AFFECTIVE AND COGNITIVE RESPONSES TO INSECTS AND OTHER ARTHROPODS

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ABSTRACT

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Insects are the most abundant and diverse group of animals on Earth. Though as a group they do far more ecological good than harm, previous studies have shown that human attitudes toward insects are mainly negative. Attitudes have affective (emotions) and cognitive (beliefs, mental representations) components that interact to influence behavior. Negative attitudes toward insects are associated with negative affect such as disgust and fear, and can have negative consequences, such as a lack of conservation funding. In addition, negative attitudes can cause people to avoid insects and/or feel distress when insects are present, prompting a disconnection between the public and the insect world.

To explore affective responses to insects, Chapter Two focuses on the emotion of disgust. Disgust is associated with avoidance of objects that cause sickness (*e.g.* rotten meat) or undesirable social conduct (*e.g.* moral disgust). Disgust is partitioned into distinct domains – pathogen, moral, sexual, etc. To determine whether disgust stimulated by insects belongs in a unique domain, incoming freshmen at a large public university were surveyed (Chapter Two). Survey items pertained to moral, pathogen, and insect-specific disgust. Factor analyses indicate that insect disgust and pathogen disgust are part of the same construct, unique from moral disgust. This implies that insects are perceived with the same feelings of disgust felt for pathogens.

To explore cognition associated with insects, Chapter Three and Appendix One focus on mental models of insects and other arthropods. Mental models are internal representations of

external entities that are used to reason, make inferences, conduct thought experiments, and anticipate future events. Drawings reflect important qualities of mental models including knowledge categorization and organization. Drawings of insects were collected from participants with high and low expertise in entomology. Salient insect features were indexed and principal components analysis applied to detect underlying patterns. Two distinct components emerged – (1) a non-winged "crawling" insect, and (2) a legless winged "flying" insect, implying that flying and crawling insects are perceived as distinct from each other (Chapter Three). A similar analysis of children's drawings of insects also showed a distinction between crawling and flying insects (Appendix One).

Finally, to explore the interaction between affective and cognitive responses to insects, drawings of "disgusting" and "not disgusting" insects from participants sampled in Chapter Three were compared. Participants were also surveyed to gain a quantitative measure of disgust associated with insects. Experts exhibited significantly lower disgust responses than novices. Additionally, the inclusion of legs on drawings of insects deemed not disgusting correlated negatively with disgust. In contrast, the inclusion of legs on drawings of disgusting insects correlated positively with disgust. This suggests that crawling insects may be regarded as being more disgusting than flying insects. A multiple linear regression was conducted on the not disgusting insect drawings to determine whether drawing a crawling insect as well as one's expertise level, could predict insect-associated disgust. Approximately 35% of the variation in disgust was attributable to subject group (expertise) and the degree to which drawings aligned with the crawling insect model. In addition, this study also demonstrates that examining drawings of insects can be a useful tool to shed light on affect and cognition associated with insects.

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CHAPTER ONE

AN INTRODUCTION TO AFFECTIVE AND COGNITIVE RESPONSES TO INSECTS AND OTHER ARTHROPODS

"We are psychologically, as well as ecologically bound up with insects."
– Adam Dodd, "Minding insects: scale, value, world"

Insects are simultaneously the most diverse and abundant animals on Earth. Their small size allows them to capitalize on many diverse ecological niches (Wilson, 1987). They are vitally important for numerous valuable ecological services such as pollination, dung burial, decomposition, and soil aeration. In the U.S. alone, ecological services provided by insects are estimated to be worth approximately $57 billion each year (Losey & Vaughan, 2006). In addition, many human medicines are derived from insects (Costa-Neto, 2005; Cherniak, 2010). Insects are animals belonging to the taxonomic Class Insecta. Insecta is part of a broader taxonomic group, the Phylum Arthropoda, which also includes spiders, scorpions, ticks, mites, centipedes, millipedes, and crustaceans. All arthropods are characterized by their hard chitinous outer covering (exoskeleton), jointed appendages, segmented bodies, an open circulatory system, and bilateral symmetry (Fig. 1.1).

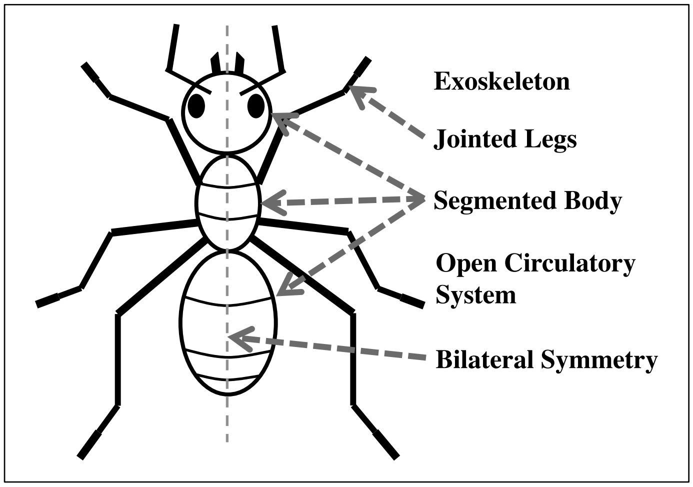

Figure 1.1. Typical representation of an arthropod with important features labeled

There are an estimated 5-10 million total species of arthropods, the bulk of which are as yet undescribed (Odegaard, 2000). The vast majority of arthropods are insects. Some non-insect arthropods, such as spiders, are frequently confused with insects (Kellert, 1993; Shepardson, 2002). A common tendency is to lump non-insect arthropods together with insects in to one group referred to simply as "bugs" (Shipley & Bixler, 2016). Interacting with insects is a common experience shared by people around the globe. Insects occur everywhere that humans do. They are present in the traditions, art, and folklore of numerous cultures (Hogue, 1987), and provide a nutritious food source for many people (DeFoliart, 1999). It is impossible to separate insects from the experience of human life. Human experiences with insects can be positive, for example, watching butterflies or beekeeping. Experiences with insects can be neutral, such as noticing an insect on the sidewalk. Experiences with insects can also be negative, such as getting stung or finding a maggot in one's food. Though insects as a whole do far more ecological good than harm, and indeed, humans would likely not exist without insects (Wilson, 1987), studies have shown that public attitudes toward insects are negatively biased (Byrne et al., 1984; Kellert, 1993; Driscoll, 1995; Bjerke et al., 1998; Schlegel & Rupf, 2010; Prokop et al., 2011; Shipley & Bixler, 2016).

Negative public attitudes toward insects are characterized by negative emotional responses to them such as disgust and fear (Bjerke et al., 1998; Smithsonian Institute, 2007; Gerdes et al., 2009), and this likely encourages negative behaviors toward insects such as avoidance or destruction. Studies addressing negative biases toward insects have given important insights about human attitudes toward insects (as well as non-insect arthropods that are mistaken for insects, *e.g.* spiders). These types of studies have shown that attitudes toward arthropods are more negative if they are perceived as being harmful or associated with disease (*e.g.* parasites, mosquitoes, ticks, etc.) (Gerdes et al., 2009; Prokop & Fančovičová, 2010), and that the disgust elicited by insects is similar to the disgust elicited by pathogenic substances (Lorenz et al., 2014).

Another important insight about attitudes toward insects is that the location where an insect is observed influences the attitudinal response – insects found inside the home are more negatively perceived than insects found outdoors (Byrne et al., 1984; Baldwin et al., 1998). Attitudes toward insects also vary according to the type of insect, with butterflies and lady beetles evoking more positive attitudes than other insects (Byrne et al., 1984; Kellert, 1993; Gerdes et al., 2009; Lorenz et al., 2014). Finally, it has also been noted that a common belief about insects is that every insect observed in or around the home is a pest capable of causing damage (Byrne et al., 1984; Baldwin et al., 1998).

