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Short Communication

A Novel Method of Identifying Behavioral Reaction Norms in Captive Animals

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Behavioral instability has recently been introduced as a new quantitative method for investigating the personality of animals through the use of behavioral reaction norms (Linder et al. 2020). Previous methods used in the field are unable to produce comparable quantitative results and lack a protocol ensuring systematic data sampling (Shyne 2006, Rose et al. 2017, Linder et al. 2020). The methods used in the past have primarily been used to estimate the percentage of time spent on various behaviors (Altmann 1974). These traditional methods are deeply dependent on the ethogram used, since the percentage of time spent on one behavior always will be dependent on the amount of time spent on other behaviors. Hence, reducing the reproducibility of results and making comparisons between studies difficult (Linder et al. 2020). Furthermore, the methods previously used do not account for the predictability of an individual (the probability that a given behavior occurs). The predictability of an individual is an important factor when assessing its personality and the novel approach using behavioral instability takes the predictability of the individual into account when assessing their personality. This is enabled by analyzing the variables: median, variance, asymmetry index and kurtosis of the time spent on all occurrences of an individual's various behaviors (Linder et al. 2020). The asymmetry index (skewness) is a measure of the asymmetry of a distribution, i.e. how much a distribution is tilted due to a high frequency of extreme values in one direction (Mann 2016). The kurtosis is a measure of the relative distance from the center of the distribution to the tails, i.e. how spread the values are around the center of the distribution (Balanda and MacGillivray 1988).

Linder et al. (2020) have showed the application of behavioral instability in the investigation of behavioral reaction norms in a case study investigating the behavior of two captive polar bears at Aalborg Zoo. Thus, showing how the estimation of the variables: median, variance, asymmetry index and kurtosis can be used for assessing the effectiveness of enrichment manipulation. The results presented in Linder et al. (2020) show an intuitive visual representation of the individuals' reaction norms where the variables describing behavioral instability are plotted as a response to an environmental stimulus.

Our aim is to demonstrate a novel way of visually representing this type of data as a three-dimensional plot, exemplified with the data collected and presented in Linder et al. (2020). First, the variables of behavioral instability were plotted simultaneously for different behaviors demonstrating the effect of the environmental stimuli and secondly, three different behaviors were plotted against each other showing the individuals' responses to the environmental stimuli for each of the variables, respectively. This novel way of illustrating an individual's reaction norms, enables the immediate identification of changes in an individual's predictability for a given behavior. This is exemplified in the figures presented below.

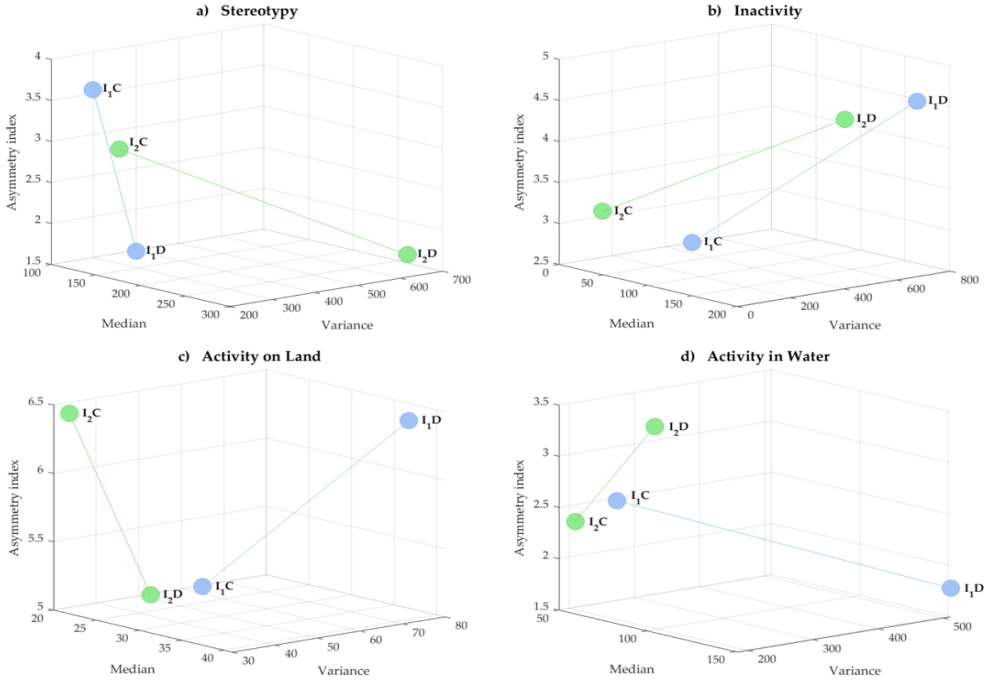

Figure 1a-d. Behavioral reaction norms: median, variance and asymmetry index of time spent on each occurrence of a given behavior for two individuals (I_1 and I_2) and two different treatments (C = control and D = stimulus) along with trend lines between the treatments for each individual.

