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Abstract

This study examined the interplay of taxonomic and contextual knowledge in cross-classification by assessing the interaction of taxonomic and ecological knowledge in folk biology. Stimuli were pairs of animal species in which the presence or absence of taxonomic and ecological relations was manipulated orthogonally. Participants judged whether each pair was related taxonomically and ecologically; we measures speed and accuracy. Presence of taxonomic relations facilitated ecological judgments for ecologically related pairs, and hindered judgments for unrelated pairs. In contrast, although ecological relations hindered taxonomic judgments for taxonomically unrelated pairs, they failed to facilitate judgments for taxonomically related pairs. These results underscore the interactive nature of different conceptual systems for cross-classified categories and suggest a disproportionally strong influence of taxonomic categories.

Keywords: Multiple categories; cross-cutting categorization; taxonomic knowledge; ecological categories; contextual categories; folkbiology.

Complex real-world knowledge is usually multidimensional. Most things fall into multiple categories, and multiple kinds of category systems. For example, although ducks and roadrunners are *birds* and otters and coyotes are *mammals*, these species can also be cross-classified as *pond animals* and *desert animals.*

Two broad kinds of categories that seem to recur across domains are *taxonomic* categories, wherein common membership stems from shared intrinsic properties of the members themselves, and *contextual* categories (also known as thematic or relational categories), wherein common membership stems from shared extrinsic properties including causal relations and spatio-temporal co-occurrence. Traditionally, taxonomic categories have been assumed to provide the mainstay of conceptual structure (e.g. Rosch, 1978; Smith & Medin, 1981; Murphy, 2002). Past research suggests that taxonomic categories may be more accessible than contextual categories (Ross & Murphy, 1999) and that accessing taxonomic knowledge may inhibit access to contextual knowledge (Macrae, Bodenhausen & Milne, 1995; Vitkin, Coley & Feigin, 2005). However, cognitive scientists are increasingly acknowledging the important role of contextual categories in both organizing knowledge and guiding reasoning (e.g., Lin & Murphy, 2001; López, Atran, Coley, Medin & Smith, 1997; Medin, Lynch, Coley & Atran, 1997; Murphy, 2001; Ross & Murphy, 1999; Shafto & Coley, 2003). This highlights the importance of understanding cross-classification and its implications for conceptual structure and reasoning.

In previous studies taxonomic and contextual categories have typically been considered independently to contrast their representation, accessibility, and use (e.g., Ross & Murphy, 1999). As a result, we still know relatively little about how these kinds of conceptual systems interact. In this study we examine how simultaneous membership in multiple categories influences detection of relationships between entities in the complex real-world domain of folk biology.

One possibility is that taxonomic and contextual conceptual systems are relatively independent, and that accessing one kind of category has little effect on the other. Alternatively, multiple cross-cutting conceptual systems might interact symmetrically to facilitate or inhibit each other. In line with a spreading activation view of semantic memory (e.g., Collins and Quillian, 1969), accessing one kind of category information could facilitate the accessibility of semantically related knowledge about other conceptual systems an object belonged to. In contrast, accessing one kind of category information might serve to inhibit accessibility of other kinds of knowledge. Empirical support for this prediction comes from a study by Macrae, Bodenhausen and Milne (1995) who primed participants with either an ethnic (Chinese) or gender (female) stereotype, then exposed them to a cross-classified stimulus (a video of a Chinese woman reading a book). On a subsequent lexical decision task participants were faster to make decisions about words pertaining to the primed stereotype relative to neutral words, and slower to respond to words related to the unprimed stereotype. This finding suggests that availability of one category can inhibit competing categories.

A final possibility is that multiple conceptual systems might interact, but that interaction might be asymmetrical due to differences in salience or accessibility of those systems. In other words, a more salient or accessible category system might exert stronger effects on a less accessible system than vice versa. Indeed, a number of findings suggest that taxonomic categories may be privileged over contextual categories. First, taxonomic categories may be more readily accessible. For example, taxonomic categorization tends to be faster and more accurate than script categorization (Ross & Murphy, 1999), and time pressure impedes the use of contextual categories, but not taxonomic categories, in induction (Coley, Shafto, Stepanova & Barraff, 2005; Shafto, Coley & Baldwin, 2007). Second, taxonomic categories may be a default for categorization and reasoning. For instance, neutral sorting instructions yield predominantly taxonomic groupings (Ross & Murphy, 1999); moreover, taxonomic categories are readily employed by novices in a given domain (e.g., López et al., 1997) and utilized by experts in the absence of meaningful cues to more specific relations (Shafto & Coley, 2003).