Scientists and policymakers should be concerned about widespread negative attitudes toward insects because they may lead to negative environmental consequences such as misuse or overuse of pesticides by homeowners, or other widescale eliminations of insects. Additionally, invertebrates represent the largest proportion of biodiversity in the animal kingdom, and thus preserving biodiversity necessitates preserving invertebrates (Leather, 2013). However, a relative paucity of conservation funding is spent on conserving insects and other invertebrates, relative to the dollars spent conserving vertebrate animals (Cardoso et al., 2011). This may be related to negative attitudes toward insects, since people are more willing to contribute money toward the conservation of species for which they hold positive attitudes (Martín-López et al., 2009).

Studies suggest that participation in educational programs about insects and other arthropods may be effective at improving attitudes toward them. For example, Wagler and Wagler (2011) showed that pre-service elementary teachers were more likely to say that they would include insects in their curriculum after they had participated in a program where they were exposed to live insects. Byrne et al. (1984) reported that college-educated individuals tended to hold more positive attitudes toward arthropods than those with a high school diploma or less, and postulated this was because college-educated individuals had greater knowledge of the environment compared to others. Participation in educational programs is often an effective mediator of negative attitudes in other disciplines outside of entomology. For example, Randler et al. (2012) found that students who had previously performed a dissection of a dead animal were less disgusted by the task than students who had never performed a dissection.

In order to improve the ability of education to promote positive attitudes toward insects, it is important to first understand the attitudes, ideas, and beliefs that people already hold about insects. Human beings are not blank slates – they approach and interpret new information or experiences using what they already know and feel as a basis. Thus, from an educational standpoint, in order to facilitate the acquisition of new knowledge, it is important to be aware of students' pre-existing ideas and biases. Attitudes are learned "favorable or unfavorable feelings toward objects, persons, groups, or any other identifiable aspects of our environment" (Koballa, 1988, p. 117), which can be more broadly defined as responses to stimuli (Breckler, 1984). Attitudes are often regarded to be products of interactions between three types of response: cognition, affect, and behavior (Breckler, 1984; Farley & Stasson, 2003; etc.). Affect refers to emotional reactions; cognition refers to thoughts, beliefs, and mental representations; and behavior refers to actions or intentions to act (Breckler, 1984). These three types of responses to stimuli interact to constitute an attitude toward stimuli.

Attitudes are incorporated in mental models (Jones et al., 2011; Jung & Yim, 2015). Mental models are internal cognitive representations of objects or systems (Vosniadou & Brewer, 1994; Merrill, 2000; Jones et al., 2011). Mental models are representative of the current state of one's understanding and knowledge about a subject, and are also shaped by one's attitudes, beliefs, and values pertaining to the subject (Jones et al., 2011; Jung & Yim, 2015).

The structure of a mental model is representative of the structure of the corresponding object or system, thus, by manipulating a mental model, an individual interacts with their knowledge (Jones et al., 2011). Mental models are used during reasoning and problem solving tasks, as well as to make predictions about the outcomes of events. Thus, they drive decision-making and other behaviors. Mental models are simplified from reality in that they do not capture all minutiae and other particulars (Jones et al., 2011). One of the most important properties of mental models is that they are dynamic; they are created at a point of need and housed in working memory (Vosniadou & Brewer, 1994).

Attitudes and mental models can be difficult to study because they exist only in the mind of an individual. In previous literature, information about the composition of mental models is often obtained by using such techniques as interviewing, diagramming, and estimating relatedness between model components (Rowe & Cooke, 1995; Diaz, 2009). Drawing is another useful method of eliciting information about the content and configuration of mental models (Dove et al., 1999; Moseley et al., 2010; Libarkin et al., 2015; Quillin & Thomas, 2015). This is because people interact with their mental models as they are drawing (Quillin & Thomas, 2015). The action of creating a drawing requires an individual to first recall the important components of the model, and then arrange those components in a way that is representative of the concept being modeled. Though most studies eliciting drawings are focused on gaining insights about cognition, drawings can also be utilized to study affect (e.g. Oster & Crone, 2004; Löfström & Nevgi, 2012). In addition, drawings are free from limitations imposed by the collection of spoken or written responses, such as vocabulary size and language fluency.

One method that is commonly used to gain insight from drawings is indexing (Libarkin et al., 2015). Indexing involves detection and documentation of salient features in a drawing.

Insights can then be drawn from the presence or absence of salient features, as well as the relationships between features. Typically, Thematic Content Analysis (TCA) is used to identify meaningful patterns in relationships between features. Thematic content analysis is characterized by the detection of common themes across participants (Anderson, unpublished data) after visual inspection by the researcher. However, despite the best intentions it is possible for bias to occur with human researchers, or they may miss an important theme (Anderson, unpublished data). To avoid these potential pitfalls associated with TCA, it is beneficial to have a computer program, rather than a researcher, search for patterns in the data. For example, Libarkin et al.'s use of principal components analysis resulted in the emergence of underlying mental models of the greenhouse effect (2015).

Research questions

This dissertation is aimed at exploring affective (disgust) and cognitive (mental models) responses stimulated by interactions with insects and other arthropods. Another aim of this dissertation is to determine how expertise influences affective and cognitive responses. Thus, the main research questions investigated in this dissertation are as follows:

1) Is disgust elicited by insects unique from other domains of disgust? (Chapter 2)
2) Can we learn about underlying mental models of insects by examining people's drawings of insects? (Chapter 3)
3) How do drawings of insects differ between experts and novices, and do they suggest major differences in their mental models? (Chapter 3)
4) What can people's drawings of insects tell us about their level of disgust associated with insects, and how is this influenced by expertise? (Chapter 4)

Results from this research will provide insights about human affect and cognition stimulated by insects and other arthropods. These insights will assist educators in developing new educational programs about insects that effectively challenge pre-existing misconceptions and negative biases. The ultimate goal is for this work to facilitate improved public attitudes toward insects, leading to increased public engagement in entomology.

REFERENCES

REFERENCES

Anderson R. Thematic Content Analysis (TCA): Descriptive presentation of qualitative data. Unpublished data. Available at http://rosemarieanderson.com/wp-content/uploads/2014/08/ThematicContentAnalysis.pdf Accessed July 6, 2017.

Askew, C., Çakır, K., Põldsam, L. and Reynolds, G. (2014) The effect of disgust and fear modeling on children's disgust and fear for animals. *Journal of Abnormal Psychology, 123*(3): 566–577.

Baldwin, R. W., Koehler, P. G., Pereira, R. M., and Oi, F. M. (2008) Public perceptions of pest problems. *American Entomologist*, *54*(2): 73-79.

Bandura, A. (1971) Social learning theory. *General Learning Press, New York, New York, USA*.

Breckler, S. J. (1984) Empirical validation of affect, behavior, and cognition as distinct components of attitude. *Journal of Personality and Social Psychology, 47*(6): 1191–1205.

Bjerke, T., Ødegårdstuen, T. S., and Kaltenborn, B. P. (1998) Attitudes toward animals among Norwegian adolescents. *Anthrozoös, 11*(2): 79–86.

Byrne, D. N., Carpenter, E. H., Thoms, E. M., and Cotty, S. T. (1984) Public attitudes toward urban arthropods. *Bulletin of the Entomological Society of America, 30*(2): 40–44.

Cardoso, P., Erwin, T. L., Borges, P. A. V., and New, T. R. (2011) The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation, 144*(11): 2647–2655.

Costa-Neto, E. M. (2005) Entomotherapy, or the medicinal use of insects. *Journal of Ethnobiology, 25*(1): 93–114.

Cherniak, E.P. (2010) Bugs as drugs, Part 1: insects: the new alternative medicine for the 21st century? *Alternative Medicine Review, 15*: 124–135.

Davey, G. C. L., Forster, L., and Mayhew, G. (1993) Familial resemblances in disgust sensitivity and animal phobias. *Behaviour Research and Therapy, 31*(1): 41–50.