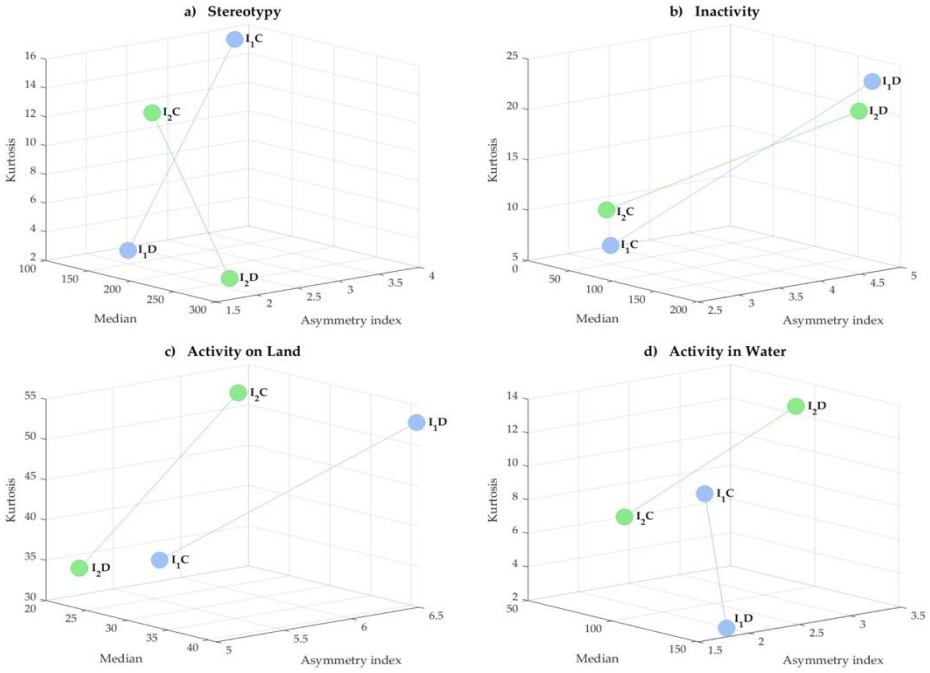

Figure 2a-d. Behavioral reaction norms: the median, asymmetry index and kurtosis of time spent on each occurrence of a given behavior for two individuals (I_1 and I_2) and two different treatments (C = control and D = stimulus) along with trend lines between the treatments for each individual.

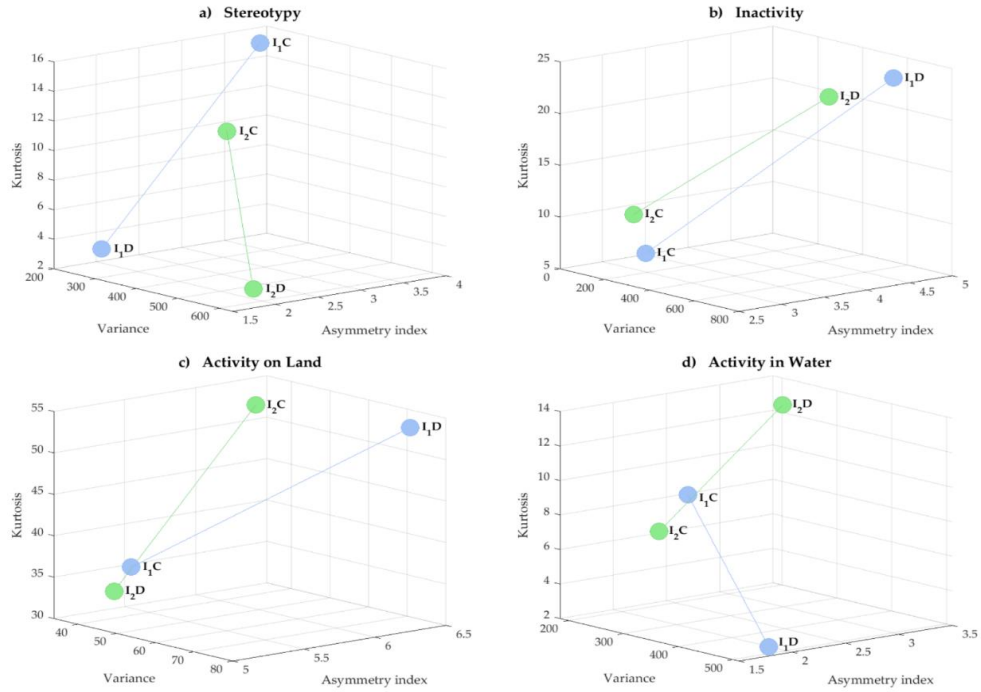

Figure 3a-d. Behavioral reaction norms: the variance, asymmetry index and kurtosis of time spent on each occurrence of a given behavior for two individuals (I_1 and I_2) and two different treatments (C = control and D = stimulus) along with trend lines between the treatments for each individual.

