random walks. *Journal of Theoretical Biology*, *233*(4), 573–588. https://doi.org/10.1016/j.jtbi.2004.11.008

Cornwell, T. O., McCarthy, I. D., Snyder, C. R. A., & Biro, P. A. (2019). The influence of environmental gradients on individual behaviour: Individual plasticity is consistent across risk and temperature gradients. *Journal of Animal Ecology*, *88*, 511–520. https://doi.org/10.1111/1365-2656.12935

David, M., Auclair, Y., & Cezilly, F. (2012). Assessing short- and long-term repeatability and stability of personality in captive zebra finches using longitudinal data. *Ethology*, *118*, 932–942. https://doi.org/10.1111/j.1439-0310.2012.02085.x

Delcourt, J., Denoël, M., Ylieff, M., & Poncin, P. (2013). Video multitracking of fish behaviour: A synthesis and future perspectives. *Fish and Fisheries*, *14*(2), 186–204. https://doi.org/10.1111/j.1467-2979.2012.00462.x

Dell, A. I., Bender, J. A., Branson, K., Couzin, I. D., de Polavieja, G. G., Noldus, L. P., Pérez-Escudero, A., Perona, P., Straw, A. D., Wikelski, M., & Brose, U. (2014). Automated image-based tracking and its application in ecology. *Trends in Ecology & Evolution*, *29*(7), 417–428. https://doi.org/10.1016/j.tree.2014.05.004

Dingemanse, N. J., Both, C., Drent, P. J., Van Oers, K., & Van Noordwijk, A. J. (2002). Repeatability and heritability of exploratory behaviour in great tits from the wild. *Animal Behaviour*, *64*, 929–938. https://doi.org/10.1006/anbe.2002.2006

Dingemanse, N. J., & Dochtermann, N. A. (2013). Quantifying individual variation in behaviour: Mixed-effect modelling approaches. *Journal of Animal Ecology*, *82*, 39–54. https://doi.org/10.1111/1365-2656.12013

Dingemanse, N. J., Kazem, A. J. N., Reale, D., & Wright, J. (2010). Behavioural reaction norms: Animal personality meets individual plasticity. *Trends in Ecology & Evolution*, *25*, 81–89. https://doi.org/10.1016/j.tree.2009.07.013

Dingemanse, N. J., Wright, J., Kazem, A. J., Thomas, D. K., Hickling, R., & Dawnay, N. (2007). Behavioural syndromes differ predictably between 12 populations of three-spined stickleback. *Journal of Animal Ecology*, *76*(6), 1128–1138. https://doi.org/10.1111/j.1365-2656.2007.01284.x

Duteil, M., Pope, E. C., Pérez-Escudero, A., de Polavieja, G. G., Fürtbauer, I., Brown, M. R., & King, A. J. (2016). European sea bass show behavioural resilience to near-future ocean acidification. *Royal Society Open Science*, *3*(11), 160656. https://doi.org/10.1098/rsos.160656

Dzieweczynski, T. L., & Crovo, J. A. (2011). Shyness and boldness differences across contexts in juvenile three-spined stickleback *Gasterosteus aculeatus* from an anadromous population. *Journal of Fish Biology*, *79*, 776–788. https://doi.org/10.1111/j.1095-8649.2011.03064.x

Fehlmann, G., O'Riain, M. J., Kerr-Smith, C., Hailes, S., Luckman, A., Shepard, E. L. C., & King, A. J. (2017). Extreme behavioural shifts by baboons exploiting risky, resource-rich, human-modified environments. *Scientific Reports*, *7*, 15057.

Fofana, A. M., & Hurford, A. (2017). Mechanistic movement models to understand epidemic spread. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *372*, 20160086.