DeFoliart, G. R. (2003) Insects as food: why the western attitude is important. *Annual Review of Entomology, 44*: 21-50.

Diaz, A. E. (2009) Undergraduates' mental models about insect anatomy and insect life cycles. M.S. Thesis, California State University, Fullerton.

Dodd, A. (2013) Minding insects: scale, value, world. In *The Management of Insects in Recreation and Tourism*, pages 23-36. Edited by R. H. Lemelin. Cambridge University Press: Cambridge, UK.

Dove, J. E., Everett, L. A., and Preece, P. F. W. (1999) Exploring a Hydrological Concept through Children's Drawings. *International Journal of Science Education, 21*(5): 485-497.

Driscoll, J. W. (1995) Attitudes toward animals: species ratings. *Society and Animals, 3*(2): 139–150.

Dunn, R. R. (2005) Modern insect extinctions, the neglected majority. *Conservation Biology, 19*(4): 1030–1036.

Farley, S. D., and Stasson, M. F. (2003) Relative influences of affect and cognition on behavior: are feelings or beliefs more related to blood donation intentions? *Experimental Psychology, 50*: 55-62.

Gerdes, A. B. M., Uhl, G., and Alpers, G. W. (2009) Spiders are special: fear and disgust evoked by pictures of arthropods. *Evolution and Human Behavior, 30*: 66–73.

Hogue, C. L. (1987) Cultural entomology. *Annual Review of Entomology, 32*: 181–199.

Jones, N., Ross, H., Lynam, T., Perez, P., and Leitch, A. (2011) Mental models: An interdisciplinary synthesis of theory and methods. *Ecology and Society, 16*: 46.

Jung, W., and Kim, H. R. (2015) The effects of mental model on the variables in the technology acceptance model. *International Journal of Multimedia and Ubiquitous Engineering, 10*(3): 171-180.

Kellert, S. (1993) Values and perceptions of invertebrates. *Conservation Biology, 7*(4): 845–855.

Koballa, Jr., T. R. (1988) Attitude and related concepts in science education. *Science Education, 72*(2): 115–126.

Leather, S. R. (2013) Institutional vertebratism hampers insect conservation generally; not just saproxylic beetle conservation. *Animal Conservation, 16*(4): 379–380.

Libarkin, J. C., Thomas, S. R., and Ording, G. (2015) Factor analysis of drawings: Application to college student models of the greenhouse effect. *International Journal of Science Education, 37*(13): 2214-2236.

Löfström, E., and Nevgi, A. (2014) Giving shape and form to emotion: using drawings to identify emotions in university teaching. *International Journal for Academic Development*, *19*(2): 99-111.

Lorenz, A.R., Libarkin, J.C., and Ording, G.J. (2014) Disgust in response to some arthropods aligns with disgust provoked by pathogens. *Global Ecology and Conservation, 2*: 248-254.

Losey, J. E., and Vaughan, M. (2009) The economic value of ecological services provided by insects. *BioScience, 56*(4): 311–323.

Martín-López, B., Montes, C., Benayas, J. (2009) The non-economic motives behind the willingness to pay for biodiversity conservation. *Biological Conservation, 139*: 67–82.

Merrill, M. D. (2002). Knowledge objects and mental models. In *Instructional Use of Knowledge Objects,* pages 261–280. Edited by D. Wiley. Agency for Instructional Technology and Association for Educational Communications & Technology: Washington D.C., U.S.A.

Monge-Nájera, J. (2017) The power of short lectures to improve support for biodiversity conservation of unpopular organisms: an experiment with worms. *UNED Research Journal*, *9*(1).

Moseley, C., Desjean‐Perrotta, B., and Utley, J. (2010) The draw‐an‐environment test rubric (DAET‐R): Exploring pre‐service teachers' mental models of the environment. *Environmental Education Research*, *16*(2): 189-208.

Oster, G. D., and Crone, P. G. (2004) *Using drawings in assessment and therapy: A guide for mental health professionals.* Psychology Press.

Prokop, P., Usak,M., Erdogan, M., Fancovicova, J., and Bahar, M. (2011) Slovakian and Turkish students' fear, disgust and perceived danger of invertebrates. *Hacettepe University Journal of Education, 40*(40): 344–352.

Quillin, K., and Thomas, S. (2015) Drawing-to-learn: A framework for using drawings to promote model-based reasoning in biology. *CBE-Life Sciences Education*, *14*:es2.

Randler, C., Wüst-Ackermann, P., Vollmer, C., and Hummel, E. (2012) The relationship between disgust, state-anxiety and motivation during a dissection task. *Learning and Individual Differences, 22*(3): 419–424.

Rowe, A. L., and Cooke, N. J. (1995) Measuring mental models: Choosing the right tools for the job. *Human resource development quarterly*, *6*(3): 243-255.

Schlegel, J., and Rupf, R. (2010) Attitudes towards potential animal flagship species in nature conservation: a survey among students of different educational institutions. *Journal for Nature Conservation, 18*(4): 278–290.

Shepardson, D. P. (2002) Bugs, butterflies, and spiders: children's understandings about insects. *International Journal of Science Education*, *24*(6): 627-643.

Shipley, N. J., and Bixler, R. D. (2016) On the need to interpret insects: an always small but gargantuan opportunity. *Journal of Interpretation Research, 21*(2): 63–72.

Smithsonian Institution Office of Policy and Analysis. (2007) The buzz on insects: a study of attitudes and knowledge among visitors to the National Museum of Natural History. Retrieved 15, January, 2017 from https://www.si.edu/content/opanda/docs/Rpts2007/07.09.Insects.Final.pdf.

Vosniadou, S., and Brewer, W. F. (1994) Mental models of the day/night cycle. *Cognitive Science, 18*: 123-183.

Wagler, R., and Wagler, A. (2011) Arthropods: attitude and incorporation in preservice elementary teachers. *International Journal of Environmental and Science Education, 6*(3): 229–250.

Wilson, E. O. (1987) The little things that run the world (the importance and conservation of invertebrates). *Conservation Biology, 1*(4): 344–346.

CHAPTER TWO

DISGUST IN RESPONSE TO SOME ARTHROPODS ALIGNS WITH DISGUST PROVOKED BY PATHOGENS

Lorenz, A.R., Libarkin, J.C., and Ording, G.J. (2014) Disgust in response to some arthropods aligns with disgust provoked by pathogens. *Global Ecology and Conservation, 2*: 248-254.

ABSTRACT

Insects are disliked by the public, despite the fact that they provide valuable ecosystem services and are vital components of ecosystems. Public support toward wildlife conservation is influenced by attitudes toward different taxa, thus, the widespread negativity toward insects shown by the general public almost certainly detracts from conservation efforts for them. Negative attitudes toward insects and other invertebrates take many forms, one of which is the feeling of disgust. Disgust has been widely researched and is typically divided into distinct domains (e.g., moral disgust). In order to determine whether insect-specific disgust is unique from other domains of disgust, we conducted a survey of 704 incoming freshmen at a major Midwestern university with questions pertaining to Moral, Pathogen, and Insect-specific Disgust. Factor analyses indicate that Insect Disgust and Pathogen Disgust are part of the same construct, unique from Moral Disgust. Our results suggest that survey respondents perceived insects in the same way as they would pathogens, at least in regard to disgust. This research provides insight into how the public views insects, and will facilitate educational interventions aimed at challenging negative attitudes toward insects. The Insect Disgust Scale will be a useful measure of insect-related disgust in future studies.

INTRODUCTION

The importance of species conservation for ecosystems and human wellbeing is widely recognized. Practices promoting the conservation of wildlife and natural resources are essential for the preservation of biodiversity, which is crucial in all ecosystems and for all populations, particularly in developing countries where people depend on endemic plants and animals for medicines, food, and a source of livelihood (Adenle, 2012). Although the importance of conservation in general is clear, a fundamental inequality exists in the types of organisms that receive the largest conservation efforts; conservation endeavors toward vertebrate animals are more likely to receive support than efforts toward invertebrates, fungi, or plants (Black et al., 2001; Clark and May, 2002; Cardoso et al., 2011). For example, in 2009, the largest expenditures of conservation dollars in the US all went toward vertebrate animals, including salmon, pallid sturgeon, red-cockaded woodpecker, and bull trout (Buck et al., 2012).

