Human observers differ in ability to perceive insect diversity

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Summary:

Human perception of biological variation is an important and understudied issue in the conservation and management of natural resources. We take a novel approach by asking 1152 participants, primarily college biology students, to score examples of insect mimicry by the number of distinct kinds of animals they see. Latent class analysis successfully separated participants based on their accuracy of perception as well as demographic information and opinions about biodiversity. Contrary to expectations, factors such as childhood experience (growing up in urban, suburban or rural areas) did not affect the ability to see biodiversity as much as political views (location on a spectrum from liberal to conservative) or the position that biodiversity is important for the health of the environment. We conclude that research into effective measures of biological education should consider the connection between personal views and perceptions of natural variation.

Keywords:

Biodiversity, conservation, mimicry, identifying biodiversity

Introduction

In their efforts to protect natural resources and biodiversity, conservation biologists often face a gap between the need for protection as identified by scientists and the perception of that same need as expressed by the general public (Nabhan 1995; Miller 2005). It has often been assumed that the lack of public engagement in biodiversity conservation is a consequence of education or a lack thereof (Kaplan *et al.* 1998), yet education programs have not always produced the desired results (Miller 2005). Consequently, several studies have attempted to determine which factors influence how biodiversity is perceived, from investigating what people think biodiversity is (Turner-Erfort 1996), to trying to determine which factors influence how people assess photos showing differing degrees of habitat degradation (Bayne *et al.* 2012).

Several hypotheses have emerged about factors that might influence perceptions of biodiversity. Several authors, for example, have suggested that urbanization can negatively impact perceptions of biodiversity as people become increasingly disconnected from nature (Miller 2005; Schwartz 2006), and that perceptions will likely differ between inhabitants of cities and rural areas (Heywood 1995; Maiti and Maiti 2011). Others have suggested that education (Lindermann-Matthies 2002; Lindermann-Matthies and Bose 2008) and political views (Dunlap and McCright 2008) can influence how nature is perceived.

Typically, these studies have focused on attitudes towards conservation of species and natural areas, and not necessarily on the extent to which people might or might not differ in their actual perceptions of natural variation (e.g., Dallimer *et al.* 2012). This knowledge gap, with respect to individual variation in perception, is important because it has been suggested that human well-being is linked to perceived species richness, but researchers found that most people have poor biodiversity identification skills (McKinney 2002). Acknowledging the finding that most people have generally poor natural history or biodiveristy identification skills, we asked if differing abilities in perception can be predicted based on demographic histories (e.g. education) or opinions expressed about biodiversity. To test perception, we took advantage of the natural visual riddles presented by mimicry among distantly related insects, from which sets of species can be examined that cover a range of similarity, including sets of species that can be readily distinguished, to mimicry complexes that are difficult for biologists to separate.

Methods

To quantify variation among individuals in the extent to which subtle biological differences can be perceived, we designed an online survey that first presented participants with a series of slides, each slide displaying six images of arthropods. Students were instructed that they would be asked to decide how many kinds of animals (from 1-6) were being shown. We did not ask 'how many species are there' because the term 'species' can cause confusion, and lacks a universal definition among biologists. After presenting a training slide that showed the correct answers (electronic supplementary material), we presented seven different slides showing a variety of arthropod orders, many of which are mimics of each other (Fig. 1a,b; electronic supplementary material). The correct number of species on each of the seven slides ranged from 2 - 6. The time participants spent on each of these slides was recorded to control for search effort.

Next, participants were asked a series of survey questions, which included questions about community structure (urban, suburban, rural), state, age, education level, parent’s education, knowledge of biology, political views, and three questions measuring participant’s feelings toward biodiversity (Table 1). Because not every state was represented, we pooled states into four regions, northeast, southeast, northwest, and southwest. Some participants were offered extra credit by their professors for participating in the survey. To account for potential differences between those receiving credit and others, we included a question asking if the participants expect to receive credit.

Participants

Survey participants were recruited primarily through college biology classes (both lower division and upper division courses). A link to the survey was provided to instructors and they gave students the option to participate in the survey. Participation was strictly voluntary and all participant data were collected and anonymized using the online survey tools via Qualtrics.com. Survey methodology and recruitment procedures were approved through the Utah State University's Institutional review board (Protocol #4671).

Statistical analyses

To address our primary question regarding the capability of survey data to predict the participant’s ability to perceive biological variation, we utilized latent class analysis (LCA) to look for structure among participants (i.e., groups of participants with similar survey responses). Latent class analysis is analogous to multivariate factor analysis, but appropriate for categorical data. As implemented in R (the poLCA package), LCA can incorporate continuous covariates (in addition to the categorical data) when looking for underlying, latent variables that determine membership in different clusters of (in our case) individuals participating in the survey. We treated all of the answers to survey questions as ordered, categorical data, and we calculated three continuous covariates.