Frost, A. J., Winrow-Giffen, A., Ashley, P. J., & Sneddon, L. U. (2007). Plasticity in animal personality traits: Does prior experience alter the degree of boldness? *Proceedings of the Royal Society B-Biological Sciences*, *274*, 333–339. https://doi.org/10.1098/rspb.2006.3751

Fürtbauer, I., & Fry, A. (2018). Social conformity in solitary crabs, *Carcinus maenas*, is driven by individual differences in behavioural plasticity. *Animal Behaviour*, *135*, 131–137. https://doi.org/10.1016/j.anbehav.2017.11.010

Fürtbauer, I., Pond, A., Heistermann, M., & King, A. J. (2015). Personality, plasticity and predation: Linking endocrine and behavioural reaction norms in stickleback fish. *Functional Ecology*, *29*, 931–940. https://doi.org/10.1111/1365-2435.12400

Gernat, T., Rao, V. D., Middendorf, M., Dankowicz, H., Goldenfeld, N., & Robinson, G. E. (2018). Automated monitoring of behavior reveals bursty interaction patterns and rapid spreading dynamics in honeybee social networks. *Proceedings of the National Academy of Sciences of the United States of America*, *115*, 1433–1438. https://doi.org/10.1073/pnas.1713568115

Getz, W. M., Marshall, C. R., Carlson, C. J., Giuggioli, L., Ryan, S. J., Romanach, S. S., Boettiger, C., Chamberlain, S. D., Larsen, L., D'Odorico, P., & O'Sullivan, D. (2018). Making ecological models adequate. *Ecology Letters*, *21*, 153–166. https://doi.org/10.1111/ele.12893

Grunbaum, D. (1998). Using spatially explicit models to characterize foraging performance in heterogeneous landscapes. *The American Naturalist*, *151*, 97–115. https://doi.org/10.1086/286105

Guillette, L. M., Reddon, A. R., Hurd, P. L., & Sturdy, C. B. (2009). Exploration of a novel space is associated with individual differences in learning speed in black-capped chickadees, *Poecile atricapillus*. *Behavioural Processes*, *82*, 265–270. https://doi.org/10.1016/j.beproc.2009.07.005

Gurarie, E., & Ovaskainen, O. (2011). Characteristic spatial and temporal scales unify models of animal movement. *The American Naturalist*, *178*(1), 113–123. https://doi.org/10.1086/660285

Hadfield, J. D. (2010). MCMC methods for multi-response generalised linear mixed models: The MCMCglmm R package. *Journal of Statistical Software*, *33*, 1–22.

Hansen, M. J., Ward, A. J. W., Fürtbauer, I., & King, A. J. (2016). Environmental quality determines finder-joiner dynamics in socially foraging three-spined sticklebacks (Gasterosteus aculeatus). *Behavioral Ecology & Sociobiology*, *70*, 889–899. https://link.springer.com/article/10.1007/s00265-016-2111-5

Harris, S. M., Descamps, S., Sneddon, L. U., Bertrand, P., Chastel, O., & Patrick, S. C. (2020). Personality predicts foraging site fidelity and trip repeatability in a marine predator. *Journal of Animal Ecology*, *89*, 68–79. https://doi.org/10.1111/1365-2656.13106

Harrison, P. M., Keeler, R. A., Robichaud, D., Mossop, B., Power, M., & Cooke, S. J. (2019). Individual differences exceed species differences in the movements of a river fish community. *Behavioral Ecology*, *30*, 1289–1297. https://doi.org/10.1093/beheco/arz076

Henry, D., Aubert, H., Ricard, E., Hazard, D., & Lihoreau, M. (2018). Automated monitoring of livestock behavior using frequency-modulated continuous-wave radars. *Progress in Electromagnetics Research M*, *69*, 151–160. https://doi.org/10.2528/PIERM18040404

Herbert-Read, J. E., Krause, S., Morrell, L. J., Schaerf, T. M., Krause, J., & Ward, A. J. W. (2013). The role of individuality in collective group movement. *Proceedings of the Royal Society B: Biological Sciences*, *280*, 20122564. https://doi.org/10.1098/rspb.2012.2564

Herborn, K. A., Macleod, R., Miles, W. T. S., Schofield, A. N. B., Alexander, L., & Arnold, K. E. (2010). Personality in captivity reflects personality in the wild. *Animal Behaviour*, *79*, 835–843. https://doi.org/10.1016/j.anbehav.2009.12.026

Hertel, A. G., Leclerc, M., Warren, D., Pelletier, F., Zedrosser, A., & Mueller, T. (2019). Don't poke the bear: Using tracking data to quantify behavioural syndromes in elusive wildlife. *Animal Behaviour*, *147*, 91–104. https://doi.org/10.1016/j.anbehav.2018.11.008