Although invertebrates comprise 80% of all known species on Earth, they are the recipients of only 10% of conservation funding (Cardoso et al., 2011; Collen et al., 2012). The bias against invertebrates partly stems from the negative perception of insects by the general public (Cardoso et al., 2011). The majority of people find insects to be scary, disgusting, dangerous, or ugly. This is problematic for invertebrate conservation because negative attitudes toward specific groups of organisms have been shown to adversely impact people's willingness to support the preservation of those organisms (Maresova & Frynta, 2007; Martín-López et al., 2009; Knight, 2008; Prokop & Fančovičová, 2012; Prokop and Fančovičová, 2013a,b). Though some insects are perceived positively (e.g., butterflies, dragonflies), the majority of insects as well as other terrestrial arthropods are generally regarded in a negative light.

One prominent emotion that is often directed toward insects and their kin is disgust.

Disgust is considered to be, at its core, an evolutionary mechanism to avoid ingestion of harmful substances (e.g., feces, spoiled food; Darwin, 1872/1965; Rozin & Fallon, 1987). However, the feeling of disgust can be provoked by a diverse range of stimuli, including concrete objects (e.g., blood, worms, etc.) and individual behaviors (e.g., incest, stealing, etc.) that are unrelated to food habits (Haidt et al., 1994; Oaten et al., 2009; Tybur et al., 2009, 2013; etc.). Disgust has consequently been divided into separate ‘‘domains’’. For example, Haidt et al. (1994) created a survey that divides disgust into seven different domains (e.g., food, sex, hygiene, animals, etc.) and concludes that disgust is a mechanism whose primary purpose is to differentiate humans from other animals. In contrast, some evolutionary psychologists (Tybur et al., 2009, 2013) suggest that disgust can be divided into just three major domains: Moral (e.g., violation of societal norms), Pathogen (e.g., infection by microorganisms), and Sexual (e.g., sexual behaviors that may be damaging to one’s reproductive fitness). Thus, according to this interpretation, disgust is not only a mechanism to avoid disease, but also functions as a regulator of mate choice and social relations. We chose to model our Insect Disgust scale on the survey developed by Tybur et al. (2009).

Logically, feelings of disgust inspired by insects can be anticipated to align most closely with Pathogen Disgust, rather than Moral or Sexual Disgust. Insects and other arthropods share commonalities with Pathogens in that they can occur in ‘‘outbreak’’ numbers, are of small size, and often exhibit large populations and rapid reproduction rates. In addition, there are many arthropod species that are ‘‘disease-relevant’’ by being either actively involved in the transmission of disease (e.g., mosquitoes, fleas, and ticks), or associated with unhygienic conditions (e.g., some flies). In one study, ratings of disgusting pictures of insects correlated strongly with Pathogen Disgust (Prokop & Jančovičová, 2013). In contrast, there are no or few conceptual links between insects and moral issues (Prokop & Jančovičová, 2013), or insects and human sexual habits. In our survey, we included both the Pathogen Disgust scale from Tybur et al. (2009) as well as the Moral Disgust scale, in order to compare disgust in response to insects with these two previously validated domains of disgust. We did not include the Sexual Disgust scale because it is not relevant to insect-related disgust, and because the inclusion of the Moral Disgust scale already provided an effective comparison with the Pathogen Disgust Scale and our Insect Disgust Scale.

The current study investigated the disgust responses of incoming freshmen at a large Midwestern university. We chose to focus our invertebrate-specific survey items on a combination of neutral insects (e.g., ants, crickets, bugs) as well as stereotypically unpopular or disease-relevant insects and arachnids (e.g., cockroaches, scorpions, spiders). We avoided the inclusion of charismatic insects that were not anticipated to evoke disgust, with the exception of one item that was specific to butterflies. However, this item was removed from analysis once it became clear that subjects responded to the butterfly question differently than to the other insect-related questions (see Section 3).

We postulated that disgust in response to insects would emerge as a unique construct when compared to disgust in response to non-insect stimuli, with this expectation based on prior research suggesting that Insect and Pathogen Disgust, although different, would be correlated. We also hypothesized that demographic variables would correlate with Insect Disgust. In many studies on disgust, women display higher disgust sensitivity than men (Davey, 1994; Tucker & Bond, 1997; Gerdes et al., 2009; Oaten et al., 2009; Prokop & Jančovičová, 2013; etc.). This may be resultant of the traditionally higher parental investment exerted by women, although this theory has not yielded any strong support (Prokop & Jančovičová, 2013). Other variables are known to affect disgust sensitivity, such as cultural affiliation (Prokop & Fančovičová, 2010) and political affiliation (Inbar et al., 2011), as well as participation in educational programs that feature the disgusting object (Randler et al., 2012). However, gender is considered to be the most dominantly influential demographic (Berger & Anaki, 2014). In our study, we chose to analyze gender and college major, since our respondents were of similar ages and were all occupied as full-time students at the same university. Sherman and Sherman (1998) reported lower disgust sensitivity in nursing majors compared to other majors, though this was specific to items related to their profession (e.g., bodily fluids). We specifically postulated that women would exhibit higher disgust responses than men. We also postulated that non-science majors, who likely had less biology background than science majors, would exhibit higher levels of disgust.

METHODS

Participants

College freshmen attending a university orientation program completed several surveys, including a survey measuring disgust. We report on an analysis of 704 completed disgust surveys. The study population was 49% male, had a median age of 18 years old, and an average age of 17.9 ± 02 years. Sixty-six percent of participants had declared majors in a STEM (Science, Technology, Engineering, or Mathematics) field.

Materials

Participants completed a survey containing 23 items related to disgust (Table 1). We utilized disgust scales created by Tybur et al. (2009) to measure Moral and Pathogen-specific Disgust. A set of items specifically related to insects was also added. One insect-related item came from Tybur et al. (2009) (‘‘seeing a cockroach run across the floor’’); remaining items were created for this study but were inspired by Tybur et al. (2009) as well as Bixler and Floyd (1999). Morality concepts incorporated into items included lying, cheating, or stealing; pathogens included blood, vomit, and excrement; and insects included mosquitoes, ants, and cockroaches (Table 1). Survey participants responded to each item by rating their disgust level on a scale from A to D; with A being ‘‘not at all disgusting’’, B ‘‘somewhat disgusting’’, C ‘‘very disgusting’’, and D ‘‘extremely disgusting’’. The scale also included demographic questions relating to gender and major. This research followed all human subject protocols as required by institutional IRB. Survey questions are provided in Table 1.

Analyses

All statistical analyses were conducted in SPSS 21.0, except for a confirmatory factor analysis run in AMOS 21.0. We ran exploratory factor analysis and confirmatory analysis in order to investigate the unidimensionality of Insect Disgust items and their relationship to Pathogen and Moral Disgust. A multivariate analysis of variance (MANOVA) was also performed to investigate the variance in scores on identified disgust scales that could be explained by the common demographic variables of gender and area of study. Disgust scores were calculated for each survey respondent by calculating the mean of their scores for each identified disgust scale. Disgust scores in this analysis were the dependent variables, and gender and major served as two independent variables.

RESULTS

Exploratory factor analysis

An initial exploratory factor analysis was used to determine the relationships between disgust related to insects, morals, and pathogens. Forty-four surveys were discarded due to missing or compromised data. 704 surveys remained and were included in the analysis. Exploratory factor analysis was then used to identify covariance among the 23 survey items. To test for normality, we tested each item for skewness and kurtosis, and discovered that all items had skewness or kurtosis values less than |2| (Tybur et al., 2009), with the exception of a butterfly item (''Feeling a butterfly land on your arm''). The butterfly item also proved problematic upon examination of correlation matrices, which revealed low (below 0.3) and irregular Pearson Correlations. These results were interpreted to reflect the fact that butterflies are perceived quite differently (*i.e.*, non-disgusting) from the rest of the insects included in the survey, and the item was consequently removed from our analyses. The following analysis considers the remaining 22 items.