Finally, Ross and Murphy (1999) showed that taxonomic and relational categorization are differentially sensitive to priming. Priming taxonomic categories had no effect on the speed or accuracy of taxonomic category verification relative to neutral sentences, whereas priming script categories improved the speed and accuracy of script category verification relative to neutral sentences. Moreover, Vitkin, Coley & Feigin (2005) showed that priming taxonomic categories inhibited scrip classification, whereas priming script categories had no effect on taxonomic categorization.

Together, these findings suggest that taxonomic knowledge may be more accessible and less sensitive to contextual manipulations than contextual knowledge. If so, then any asymmetry in the mutual influence of taxonomic and contextual conceptual systems should favor taxonomic categories over contextual categories.

To examine interactions between taxonomic and contextual conceptual systems, we used a relation verification task. Participants were asked to judge whether pairs of animals were related taxonomically and ecologically. By manipulating whether pairs shared both, one, or neither relation, we were able to examine how the presence or absence of a one relation influenced judgments about the other.

If taxonomic and ecological conceptual systems are largely independent of each other, then ecological relatedness should have little impact on taxonomic judgments, and vice versa. If these conceptual systems are symmetrically facilitating, we would expect better performance on ecological judgments for pairs related via both ecology and taxonomy than for pairs related solely via ecology because both relations potentiate a correct "yes" response. In contrast, we would expect poorer performance on ecological judgments for pairs related solely via taxonomy than for completely unrelated pairs because the taxonomic relation might increase the likelihood of an incorrect "yes" response. And if these influences are symmetrical, the converse should hold for influences of ecological relations on taxonomic judgments. If taxonomic and ecological conceptual systems are symmetrically inhibitory, we might expect the presence of one relation to uniformly interfere with performance on the other dimension. For example, ecological judgments should be slower and less accurate for taxonomically close pairs than far pairs, and vice versa for taxonomic judgments. Finally, if effects are asymmetrical, we would expect one kind of judgment to be disproportionately affected by the presence or absence of the other kind of relation. If so, research reviewed above leads us to expect that taxonomic categories might have a larger impact on ecological judgments than ecological categories have on taxonomic judgments.

Method

Participants

Participants were 36 Northeastern University undergraduates. Undergraduates were recruited from introductory psychology classes and participated for course credit.

Stimuli and Design

Twenty four pairs of animals were chosen to independently manipulate the presence of salient taxonomic and ecological relations. Pairs were either *taxonomically near* (drawn from the same or a closely related superordinate biological class) or *taxonomically far* (drawn from different superordinate biological classes). Orthogonally, pairs were either *ecologically related*—via shared habitat and predation—or *ecologically unrelated.* This yielded four item types: close/related, close/unrelated, far/related, and far/unrelated pairs (Figure 1). Participants were presented with all 24 pairs[1] and asked to judge whether the pairs were related taxonomically and ecologically. Taxonomic and ecological judgments were blocked; order of blocks was counterbalanced. Thus, we manipulated taxonomic distance and ecological relatedness of animal pairs as well as the type of verified relationship within subjects.

[1] Stimuli pairs contained either pictures of animals only, or animal names only, or pictures and names. This manipulation did not yield significant effects and did not interact with other factors, and will not be discussed here.

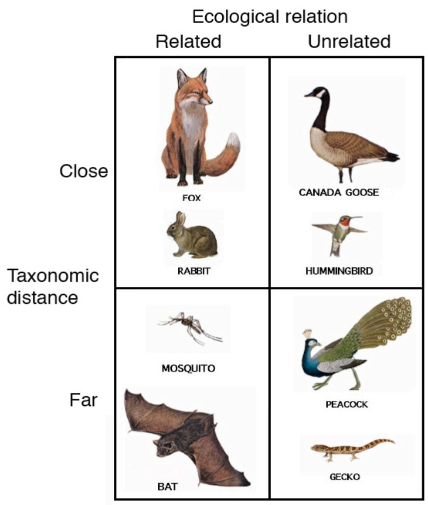

Figure 1: Orthogonal manipulation of taxonomic and ecological relation in animal pairs.