Hertel, A. G., Niemelä, P. T., Dingemanse, N. J., & Mueller, T. (2020). A guide for studying among-individual behavioral variation from movement data in the wild. *Movement Ecology*, *8*, 30. https://doi.org/10.1186/s40462-020-00216-8

Hopkins, M. E. (2016). Mantled howler monkey spatial foraging decisions reflect spatial and temporal knowledge of resource distributions. *Animal Cognition*, *19*, 387–403. https://doi.org/10.1007/s10071-015-0941-6

Houslay, T. M., Vierbuchen, M., Grimmer, A. J., Young, A. J., & Wilson, A. J. (2018). Testing the stability of behavioural coping style across stress contexts in the Trinidadian guppy. *Functional Ecology*, *32*(2), 424–438. https://doi.org/10.1111/1365-2435.12981

Houslay, T. M., & Wilson, A. J. (2017). Avoiding the misuse of BLUP in behavioural ecology. *Behavioral Ecology*, *28*(4), 948–952. https://doi.org/10.1093/beheco/arx023

Jolles, J. W., Briggs, H. D., Araya-Ajoy, Y. G., & Boogert, N. J. (2019). Personality, plasticity and predictability in sticklebacks: Bold fish are less plastic and more predictable than shy fish. *Animal Behaviour*, *154*, 193–202. https://doi.org/10.1016/j.anbehav.2019.06.022

Jolles, J. W., Laskowski, K. L., Boogert, N. J., & Manica, A. (2018). Repeatable group differences in the collective behaviour of stickleback shoals across ecological contexts. *Proceedings of the Royal Society B: Biological Sciences*, *285*, 20172629.

Jolles, J. W., Taylor, B. A., & Manica, A. (2016). Recent social conditions affect boldness repeatability in individual sticklebacks. *Animal Behaviour*, *112*, 139–145. https://doi.org/10.1016/j.anbehav.2015.12.010

Kanagaraj, R., Wiegand, T., Kramer-Schadt, S., & Goyal, S. P. (2013). Using individual-based movement models to assess inter-patch connectivity for large carnivores in fragmented landscapes. *Biological Conservation*, *167*, 298–309. https://doi.org/10.1016/j.biocon.2013.08.030

Kane, A. S., Salierno, J. D., Gipson, G. T., Molteno, T. C., & Hunter, C. (2004). A video-based movement analysis system to quantify behavioral stress responses of fish. *Water Research*, *38*(18), 3993–4001. https://doi.org/10.1016/j.watres.2004.06.028

Kareiva, P. M., & Shigesada, N. (1983). Analyzing insect movement as a correlated random walk. *Oecologia*, *56*, 234–238. https://doi.org/10.1007/BF00379695

Kays, R., Crofoot, M. C., Jetz, W., & Wikelski, M. (2015). Terrestrial animal tracking as an eye on life and planet. *Science*, *348*, aaa2478. https://doi.org/10.1126/science.aaa2478

King, A. J., Fehlmann, G., Biro, D., Ward, A. J., & Fürtbauer, I. (2018). Re-wilding collective behaviour: An ecolocical perspective. *Trends in Ecology & Evolution*, *33*, 347–357.

King, A. J., Fürtbauer, I., Mamuneas, D., James, C., & Manica, A. (2013). Sex-differences and temporal consistency in stickleback fish boldness. *PLoS One*, *8*, e81116. https://doi.org/10.1371/journal.pone.0081116

King, A. J., Williams, L. J., & Mettke-Hofmann, C. (2015). The effects of social conformity on Gouldian finch personality. *Animal Behaviour*, *99*, 25–31. https://doi.org/10.1016/j.anbehav.2014.10.016

Kralj-Fiser, S., & Schneider, J. M. (2012). Individual behavioural consistency and plasticity in an urban spider. *Animal Behaviour*, *84*, 197–204. https://doi.org/10.1016/j.anbehav.2012.04.032

Kranstauber, B., Cameron, A., Weinzerl, R., Fountain, T., Tilak, S., Wikelski, M., & Kays, R. (2011). The Movebank data model for animal tracking. *Environmental Modelling & Software*, *26*, 834–835. https://doi.org/10.1016/j.envsoft.2010.12.005