We used factor analysis to examine underlying patterns in the data. Our data followed the assumption of multicollinearity (VIF values <2). The Kaiser–Meyer–Olkin measure of sampling adequacy was 0.904, which is above the recommended threshold of 0.6. Additionally, Bartlett's test of sphericity was significant ($\chi^2(231) = 4723.3$, $p < 0.001$). Exploratory Factor Analysis (EFA) on the remaining 22 items revealed a total of four eigenvalues greater than one: 5.956, 3.054, 1.227, and 1.037. Based on eigenvalues, the first factor explained 27% of the variance, the second factor explained 13.9% of the variance, and the third and fourth factors each explained <6% of the variance. Each survey item also had diagonals greater than 0.5 in the anti-image correlation matrix, indicating that all questions should be included in the analysis (Neill, 2008).

We chose a two-factor model that explained 41% of the variance due to the previous theoretical validation of the Moral and Pathogen scales in Tybur et al. (2009), as well as the ‘‘leveling off’’ of the eigenvalues in the scree plot after two factors (Cattell, 1966). Upon extraction, promax-rotated factor loadings suggested that the ‘‘Insect’’ and ‘‘Pathogen’’ items load onto one factor, with ‘‘Moral’’ items loading on a second factor. Thus, we combined our ‘‘Insect’’ and ‘‘Pathogen’’ questions into one latent variable. For purposes of clarity in further discussion and analysis, we henceforth will refer to our insect-specific items as the ‘‘Pathogen-Insect Disgust Scale’’, and the pathogen questions from Tybur et al. (2009) as the ‘‘Pathogen-General Disgust Scale’’. Discussion of the ‘‘Pathogen Disgust Scale’’ refers to insect and general pathogen items collectively. We conducted reliability analyses on our two main Disgust Scales, which yielded a high Cronbach’s alpha for both the Pathogen Disgust Scale (0.873) and the Moral Disgust Scale (0.828). In addition, we also conducted reliability analysis on the Pathogen-Insect Disgust Scale, in order to determine if this subset of items alone could be utilized effectively in future studies. Cronbach’s alpha for insect-related items was high (0.838), and for general pathogen items was acceptable (0.725), indicating that both components of the ‘‘Pathogen Disgust Scale’’ were reliable metrics even when separated. Rotated factor loading values from our analysis with two factors extracted were utilized in the subsequent confirmatory analysis (Table 2.1).

Table 2.1. Factor loadings for each survey item using maximum likelihood factor analysis with promax rotation. Loadings below 0.32 are suppressed.

Item	Insect/Pathogen	Moral
Standing close to a person who has body odor.	0.463	
Seeing some mold on old leftovers in your refrigerator.	0.508	
Stepping on dog poop.	0.551	
Sitting next to someone who has red sores on their arm.	0.493	
Accidentally touching a person's bloody cut.	0.485	
Shaking hands with a stranger who has sweaty palms.	0.486	
Finding a scorpion in your shoe.	0.54	
Seeing an ant crawl across the floor.	0.521	
Finding a bug in your shirt.	0.715	
Watching a spider make its web.	0.606	-
Eating a chocolate-covered cricket.	0.525	
Feeling a mosquito bite you.	0.53	
Accidentally touching a spiderweb.	0.721	
Watching a centipede crawl across your leg.	0.598	
Seeing a cockroach run across a countertop.	0.658	
Stealing from a neighbor.		0.584
A student cheating to get good grades.		0.734
Deceiving a friend.		0.548
Intentionally lying during a business transaction.		0.718
Forging someone's signature on a legal document.		0.668
Shoplifting a candy bar from a convenience store.		0.677
Cutting to the front of a line to purchase the last few tickets to a show.		0.559

Confirmatory factor analysis

Based on the results of our exploratory factor analysis, we conducted a confirmatory factor analysis (CFA). This technique allows significance testing of the structure of a hypothetical model. In addition to χ^2, other measures of goodness-of-fit were used that account for sample size and parsimony. These include RMSEA (Root Mean Square Error of Approximation; values of <0.06 indicate good fit), CFI (Comparative Fit Index; values of >0.95 indicate good fit) and SRMR (Standardized Root Mean Squared Residual; values of <0.08 indicate good fit) (Hu & Bentler, 1999). Rotated factor loadings as well as the scree plot from our exploratory analysis suggested that two factors should be extracted for our model, thus we used two latent variables: Moral Disgust and Pathogen Disgust (including both insect and general pathogen items; Fig. 2.1). Goodness-of-fit tests indicated good fit, χ^2 (208, N = 704) = 654.614, $p < 0.001$, CFI = 0.902, RMSEA = 0.055, SRMR = 0.0476. Thus, confirmatory factor analysis of the model suggested by our exploratory factor analysis yielded good fit, indicating that the model is a match to our data.

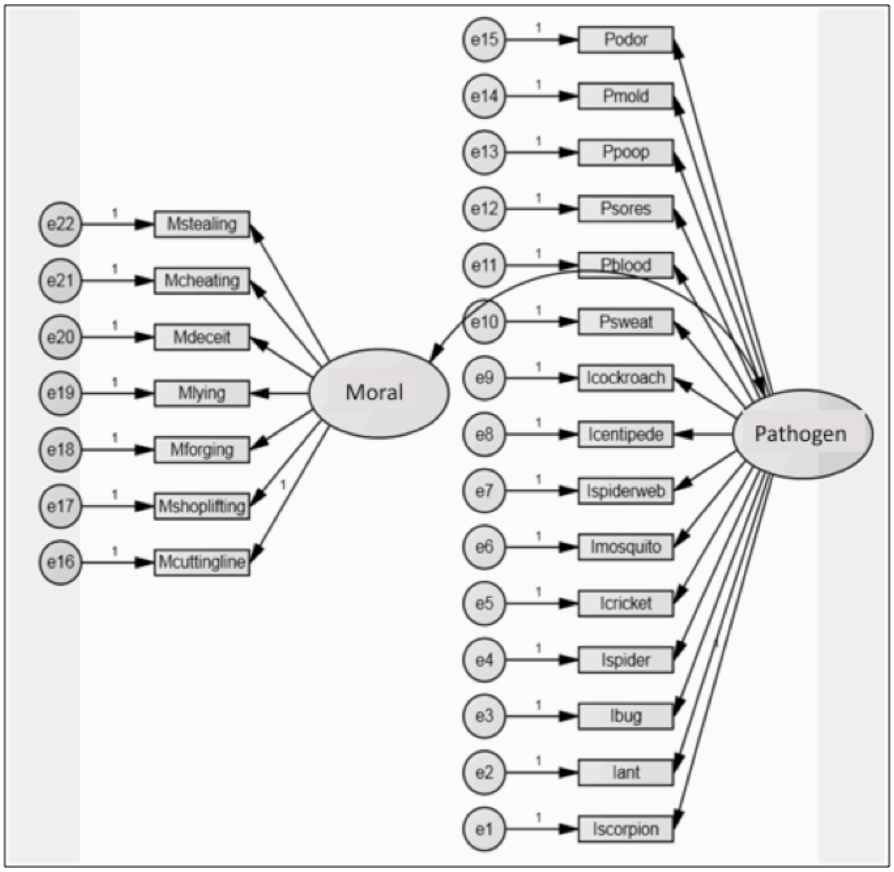

Figure 2.1. Confirmatory factor analysis with two latent variables.