Procedure

Animal pairs were presented in blocks on a computer running Superlab software. Each block started with instructions, followed by 2 practice trials with feedback, after which participants were reminded of the question and presented all 24 experimental trials. Each trial started with a blank screen. An animal pair then appeared on the screen, and the participant indicated their response by pressing the "0" key for YES or the "1" key for NO. For the taxonomic block, the question was "Do these animals belong to the same biological category?" For the ecological block, the question was "Do these animals live in the same place?" Participants were instructed to respond as quickly as possible without sacrificing accuracy.

Results

Scoring

We analyzed accuracy (proportion of items answered correctly) and reaction time. For ecological judgments, correct responses were YES for related items and NO for unrelated items. For taxonomic judgments, correct responses were YES for close items and NO for far items. Reaction time was computed for correct responses only. For each participant, proportion correct and mean reaction time was computed for each type of item, separately for ecological and taxonomic judgments.

Accuracy

In order to examine the effects of taxonomic and ecological relatedness on judgments, we conducted a 2 (taxonomic distance: close, far) x 2 (ecological relation: related, unrelated) x 2 (verification question: taxonomic, ecological) repeated measures ANOVA on mean accuracy. Results showed that overall, accuracy of taxonomic verification (M=0.78) and ecological verification (M=0.74) did not differ ($F(1,35)=1.52$, $p=.23$). However, we did observed a three-way interaction between question, taxonomic distance, and ecological relatedness ($F(1,35)=32.59$, $p<.0001$, $\eta_p^2=.48$), suggesting that taxonomic distance and ecological relatedness had different effects on the accuracy of taxonomic versus ecological judgments.

To investigate this three-way interaction further, we separately analyzed accuracy of responses to taxonomic and ecological questions. We were particularly interested in whether the presence or absence of an ostensibly irrelevant relation (ecological relatedness for taxonomic verification, and taxonomic relatedness for ecological verification) had any effect on accuracy.

Ecological Verification. A 2 (taxonomic distance) x 2 (ecological relation) repeated measures ANOVA on ecological verification accuracy revealed that responses were more accurate for ecologically related items (M=0.83) than for unrelated items (M=0.66, $F(1,35)=24.19$, $p<.0001$, $\eta_p^2=.41$). Responses were also more accurate for taxonomically far items (M=0.79) than for taxonomically close items (M=0.70, $F(1,35)=13.34$, $p=.0008$, $\eta_p^2=.28$). Most importantly, these effects were qualified by a significant interaction ($F(1,35)=119.69$, $p<.0001$, $\eta_p^2=.77$). As shown in Figure 2, among ecologically related items, taxonomic relatedness facilitated accuracy, which was higher for close/related (M=0.96) than far/related items (M=0.70, Tukey/Kramer $p<.05$). In contrast, among ecologically unrelated items, taxonomic relatedness interfered with accuracy, which was lower for close/unrelated items (M=0.44) than for far/unrelated items (M=0.88, Tukey/Kramer $p<.05$).

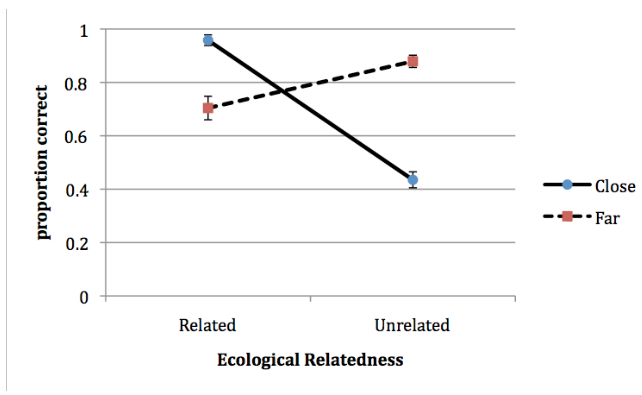

Figure 2: Accuracy for ecological verification as a function of ecological relatedness and taxonomic distance. Error bars represent one standard error of the mean.

Taxonomic Verification. A parallel 2 (taxonomic distance) x 2 (ecological relation) repeated measures ANOVA on taxonomic verification accuracy revealed that responses were more accurate for taxonomically far items (M=0.89) than for close items (M=0.66, $F(1,35)=40.38$, $p<.0001$, $\eta_p^2=.54$). Although ecological relation had no main effect on taxonomic accuracy, there was a reliable interaction ($F(1,35)=13.28$, $p=.0009$, $\eta_p^2=.28$). As shown in Figure 3, among taxonomically close items, ecological relatedness had no effect on accuracy. However, among taxonomically far items, ecological relatedness interfered with accuracy, which was lower for far/related items (*M*=0.82) than for far/unrelated items (*M*=0.96, Tukey/Kramer $p<.05$).