Our primary covariate of interest summarized the extent to which participants were able to correctly perceive the number of species on slides. For every slide, we standardized answers by the correct number of species; thus if the correct answer was 4 species, and a participant answered 3, they receive a score of -1 (they underestimated by 1). As a measure of accuracy, we took the average of the absolute values of those scores for each individual, which is the average extent to which participants misjudged, regardless of which direction (positive or negative). Secondarily, we quantified an index of bias, which was the same calculation but without taking the absolute value (thus allowing us to look at average over- or underestimation). Our third covariate was the average number of seconds that individuals spent on each slide.

Using LCA, we explored the possibility that survey participants could be classified into between 1 and 6 groups, and BIC values (as well as delta BIC values) were used to find the optimal number of clusters. Because the model implemented by LCA is relatively complex, we used simple linear models as an accessible and relatively transparent complementary approach. In these models, answers to individual survey questions were used as independent variables predicting performance on slides, while using the average amount of time spent on slides as a covariate for effort. Survey data will be made available through the authors upon request.

Results

A total of 1152 people participated in our survey. Structure in the survey answers and performance on slides was readily determined by LCA, which found 2 and higher numbers of groupings to be significantly better than no differentiation. Specifically, K=2 appeared to identify end points of a continuum that was then more finely parsed at higher levels of K (electronic supplementary material, figure S1). Individuals associated with the two groups (at K=2) differed in their answers to survey questions, as well as in their perceptions of natural variation (Fig 1c, d, Table S1). On average, group 1 was less accurate, with answers that deviated further from the correct number of species in each slide (Fig. 1c). Both groups tended to underestimate the biodiversity pictured in each slide (i.e. saw fewer species than were actually there), but group 1 estimated lower diversity than group 2 (Fig. 1d). Results from LCA were confirmed with simple linear models that found a significant relationship between most of the survey answers and accuracy (Table S2). It is important to note that (in these models) the average amount of time spent on slides was always a highly significant covariate: people that spent more time on slides tended to get closer to the right answer (Table 1; electronic supplementary material; Fig. S3). However, what is noteworthy is that while controlling for the amount of time spent on slides, we were able to detect significant relationships between answers to survey questions and performance. While the simple linear models provide a useful confirmation, they are coarse in that they do not account for correlations among variables; thus we focus most of our further discussion on the results from LCA.

Individuals assigned to groups 1 and 2 differed in a number of ways (Fig. 2; Table 1; electronic supplementary material, Figure S2A, B). Among the survey questions that most strongly delineated group 1 and group 2 were: (1) how strongly individuals valued biodiversity personally (Value), (2) if they thought biodiversity was important to the health of the ecosystem (Health), (3) their political views on a scale from conservative to liberal (Views), (4) the age and grade level of participants (Age), and (5) whether or not they expected to receive extra credit for participation (Credit) (Table 1; electronic supplementary material Table S1; Fig S2A, B). How knowledgeable someone considered themselves to be about biology seemed to contribute to group delineation in the LCA analysis, but was not significant in the linear model). Several other survey questions were only weakly associated with the differences between group 1 and 2, including community structure, region of the country, the education level of parents, and if they consider biodiversity a political issue.

Discussion

Differences in community structure (urban, suburban, rural) have long been targeted as a major factor influencing how humans relate to biodiversity (Dunlap *et al.* 2000). At least among the participants of our study, results suggest that urbanization does not necessarily impact perceptions of natural variation. Instead of community background or education, we find that more personal or internal variables are successful predictors of biodiversity perception. These included the value placed on biodiversity and political views. With respect to the latter, political leanings are known to influence views on environmental issues (Dunlap and McCright 2008), and we find that self-described liberal-leaning individuals were more accurate in their ability to distinguish among mimetic species relative to self-described conservative-leaning individuals. In sum, these results suggest that liberal-minded individuals place a higher value on biodiversity and are better able to perceive differences among animals that are superficially very similar in appearance. While our results raise this interesting pattern, we do not at this time understand the mechanism linking, for example, political views and perception of biological differences, as discussed further below.

We find that a participant's age and grade level were somewhat related to the accuracy of their biodiversity estimates, with older individuals and upperclassmen (particularly graduate students) being more accurate in their estimates. Interestingly, whether or not an individual expected to receive extra credit for participating in the survey was related to how accurate they were in their assessment of biodiversity (Fig. S2). Those participants that expected credit for participation were often much less accurate in their biodiversity estimates than people that did not expect credit, presumably because those people not working for credit were inherently more interested in the task. This may pose a challenge to educators because it suggests that traditional approaches for generating student interest might fail to truly motivate students to invest the time to arrive at a carefully-considered answer, and this could be particularly true of computer based tasks that can be quickly "clicked through" to get to the end. With respect to teaching natural diversity and taxonomy, perhaps educators should focus on appreciation first, possibly through the use of stories and examples of complex and fascinating interactions among species that could facilitate later, more traditional lessons.