Comparison of the means

We assessed normality of the two primary Disgust scales: Moral Disgust and Pathogen Disgust, as well as the two subsets of Pathogen Disgust: Pathogen-Insect Disgust and Pathogen-General Disgust. All four scales showed normal Q–Q plots and frequency distributions, and also exhibited homogeneity of variance (Levene's test, $p > 0.05$ for all four scales), although the Shapiro–Wilk test results from all four scales exhibited significant deviation from normality ($p < 0.001$). After considering both the visual examinations and normality test results, and taking the large sample sizes into account, we decided to proceed with parametric tests in our analyses (Ghasemi & Zahediasl, 2012).

In order to compare the effects of gender and area of study on scores from all four Disgust scales (differentiating between Pathogen-General and Pathogen-Insect), we conducted a multivariate analysis of variance (MANOVA; Table 2.2). Disgust scores for women (M = 2.909, SD = 0.451) were found to be significantly higher than Disgust scores for men (M = 2.652, SD = 0.450) across all scales ($p < 0.05$). In contrast, both science majors (M = 2.742, SD = 0.456) and non-science majors (M = 2.857, SD = 0.485) exhibited similar Disgust scores across all scales ($p > 0.1$). There was no interaction between gender and area of study on Disgust scores ($p > 0.5$).

Table 2.2. Mutivariate analysis of variance (MANOVA) to determine the effects of gender and major on our two main Disgust Scales (Pathogen and Moral), as well as the two subscales of Pathogen Disgust (Pathogen-General and Pathogen-Insect).

Independent Variable	Dependent Variable	df	F	Sig.
Gender				
	Pathogen Disgust	2	16.208	< 0.001
	Moral Disgust	2	17.29	< 0.001
	Pathogen-General Disgust	2	3.438	0.033
	Pathogen-Insect Disgust	2	22.845	< 0.001
Major				
	Pathogen Disgust	1	1.162	0.281
	Moral Disgust	1	0.01	0.92
	Pathogen-General Disgust	1	0.169	0.681
	Pathogen-Insect Disgust	1	1.663	0.198
Gender*Major				
	Pathogen Disgust	2	0.311	0.733
	Moral Disgust	2	0.096	0.909
	Pathogen-General Disgust	2	0.118	0.889
	Pathogen-Insect Disgust	2	0.437	0.646

DISCUSSION

The ecological and economical importance of invertebrates cannot be overstated. Insects and other terrestrial arthropods are valuable commodities because they provide many ecosystem services that benefit both human and environmental interests (Kellert, 1993). These ecosystem services include pollination, organic matter decomposition, and pest control. In the United States alone, insect-mediated ecosystem services have been valued at $57 billion annually (Losey and Vaughan, 2006).

Despite their importance, insects provoke largely negative emotions in people (Kellert, 1993; Bjerke and Østdahl, 2004; Schlegel and Rupf, 2009). For example, insects ranked number two in a list of topics which urban students reported as frightening, second only to snakes (Bixler et al., 1994). In addition, Shepardson (2002) noted that many children's perceptions of insects are largely negative and emphasize harmful aspects of human–insect interactions such as bites and stings. People's perceptions of organisms are influential in determining their willingness to conserve those organisms (Knight, 2008; Martín-López et al., 2009; Prokop & Fančovičová, 2012; Prokop and Fančovičová, 2013a,b). Thus, it is important to gain a better understanding of the fundamental ways in which insects and other arthropods are perceived by the general public.

We postulated that disgust experienced in response to insects and other arthropods is a construct unique from other previously described domains of disgust, albeit with expectations of correlation with pathogen-related disgust. To test this hypothesis, we conducted a survey of over 700 incoming freshmen at a large Midwestern university with questions pertaining to three different topics known to raise disgust responses: morality, pathogens, and insects. We tested our data for underlying patterns using exploratory and confirmatory factor analysis. Contrary to our hypothesis, our results suggested that disgust in response to pathogens and disgust in response to insects are part of the same construct. Our data shows that the insects included in our survey were perceived in the same way as pathogens. Prokop and Jančovičová. (2013) documented similar results when they measured disgust in young adolescents in response to pictures of insects. In their study, Prokop and Jančovičová (2013) utilized the same Pathogen and Moral Disgust Scales from Tybur et al. (2009) and documented a significant positive correlation between the subjects' ratings of Pathogen Disgust and the ratings of disgusting insect pictures, and no significant correlation between the insect pictures and Moral Disgust scores. These results are interesting because although many insects do pose health risks, the majority of insect species are fairly innocuous and many are beneficial to human interests. Many of the insects included in our survey were not associated with disease risk, including crickets and ants. Why then, did the respondents still feel disgusted by insects that pose no threats or risk of disease? Early in our analysis, we noted a differential response to a butterfly survey item that led to that item being dropped from the analyses. Thus, it is probable that any other marked differences in responses to a particular insect item would have been similarly distinct. Davey et al. (1998) also documented a disgust response to harmless insects among students from varying countries. In contrast, a study comparing affective responses of students after viewing disease-relevant and disease-irrelevant pictures of arthropods revealed differential disgust responses, indicating that subjects responded to disease-irrelevant insects with a lesser degree of disgust than to their disease-causing counterparts (Prokop & Fančovičová, 2010). Additionally, a study by Gerdes et al. (2009) demonstrated that people direct greater disgust responses toward disease-relevant or dangerous insects than toward harmless insects. The current study supports the finding that insects and pathogens are viewed similarly, regardless of the disease-relevance of specific insects.

The insects-as-pathogens model fits with the established theory of disease avoidance as a driver of disgust (Matchett & Davey, 1991; Oaten et al., 2009). The perception of insects as pathogens is one possible explanation for the widely held negative attitudes toward insects by the general public. Additionally, demographic variables are known to correlate with feelings about insects. Previous studies of disgust have shown a gender bias in terms of disgust and fear toward specific animals, with females showing higher sensitivity than males (Davey, 1994; Tucker & Bond, 1997; Gerdes et al., 2009; Oaten et al., 2009; Prokop & Fančovičová, 2010; Prokop et al., 2010; Prokop & Jančovičová, 2013; etc.). The results of this study are consistent with this pattern. In terms of college major, we expected to see lower Pathogen-Insect Disgust from students majoring in a science (STEM—Science, Technology, Engineering or Math) field, since those students are likely to have a stronger background in the biological sciences and previous studies suggest that habituation to distasteful objects such as insects decreases the disgust response toward those objects (Bixler & Floyd, 1999; Randler et al., 2012). However, we observed no difference in terms of Pathogen-Insect Disgust between STEM and non-STEM students. This may be due to the fact that the students we surveyed were incoming freshmen and had not yet experienced college-level courses in STEM disciplines.

Insects in general share certain commonalities with pathogens. Like pathogens, we often do not notice insects due to their small size, and some do indeed cause harm to humans. However, being disgusted by the vast majority of insects promotes unnecessary anxiety and the avoidance of many invertebrates that are potentially beneficial. Additionally, an exaggerated sense of disgust toward insects in general poses problems for society at large. For example, the practice of entomophagy (eating insects) has been proposed as a global solution to world hunger, and one of the major barriers to its progress is the disgust response toward insects, particularly in western cultures (see Defoliart, 1999).

Our study has shown that insects appear to be perceived in the same way as pathogens by incoming freshmen at a large Midwestern university. Whether this perception of insects is generalizable toward the general public remains to be examined. Future research should investigate which characteristics of insects specifically influence disgust, as well as investigate how targeting these characteristics in educational programming can impact public support for invertebrate conservation efforts. For example, Wagler and Wagler (2012) demonstrated that elements of external insect morphology affected preservice teachers' willingness to teach about insects. Current estimations suggest that only 0.5% of total invertebrate diversity has been assessed by the International Union for the Conservation of Nature (IUCN) for its Red List, which is responsible for determining the endangerment status of individual taxa (Leather, 2013).