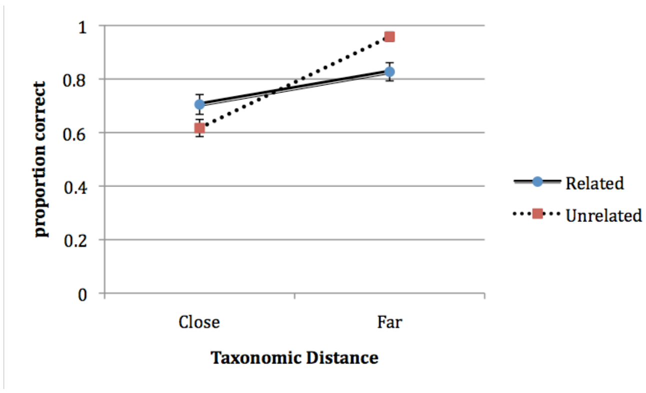

Figure 3: Accuracy for taxonomic verification as a function of ecological relatedness and taxonomic distance. Error bars represent one standard error of the mean.

So far, the effects of taxonomic distance on ecological verification appear larger than the reciprocal effects of ecological relatedness on taxonomic verification. To test this, we calculated separate facilitation and interference scores for each participant. Facilitation scores measured the extent to which the presence of a second relation increased accuracy when the target relation was also present. Thus, taxonomic facilitation for ecological verification was calculated by subtracting accuracy for far/related items from accuracy for close/related items, and ecological facilitation for taxonomic verification was calculated by subtracting accuracy for close/unrelated items from accuracy for close/related items. Likewise, interference scores measured the extent to which the presence of a non-target relation decreased accuracy in the absence of the target relation. Taxonomic interference on ecological verification was calculated by subtracting accuracy for close/unrelated items from accuracy for far/unrelated items, and ecological interference on taxonomic verification was computed by subtracting accuracy for far-related items from accuracy for far/unrelated items. In both cases higher scores indicated stronger facilitation or interference.

Analyses confirmed that the presence of taxonomic relations had a stronger facilitation effect on ecological verification (*M*=0.26) than the presence of ecological relations had on taxonomic verification (*M*=0.09, $t(35)=2.98$, $p=.005$). Likewise, the presence of taxonomic relations had a stronger interference effect on ecological verification (*M*=0.44) than the presence of ecological relations had on taxonomic verification (*M*=0.13, $t(35)=6.42$, $p<.0001$). These results demonstrate mutual albeit asymmetrical effects of taxonomic and ecological relations on judgments; the presence of taxonomic relations had a stronger effect on the accuracy of ecological verification than the presence of ecological relations had on the accuracy of taxonomic verification.

Reaction Time

In order to examine the effects of taxonomic and ecological relatedness on reaction time, we conducted a 2 (taxonomic distance: close, far) x 2 (ecological relation: related, unrelated) x 2 (verification question: taxonomic, ecological) repeated measures ANOVA on mean reaction time for correct responses. Overall RT for taxonomic verification (*M*=2105 msec) and ecological verification (*M*=2248 msec) did not differ ($F(1,35)=2.35$, $p=.14$). However, because the three-way interaction between question, taxonomic distance, and ecological relatedness approached significance ($F(1,35)=3.48$, $p=.071$, $\eta_p^2=.09$), we separately analyzed RT for taxonomic and ecological verification, as we did for accuracy.

Ecological Verification. A 2 (taxonomic distance) x 2 (ecological relation) repeated measures ANOVA on RT for ecological verification revealed that taxonomically close items (M=2081 msec) were verified faster than far items (M=2415 msec, $F(1,35)=15.28$, $p=.0004$, $\eta_p^2=.30$), and showed a significant interaction of taxonomic distance and ecological relatedness ($F(1,35)=7.55$, $p=.009$, $\eta_p^2=.18$). As depicted in Figure 4, among ecologically related items, taxonomic relatedness facilitated speed of verification, which was faster for close/related items (*M*=1846 msec) than far/related items (*M*=2427 msec, Tukey/Kramer $p<.05$). In contrast, RT did not differ for close/unrelated items (*M*=2316 msec) versus far/unrelated items (*M*=2407 msec).