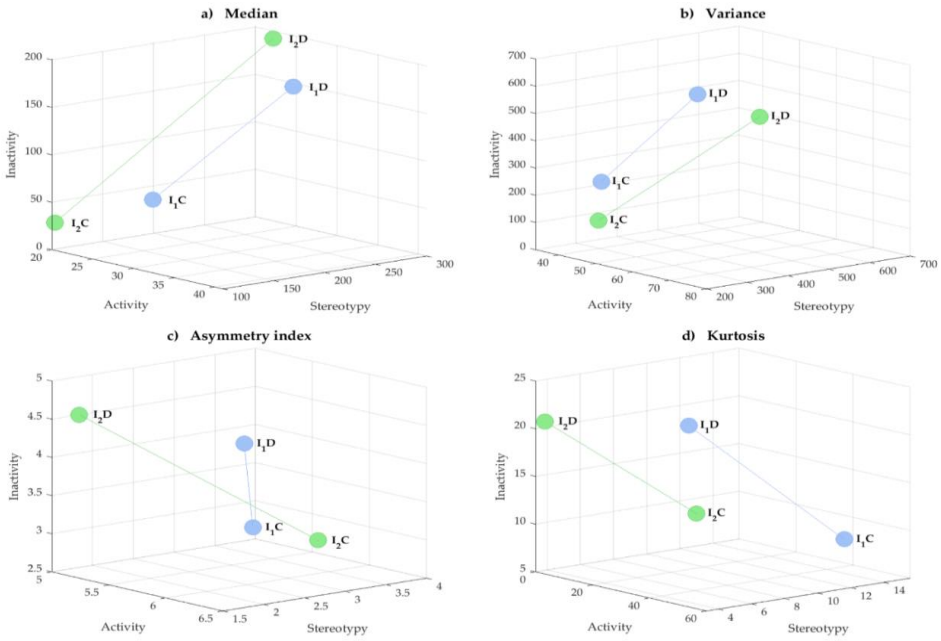

Figure 4a-d. Behavioral reaction norms shown individually for the three behaviors stereotypy, activity and inactivity. Each plot shows a single reaction norm for the three behaviors for two individuals (I_1 and I_2) and two different treatments (C = control and D = stimulus) along with trend lines between the treatments for each individual.

Figure 1a shows that individual 1 (I_1) spent less time on stereotypic behavior per occurrence than individual 2 (I_2). In this figure it can also be seen that there is a smaller variation in the time I_1 spends on stereotypic

behavior per sequence, hence showing that I_1 is more predictable than I_2, when it comes to stereotypic behavior. Furthermore, the figure shows that the distribution of the time sequences spent on stereotypic behavior is for both individuals less asymmetric when the individuals were not exposed to stimuli (treatment C). This means that the distributions included more extreme values during treatment C. Furthermore, figures 2a-d and 3a-d display other combinations of the variables of behavioral instability e.g. including the kurtosis.

Figures 4a-d illustrate a different way of plotting the reaction norms in which three different behaviors were plotted for each of the four variables, respectively. This figure highlights the same overall tendencies as figures 1a-d, but the visual presentation of the individuals' time budget is more distinct. In figure 4a an increase in the median time spent on activity, inactivity and stereotypy can be seen between treatment C and the treatment with stimulus (treatment D), thus the time the individuals spent on the behaviors increased for each occurrence when they were exposed to the stimulus. Figure 4c shows an increase in the asymmetry index for the time both individuals spent on inactivity, while a decrease was found for stereotypy, when comparing treatment C and D. Illustrating that more extreme values were found for inactivity, while less extreme values were found for stereotypy, thus the time spent on each occurrence of stereotypic behavior was more predictable. The asymmetry index for the distribution of occurrences of the behavior activity for one individual increases, while it decreases for the other individual, hence showing a difference in the predictability of the time they spend on the behavior activity.

The figures shown are based on categorical data e.g. control and enrichment, however, this novel way of visually presenting behavioral reaction norms can also be applied to continuous data. This would lead to a continuous curve as a three-dimensional visualization showing trends for multiple variables at the same time. These types of three-dimensional figures should always be accompanied by further statistical analyses such as comparisons of the slopes of the different trendlines. Lastly, we would like to comment on the development of software tools that enables automatized monitoring and scoring of animal behavior e.g. Noldus (Noldus 2020). The application of this software will enable more efficient data collection and analyses to which this novel way of visual presentation can be applied. The use of three-dimensional visualizations of behavioral reaction norms will enhance the identification of personality in animals. The application of three-dimensional visualizations can therefore be a valuable tool when assessing the personality of animals.

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Author's Contributions

All authors contributed equally.

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