Krause, J., Krause, S., Arlinghaus, R., Psorakis, I., Roberts, S., & Rutz, C. (2013). Reality mining of animal social systems. *Trends in Ecology & Evolution*, *28*, 541–551. https://doi.org/10.1016/j.tree.2013.06.002

Lemasson, B. H., Anderson, J. J., & Goodwin, R. A. (2009). Collective motion in animal groups from a neurobiological perspective: The adaptive benefits of dynamic sensory loads and selective attention. *Journal of Theoretical Biology*, *261*, 501–510. https://doi.org/10.1016/j.jtbi.2009.08.013

Lima, S. L., & Zollner, P. A. (1996). Towards a behavioral ecology of ecological landscapes. *Trends in Ecology & Evolution*, *11*, 131–135. https://doi.org/10.1016/0169-5347(96)81094-9

MacKay, J. R. D., Turner, S. P., Hyslop, J., Deag, J. M., & Haskell, M. J. (2013). Short-term temperament tests in beef cattle relate to long-term measures of behavior recorded in the home pen. *Journal of Animal Science*, *91*, 4917–4924.

Mamuneas, D., Spence, A. J., Manica, A., & King, A. J. (2015). Bolder stickleback fish make faster decisions, but they are not less accurate. *Behavioral Ecology*, *26*, 91–96. https://doi.org/10.1093/beheco/aru160

Matthews, S. G., Miller, A. L., Plotz, T., & Kyriazakis, I. (2017). Automated tracking to measure behavioural changes in pigs for health and welfare monitoring. *Scientific Reports*, *7*, 17582. https://doi.org/10.1038/s41598-017-17451-6

Moorcroft, P. R. (2012). Mechanistic approaches to understanding and predicting mammalian space use: Recent advances, future directions. *Journal of Mammalogy*, *93*, 903–916. https://doi.org/10.1644/11-MAMM-S-254.1

Morales, J. M., & Ellner, S. P. (2002). Scaling up animal movements in heterogeneous landscapes: The importance of behavior. *Ecology*, *83*, 2240–2247. https://doi.org/10.1890/0012-9658(2002)083[2240:SUAMIH]2.0.CO;2

Nakagawa, S., & Schielzeth, H. (2010). Repeatability for Gaussian and non-Gaussian data: A practical guide for biologists. *Biological Reviews*, *85*(4), 935–956. https://doi.org/10.1111/j.1469-185X.2010.00141.x

Nakagawa, S., & Schielzeth, H. (2013). A general and simple method for obtaining R2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution*, *4*(2), 133–142.

Nathan, R., Getz, W. M., Revilla, E., Holyoak, M., Kadmon, R., Saltz, D., & Smouse, P. E. (2008). A movement ecology paradigm for unifying organismal movement research. *Proceedings of the National Academy of Sciences of the United States of America*, *105*, 19052–19059.

Perez-Escudero, A., Vicente-Page, J., Hinz, R. C., Arganda, S., & de Polavieja, G. G. (2014). idTracker: Tracking individuals in a group by automatic identification of unmarked animals. *Nature Methods*, *11*, 743–748.

Picard, D. (1985). Testing and estimating change-points in time-series. *Advances in Applied Probability*, *17*, 841–867.

Plummer, M., Best, N., Cowles, K., & Vines, K. (2006). CODA: Convergence diagnosis and output analysis for MCMC. *R News*, *6*(1), 7–11.

Quinn, J. L., & Cresswell, W. (2005). Personality, anti-predation behaviour and behavioural plasticity in the chaffinch Fringilla coelebs. *Behaviour*, *142*, 1377–1402.

R Core Team (2018). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

Roche, D. G., Careau, V., & Binning, S. A. (2016). Demystifying animal 'personality' (or not): Why individual variation matters to experimental biologists. *Journal of Experimental Biology*, *219*(24), 3832–3843.