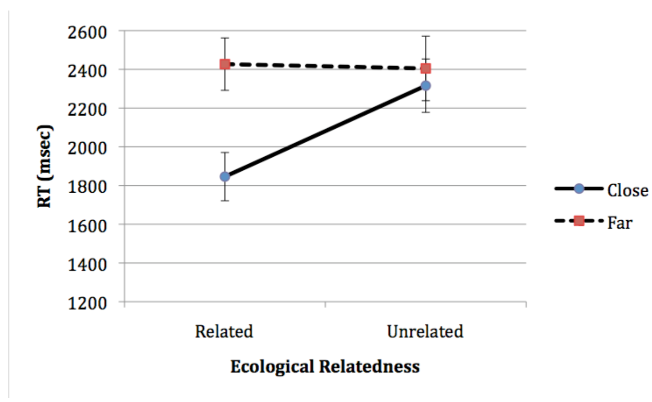

Figure 4: Reaction time for ecological verification as a function of ecological relatedness and taxonomic distance. Error bars represent one standard error of the mean.

Taxonomic Verification. A second 2 (taxonomic distance) x 2 (ecological relation) repeated measures ANOVA on RT for taxonomic verification revealed that participants were faster to respond to taxonomically far items (*M*=2016 msec) than close items (*M*=2193 msec, $F(1,35)=6.79$, $p=.013$, $\eta_p^2=.16$), and marginally faster to respond to ecologically unrelated items (*M*=2033 msec) than related items (*M*=2177 msec, $F(1,35)=3.50$, $p=.07$, $\eta_p^2=.09$). The interaction was not significant (see Figure 5).

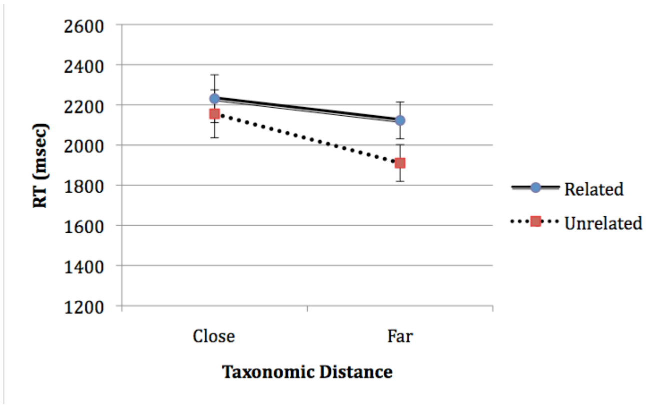

Figure 5: Reaction time for taxonomic verification as a function of ecological relatedness and taxonomic distance. Error bars represent one standard error of the mean.

To evaluate the relative strength of taxonomic and ecological relation effects on RT, we calculated facilitation and interference scores as we did for accuracy, except that the subtraction direction was reversed because facilitation corresponds to lower RT. As with accuracy, analyses confirmed that the presence of taxonomic relations had a stronger facilitation effect on ecological verification (M=581 msec) than the presence of ecological relations had on taxonomic verification (M=-75 msec, $t(35)=3.76$, p=.0006). Unlike for accuracy, taxonomic and ecological interference did not significantly differ. The overall pattern of RT results echoes the findings with accuracy, and suggests an asymmetry in mutual effects of taxonomic and ecological relations, with taxonomy exerting stronger influence on ecological verification than vice versa, although the pattern is weaker than in the accuracy analyses.

Discussion

This study was conducted to examine the cognitive consequences of cross-classification. More specifically, we investigated the interaction of taxonomic and ecological knowledge in folk biology.

Results of a relation verification task showed that the *taxonomic* relatedness of a pair of animals had a marked effect on the accuracy of *ecological* judgments about the pair. Specifically, ecological judgments for pairs related via both ecology and taxonomy were faster and more accurate than for pairs related solely via ecology. In contrast, ecological judgments for pairs related solely via taxonomy were less accurate than for unrelated pairs, but did not differ in RT.

Results also showed that the *ecological* relatedness of a pair of animals had a reciprocal, albeit weaker, effect on the accuracy of *taxonomic* judgments about the pair. Specifically, taxonomic judgments for pairs related solely via ecology were less accurate (but not slower) than for unrelated pairs. However, taxonomic judgments for pairs related via both ecology and taxonomy did not differ in speed or accuracy from taxonomic judgments for pairs related via taxonomy alone.