The sheer overwhelming diversity of insects, especially in comparison with vertebrate groups, has prevented accurate large-scale estimates of relative numbers of endangered insect species (Wilcove & Master, 2005). The potential loss of these insect species may have untold effects on both the health of ecosystems and economic stability.

In terms of conservation efforts, it is extremely important to understand the emotions and attitudes that people direct toward specific groups of animals, to recognize where those emotions derive from, and to generate interventions to challenge those negative perceptions. The Pathogen-Insect Disgust survey described in this study can be utilized at a large scale to determine insect-related disgust sensitivity, and may prove useful in settings such as educational outreach. Hopefully, as people become better educated about harmless neutral insects, they will come to be recognized as different from pathogens. This would translate to a separation of insect items from pathogen items during a factor analysis, rather than the clustering observed here—such a divergence of scales would indicate that insect education has been effective. We welcome future studies that evaluate the extent to which students and the general public differentiate insects from pathogens.

REFERENCES

REFERENCES

Adenle, A.A. (2012) Failure to achieve 2010 biodiversity's target in developing countries: How can conservation help? *Biodiversity and Conservation, 21*(10): 2435–2442.

Berger, U., and Anaki, D. (2014) Demographic influences on disgust: Evidence from a heterogeneous sample. *Personality and Individual Differences, 64*: 67–71.

Bixler, R.D., Carlisle, C.L., Hammltt, W.E., and Floyd, M.F. (1994) Observed fears and discomforts among urban students on field trips to wildland areas. *Journal of Environmental Education, 26*: 24–33.

Bixler, R.D., and Floyd, M.F. (1999) Hands on or hands off? Disgust sensitivity and preference for environmental education activities. *Journal of Environmental Education, 30*: 4–11.

Bjerke, T., and Østdahl, T. (2004) Animal-related attitudes and activities in an urban population. *Anthrozoos, 17*: 109–129.

Black, S.H., Shepard, M., and Allen, M.M. (2001) Endangered invertebrates: the case for greater attention to invertebrate conservation. Endanger. Species UPDATE, 18: 42–50.

Buck, E.H., Corn, M.L., Alexander, K., Sheikh, P.A., and Melz, R., 2012. U.S. Congressional Research Service. The endangered species act (ESA) in the 112th congress: Conflicting values and difficult choices (R41608), in: Federation of American Scientists CRS Reports Online; Accessed: February 26, 2014.

Cardoso, P., Erwin, T. L., Borges, P. A. V., and New, T. R. (2011) The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation, 144*: 2647–2655.

Cattell, R. B. (1966) The scree test for the number of factors. *Multivariate Behavavior Research, 1*: 245–276.

Clark, J. A., and May, R. M. (2002) Taxonomic bias in conservation research. *Science, 297(5579)*: 191–192.

Collen, B., Böhm, M., Kemp, R., and Baillie, J. E. M. (2012) Spineless: Status and Trends of the World's Invertebrates. Zoological Society of London, United Kingdom.

Darwin, C. (1965) The Expression of the Emotions in Man and Animals. University of Chicago Press, Chicago, Originally published in 1872.

Davey, G. C. L., (1994) Self-reported fears to common indigenous animals in an adult UK population: the role of disgust sensitivity. *British Journal of Psychology, 85*: 541–554.

Davey, G. C. L., McDonald, A. S., Hirisave, U., Prabhu, G. G., Iwawaki, S., Jim, C. I., Merckelbach, H., de Jong, P. G., Leung, P. W. L., and Reimann, B. C. (1998) A crosscultural study of animal fears. *Behaviour Research and Therapy, 36*: 735–750.

Defoliart, G. R., (1999) Insects as food: Why the western attitude is important. *Annual Review of Entomology, 44*: 21–50.

Gerdes, A., Uhl, G., and Alpers, G. W. (2009) Spiders are special: fear and disgust evoked by pictures of arthropods. *Evolution and Human Behavior, 30*: 66–73.

Ghasemi, A., and Zahediasl, S. (2012) Normality tests for statistical analysis: a guide for non-statisticians. *International Journal of Endocrinology and Metabolism, 10*: 486–489.

Haidt, J., McCauley, C., and Rozin, P. (1994) Individual differences in sensitivity to disgust: A scale sampling seven domains of disgust elicitors. *Personality and Individual Differences, 16*: 701–713.

Hu, L., and Bentler, P. M. (1999) Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*: 1–55.

Inbar, Y., Pizarro, D., Iyer, R., and Haidt, J. (2011) Disgust sensitivity, political conservatism, and voting. *Social Psychological and Personality Science, 3*: 537–544.

Kellert, S. R. (1993) Values and perceptions of invertebrates. *Biological Conservation, 7*: 845–855.

Knight, A. J. (2008) 'Bats, snakes and spiders, Oh my!' How aesthetic and negativistic attitudes, and other concepts predict support for species protection. *Journal of Environmental Psychology, 28*: 94–103.

Leather, S. R. (2013) Institutional vertebratism hampers insect conservation generally; not just saproxylic beetle conservation. *Animal Conservation, 16*: 379–380.

Losey, J. E., and Vaughan, M. (2006) The economic value of ecological services provided by insects. *Bioscience, 56*: 311–323.

Maresova, J., and Frynta, D. (2007) Noah's ark is full of common species attractive to humans: The case of boid snakes in zoos. *Ecological Economics, 64*: 554–558.

Martín-López, B., Montes, C., Benayas, J. (2009) The non-economic motives behind the willingness to pay for biodiversity conservation. *Biological Conservation, 139*: 67–82.

Matchett, G., Davey, G. C. L. (1991) A test of a disease-avoidance model of animal phobias. *Behavior Research and Therapy, 29*: 91–94.

Neill, J. (2008) Writing up a Factor Analysis. Retrieved from http://www.bwgriffin.com/gsu/courses/edur9131/content/Neill2008_WritingUpAFactorAnalysis.pdf.

Oaten, M., Stevenson, R. J., and Case, T. I. (2009) Disgust as a disease-avoidance mechanism. *Psychological Bulletin, 135*: 303–321.

Prokop, P., and Fančovičová, J. (2010) The association between disgust, danger and fear of macroparasites and human behaviour. *Acta Ethologica, 13*: 57–62.

Prokop, P., and Fančovičová, J. (2013a) Self-protection versus disease avoidance: The perceived physical condition is associated with fear of predators in humans. *Journal of Individual Differences, 34*: 15–23.

Prokop, P., and Fančovičová, J. (2013b). Does colour matter? The influence of animal warning coloration on human emotions and willingness to protect them. *Animal Conservation, 16*: 458–466.

Prokop, P., and Jančovičová, M. (2013) Disgust sensitivity and gender differences: An initial test of the parental investment hypothesis. In: Problems of Psychology in the 21st Century, vol. 7. pp. 40–48.

Prokop, P., Usak, M., and Fančovičová, J. (2010) Risk of parasite transmission influences perceived vulnerability to disease and perceived danger of disease-relevant animals. *Behavioural Processes, 85*: 52–57.

Randler, C., Hummel, E., and Prokop, P. (2012) Practical work at school reduces disgust and fear of unpopular animals. *Society and Animals, 20*: 61–74.

Rozin, P., and Fallon, A. E. (1987) A perspective on disgust. *Psychological Review, 94*: 23–41.

Schlegel, J., and Rupf, R. (2009) Attitudes toward potential animal flagship species in nature conservation: A survey among students of different educational institutions. *Journal for Nature Conservation, 18*: 278–290.

Shepardson, D. P. (2002) Bugs, butterflies, and spiders: children's understandings about insects. *International Journal of Science Education, 24*: 627–643.

Sherman, N. C., and Sherman, M. F. (1998) Sensitivity to disgust among college women by major. *Psychological Reports, 82*: 1192–1194.

Tucker, M., and Bond, N. W. (1997) The roles of gender, sex role, and disgust in fear of animals. *Personality and Individual Differences, 22*: 135–138.