Romero-Ferrero, F., Bergomi, M. G., Hinz, R. C., Heras, F. J. H., & de Polavieja, G. G. (2019). idtracker.ai: Tracking all individuals in small or large collectives of unmarked animals. *Nature Methods*, *16*, 179.
Rudolf, J., Dondorp, D., Canon, L., Tieo, S., & Chatzigeorgiou, M. (2019). Automated behavioural analysis reveals the basic behavioural repertoire of the urochordate *Ciona intestinalis*. *Scientific Reports*, *9*, 2416.
Sabol, A. C., Solomon, N. G., & Dantzer, B. (2018). How to study socially monogamous behavior in secretive animals? Using social network analyses and automated tracking systems to study the social behavior of prairie voles. *Frontiers in Ecology and Evolution*, *6*, 178.
Schick, R. S., Loarie, S. R., Colchero, F., Best, B. D., Boustany, A., Conde, D. A., Halpin, P. N., Joppa, L. N., McClellan, C. M., & Clark, J. S. (2008). Understanding movement data and movement processes: Current and emerging directions. *Ecology Letters*, *11*, 1338–1350.
Schirmer, A., Herde, A., Eccard, J. A., & Dammhahn, M. (2019). Individuals in space: Personality-dependent space use, movement and microhabitat use facilitate individual spatial niche specialization. *Oecologia*, *189*, 647–660.
Sih, A., Spiegel, O., Godfrey, S., Leu, S., & Bull, C. M. (2018). Integrating social networks, animal personalities, movement ecology and parasites: A framework with examples from a lizard. *Animal Behaviour*, *136*, 195–205. https://doi.org/10.1016/j.anbehav.2017.09.008
Spiegel, O., Leu, S. T., Bull, C. M., & Sih, A. (2017). What's your move? Movement as a link between personality and spatial dynamics in animal populations. *Ecology Letters*, *20*, 3–18. https://doi.org/10.1111/ele.12708
Stoffel, M. A., Nakagawa, S., & Schielzeth, H. (2017). rptR: Repeatability estimation and variance decomposition by generalized linear mixed-effects models. *Methods in Ecology and Evolution*, *8*(11), 1639–1644. https://doi.org/10.1111/2041-210X.12797
Strömbom, D., & King, A. J. (2018). Robot collection and transport of objects: A biomimetic process. *Frontiers in Robotics and AI, Section Evolutionary Robotics*, *5*, 48. https://doi.org/10.3389/frobt.2018.00048
Sueur, C., King, A. J., Conradt, L., Kerth, G., Lusseau, D., Mettke-Hofmann, C., Schaffner, C. M., Williams, L., Zinner, D., & Aureli, F. (2011). Collective decision-making and fission-fusion dynamics: A conceptual framework. *Oikos*, *120*, 1608–1617. https://doi.org/10.1111/j.1600-0706.2011.19685.x
Tan, M. K., & Tan, H. T. W. (2019). Individual-and population-level personalities in a floriphilic katydid. *Ethology*, *125*(2), 114–121. https://doi.org/10.1111/eth.12834
Valletta, J. J., Torney, C., Kings, M., Thornton, A., & Madden, J. (2017). Applications of machine learning in animal behaviour studies. *Animal Behaviour*, *124*, 203–220. https://doi.org/10.1016/j.anbehav.2016.12.005
Webber, Q. M. R., & Vander Wal, E. (2018). An evolutionary framework outlining the integration of individual social and spatial ecology. *Journal of Animal Ecology*, *87*, 113–127. https://doi.org/10.1111/1365-2656.12773
White, S. J., Pascall, D. J., & Wilson, A. J. (2019). Towards a comparative approach to the structure of animal personality variation. *Behavioral Ecology*, *31*, 340–351.
Williams, L. J., King, A. J., & Mettke-Hofmann, C. (2012). Colourful characters: Head colour reflects personality in a social bird, the Gouldian finch, *Erythrura gouldiae*. *Animal Behaviour*, *84*, 159–165. https://doi.org/10.1016/j.anbehav.2012.04.025
Wolf, M., & Weissing, F. J. (2012). Animal personalities: Consequences for ecology and evolution. *Trends in Ecology & Evolution*, *27*, 452–461. https://doi.org/10.1016/j.tree.2012.05.001
Zhang, J., King, A. J., Fürtbauer, I., Wang, Y.-W., He, Y.-Q., Zhang, Z.-W., Wan, D.-M., & Yin, Y.-X. (2020). Facilitative effects of social partners on Java sparrow activity. *Animal Behaviour*, *161*, 33–38. https://doi.org/10.1016/j.anbehav.2019.12.017

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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