Aside from grade level, most external demographic factors (e.g., region of the country, community structure (urban/suburban/rural), and parents education) were not strongly associated with abilities to perceive natural variation. Instead, the factors most strongly associated with accuracy in our survey were those of a more personal and internal nature (e.g., the importance that people place on biodiversity). This poses a challenge to conservationists and educators because it seems that rather than simply educating people about biodiversity and conservation, one must affect personal feelings if one is interested in affecting how biodiversity is perceived and appreciated.

It is important to note that the effect sizes that we have detected are not large: the average difference in accuracy between groups was less than one perceived species (Fig. 1c). However, we believe that the contribution of our study is to point out that personal attributes or background can affect not only attitudes towards biodiversity, as has been documented, but can be associated with actual ability to perceive natural variation. Direction of causality is not clear, as our study was not designed to answer the questions: are more perceptive people more likely to judge biodiversity as important? or are people that place a greater value on biodiversity more likely to take the time to perceive differences? Given the general importance of time in our models (people that looked longer tended to get closer to the right answer), we suspect that the latter might be true. Additional studies could potentially include tasks involving non-biological diversity, as the ability to perceive non-biological variation would be informative. With respect to the hypothesis that people that place a higher value on biodiversity are simply more likely to take the time to look closely, we might expect that those same people would not take as much time for non-biological variation. However, at this time we can only pose this issue as a challenge for researchers interested in the intersection between perception, conservation, and education.

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Supplementary material

For supplementary material accompanying this paper, visit http://www.journals.cambridge.org/ENC

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Conflict of interest

None.

Ethical standards

The authors assert that all procedures contributing to this work comply with applicable ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Table 1. Survey questions, and the number of participants giving different answers for each question (the order of questions here follows matches Table S2).

Abbreviation	Question	Answers
Age	What is your age?	15-19 (350); 20-24 (529); 25-29 (111); 30-39 (93); 40-49 (35); 50 and above (34)
Credit	Are you expecting to get extra credit or extra credit points in a class for taking this survey?	no (286); yes (866)
Value	How important is biodiversity to you personally?	unimportant (22); slightly important (180); important (332); very important (351); critical (267)
Health	How important is biodiversity to the health of the environment?	unimportant (0); slightly important (36); important (218); very important (350); critical (548)
Grade	What is your current grade level? or if you are not in school, what is the highest grade you completed?	freshman in college (262); sophomore in college (363); junior in college (218); senior in college (157); Master's student/degree (76); PhD student/degree (76)
Views	How would you describe your political views?	very conservative (96); somewhat conservative (273); intermediate (379); somewhat liberal (276); very liberal (128)
Region*	In what state do you currently reside?	East (54); Midwest (236); South (407); West (455)
Education	What is the highest level of education either of your parents completed?	elementary school (17); high school/GED (257); associate's degree (103); bachelor's degree (391); graduate degree (363); unknown (21)
Area	What best describes the area(s) where you were raised?	Rural (259); Suburban (642); Urban (251)
Biology	How knowledgeable do you consider yourself about biology?	I know nothing (11); limited knowledge (181); average knowledge (434); somewhat knowledgeable (377); very knowledgeable (149)
Politics	How strongly do you agree with this statement? Biodiversity is an important political issue.	strongly disagree (14); disagree (59); neither agree nor disagree (308); agree (481); strongly agree (290)

* Individuals answers by state were pooled into regions.

Figure captions

Figure 1. (a,b). Examples of slides used in the survey, **(a)** shows 2 species and **(b)** shows 4. Photos courtesy Ron Hemberger, Jean Hort, Valerie Bugh, Paul Turner of Druid Environmental, Peter Bryant, Alex Wild, Flagstaffotos, and J.S. Wilson. **(c)** Graph showing the accuracy ("score"), i.e. how well each group (1 and 2) estimated the number of species. Smaller values indicate better observer performance (in other words, the deviation from the correct answer was less). **(d).** Graph showing the biases (how much each group over or under estimated the number of species) of the two groups. Both groups underestimated diversity, but Group1 had a stronger bias (tended to see fewer species than were actually present).

Figure 2. Graphs illustrating differences between Groups 1 and 2 for three survey questions. Bar graphs on the left are results from latent class analysis (LCA) predicting group traits (shown as relative probabilities, on the y-axes, that a member of a given group would provide a particular answer, on the x-axes, to a particular question). Scatter plots on the right show linear relationships based on raw data, but color coded to indicate assignment to groups based on the outcome of LCA. **(a)** How strongly individuals value biodiversity personally with 1 being unimportant and 5 being critical, **(b)** An individual's political views with 1 being very conservative and 5 being very liberal, **(c)** how important people think biodiversity is to the health of the environment with 1 being unimportant and 5 being critical.