Moreover, focused comparisons of the magnitude of influence confirmed an asymmetry in the effects of taxonomic and ecological relations. The presence of taxonomic relations exerted stronger influence on ecological verification than the presence of ecological relations did on taxonomic verification.

These results were unlikely to be accounted for by speed-accuracy trade off, since, as examination of means suggests, higher accuracy was generally associated with lower RT.

The observed interactive effects rule out the first possibility described earlier that taxonomic and contextual systems could act independently in cross-classification. More specifically, the interaction between multiple category systems in cross-classification appears to be based on mutual facilitation, not mutual interference. Facilitation account relies on the spreading activation view of semantic memory (e.g., Collins and Quillian, 1969). On this view, accessing one kind of category may lead to activation of other conceptual systems an object belongs to. Positive categorization decisions (confirming presence of the verified relation) can benefit from additional activation spreading from ostensibly irrelevant categories, increasing likelihood of "yes" responses. In negative categorization (denying a common category in the absence of verified relation), when activation spreads from irrelevant categories and increases unwarranted activation of the verified category system, this results in higher likelihood of erroneous "yes" responses. This way, underlying facilitation in accessibility of two conceptual systems would manifest itself through facilitatory effects in positive categorization, and interference effects in negative categorization, as observed in our experiment.

A less interesting explanation for such pattern might be based on participants' inability to differentiate between taxonomic and ecological relatedness. However, the fact that responses to taxonomic and ecological questions followed markedly different patterns, and were differentially affected by taxonomic and ecological relations suggests that participants were not indiscriminately verifying presence of some general association between animals.

Importantly, the observed facilitation interaction was markedly asymmetrical. On positive verification trials, where the target relation is present and a non-target relation varies, ostensibly irrelevant taxonomic relations reliably facilitated both speed and accuracy of ecological verification of related items, whereas the presence of non-target ecological relation, on the contrary, had no effect on speed or accuracy of taxonomic verification of taxonomically related items. On negative verification trials, when the target relation was absent, although both ecological and taxonomic verification showed decrease in accuracy when a non-target relation was present, the decrease was three times more pronounced for ecological verification in the presence of taxonomic relation. These results clearly demonstrate that taxonomic relations exert stronger effect on ecological relations, than vice versa.

As a speculation, such asymmetric interaction may arise if the taxonomic category system is more clearly "tagged" as a distinct categorization dimension, and can be accessed in a relatively isolated and targeted manner. The system of ecological categories (or, more specifically, habitat categories), may lack such a tag of a distinct dimension which would allow to selectively activate it and ignore irrelevant dimensions. In the absence of a clear and easily available criterion of what kind of relatedness counts as "habitat", it is hard to identify and discount what is not habitat. By "playing it safe", such a system would allow taxonomic relation to augment decisions about ecological relatedness, but not the opposite.

Finally, it needs to be noted that in our experiment we did not observe an overall accessibility advantage of taxonomic over ecological categories (based on average accuracy or speed of relation verification). This contrasts with previous work (Ross & Murphy, 1999; Coley et al., 2005; Shafto et al., 2007) suggesting overall accessibility as an important factor on which taxonomic and contextual categories differ. Our results could be due in part to the specifics of the task mentioned above: participants were only provided with two instances and a general category type, but not the specific level to verify ("Do these animals live in the same place?", "Do these animals belong the same biological category?"), and they were free to interpret the question broadly or narrowly. In contrast, previous studies involved making decisions about single instances and their membership in explicitly provided categories ("*Is bacon a meat*?"). In our task, deriving a relevant common category could involve additional effort (with different amount of effort required for deriving a relevant common ecological vs. taxonomic category), which could result in leveling of ecological and taxonomic verification in overall accuracy and speed.

Nevertheless, the fact that such asymmetrical effects of taxonomic knowledge were observed even in the absence of overall accessibility advantage, makes these findings even more remarkable. In this study, the asymmetry of effects can not be attributed to taxonomic knowledge being at ceiling of accessibility, restricting potential influence of ecological knowledge. The observed effects highlight the fact that there are multiple ways in which increased accessibility of knowledge may be manifested in reasoning.

This work contributes to our understanding of how category knowledge is accessed for multiply classified instances. Most importantly, these results underscore the interactive nature of different conceptual systems for cross-classified categories and suggest that this interaction is markedly asymmetrical, with a disproportionally strong influence of taxonomic categories.

Acknowledgements

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