Tybur, J. M., Lieberman, D., and Griskevicius, V. (2009) Microbes, mating, and morality: Individual differences in three functional domains of disgust. *Journal of Personality and Social Psychology, 97*: 103–122.

Tybur, J. M., Lieberman, D., Kurzban, R., and DiScioli, P. (2013) Disgust: Evolved function and structure. *Psychological Review, 120*: 65–84.

Wagler, R., and Wagler, A. (2012) External insect morphology: A negative factor in attitudes toward insects and likelihood of incorporation in future science education settings. *International Journal of Environmental and Science Education, 7*: 313–325.

Wilcove, D. S., and Master, L. L. (2005) How many endangered species are there in the United States? *Frontiers in Ecology and the Environment, 3*: 414–420.

CHAPTER THREE

DRAWINGS OFFER INSIGHTS ABOUT MENTAL MODELS OF INSECTS

ABSTRACT

Insects are widely disliked despite the many ecosystem services they provide. Negative attitudes toward insects promote harmful environmental practices and hinder conservation efforts. To challenge this negativity, it is necessary to understand existing attitudes and the knowledge that underlays them. One way to do this is to study the content of mental models. Mental models are internal representations of external phenomena that are used to reason, make inferences, conduct thought experiments, and anticipate future events. Drawings reflect qualities of mental models such as content and organization. We collected drawings of insects from individuals across different levels of entomological and general scientific expertise, ranging from non-science undergraduate students to professional entomologists. Insect features included in the drawings were indexed and a principal components analysis was applied to find underlying variation in patterns of features. This analysis resulted in the emergence of two components that each resembled a distinct insect – a legged but wingless "crawling" insect, and a winged but legless "flying" insect. These two models of insect were depicted at all levels of entomological expertise, suggesting that the way that insects move about impacts how they are conceptualized in mental models. From a teaching and learning perspective, this suggests that comparing flying versus crawling may be a more approachable way to characterize insects to the public, rather than traditional taxonomic classifications. The major difference between novice and expert (entomologists) drawings was that experts' drawings contained more features and were more accurate on average. The most commonly depicted features across all participants were distinct head, antennae, long-shaped body, legs, and wings. This study provides insights about the content and organization of people's mental models of insects and shows how mental models become more complex as knowledge develops.

INTRODUCTION

Insects are extremely important to the ecology of the natural world. They provide valuable ecosystem services such as the pollination of many flowering plants, the aeration of soil, and the burial of dung. One study estimated that wild insects provide ecosystem services worth approximately $57 billion per year in the United States alone (Losey & Vaughan, 2006). While some insects do cause distress and represent legitimate danger by biting and stinging (*e.g.* disease transmission by mosquitoes), the vast majority of the beetles, ants, flies, dragonflies, caterpillars, and other insects that people typically encounter are beneficial. Despite their many benefits, studies have indicated that negative attitudes toward insects and other arthropods are extremely widespread (Byrne et al., 1984; Kellert, 1993; Bixler & Carlisle, 1994; Driscoll, 1995; Schlegel & Rupf, 2010). People frequently respond to interactions with insects with negative emotions such as disgust, fear, alarm, and dislike (Bjerke et al., 1998; Smithsonian Institute, 2007; Gerdes et al., 2009). Extreme examples of this include phobias and delusory parasitosis (Hinkle, 2000). We argue that it is important for educators to recognize and challenge negative perceptions of insects, as they result in a variety of negative consequences.

Negative attitudes toward insects may hamper conservation efforts for invertebrates. People are less willing to contribute money toward conservation of species that they dislike (Martín-López et al., 2007), and in general, people tend to have a higher affinity for mammals and other vertebrates than for insects (Bjerke et al., 1998; Schlegel & Rupf, 2010). A potential consequence of this is that little of the available conservation funding goes toward preserving insects (Leather, 2009; Leather, 2013). Butterflies are the notable exception to this trend (Shlegel & Rupf, 2010), however, butterflies are perceived differently than other insects, and many people do not identify butterflies as even being insects (Kellert, 1993). Additionally, negative interactions with insects can detract from people's overall experience of nature (Bixler et al., 1994). Thus, it follows that they may be less likely to spend their time and money on outdoor recreation (Bixler & Floyd, 1997). Another example of a negative consequence that occurs as a result of negative bias toward insects is the misuse of pesticides (Shipley & Bixler, 2016). Baldwin et al. (1998) surveyed Florida residents, and reported that a majority of respondents stated that merely seeing a live insect in their home was sufficient reason to apply pesticide. This means that there does not even have to be an infestation occurring for people to apply pesticides to their homes. A similar survey, conducted by Potter and Bessin (1998) in Lexington, KY, also found that the sight of just a couple of insects inside the home would prompt most participants to spray, regardless of whether the insect was harmful or not. This is important because the misuse of pesticides has negative consequences both for the environment and for public health (Shipley & Bixler, 2016). Most relevant to our study, negative conceptions toward insects likely form an impediment to teaching and learning about them. This has been acknowledged in previous works on entomological education (Matthews et al., 1997; Smithsonian Institute, 2007; Wagler & Wagler, 2011).

Learning is a constructive process whereby knowledge is sorted and categorized, connections are made between new and previously existing knowledge, and knowledge is organized into representational structures termed mental models (Bransford, 2000). Mental models are dynamic internal representations of external phenomena (Jones et al., 2011). Individuals use their mental models to reason, make inferences, conduct thought experiments, and anticipate future events. Mental models do not represent exact replicas of external objects or processes; rather, they are simplified and may not be entirely accurate (Jones et al., 2011). They are modified by an individual's experiences, knowledge, and attitudes. Mental models are dynamic in that they change over time as new information is learned (Jones et al., 2011). They also affect how and whether new information is incorporated. Though a collection of facts may be presented to a learner, there is no guarantee that the information will be incorporated into the learner's mental model. This is particularly so when new information contradicts the previously existing mental model (Jones et al., 2011). When people are confident in their mental model, in that they have a strong conviction that their model is correct, they tend to become more resistant to alternative viewpoints that contradict their beliefs (Lord et al., 1979; Jones et al., 2011). This implies that people who have established negative attitudes toward insects are less likely to learn new things about them that might change their views. Additionally, previous research shows that when students feel negatively toward a topic, their interest in that topic, as well as motivation to learn about it, is lowered (Holstermann et al., 2009). Positive interest and motivation are extremely important for effective learning (Schiefele, 1991). Thus, widespread negative conceptions of insects present a problem for successful entomological education.

The goal of this study was to investigate the content and organization of people's mental models of insects. The examination of mental models is challenging, since they cannot be directly measured or observed – they exist only in the mind of an individual. Previous studies have utilized techniques such as written surveys, interviews, diagramming, and estimating relatedness between model components in order to evaluate mental models (Rowe & Cooke, 1995; Diaz, 2009). Another methodology that has been used to assess mental models is by asking subjects to draw them (Dove *et al*., 1999; Shepardson, 2002; Diaz, 2009; Bartoszeck *et al*., 2011; Bartoszeck & Bartoszeck, 2012; Libarkin *et al*., 2015). Drawings are visual representations of conceptual knowledge, and as such, they can help to inform teaching practices by illuminating student understanding (Dove et al., 1999; Van Meter & Garner, 2005; Ainsworth *et al*., 2011). In addition, capturing data in the form of drawings is valuable because they are quick and efficient to collect, and have the additional advantage of being robust to barriers of language or literacy.

Drawings reflect characteristics of mental models including knowledge categorization and organization. The action of making a drawing requires the participant to interact with their mental model of an object or process (Van Meter & Garner, 2005). Even the action of making a drawing can inform the configuration of a mental model (Van Meter & Garner, 2005; Quillin & Thomas, 2014). In accordance with the generative theory of drawing construction (Van Meter & Garner, 2005), Quillin and Thomas (2014) provide a diagram of the relationship between internal mental processes and the creation of a drawing (Fig. 3.1). Though drawings have been used as a means of unpacking student understanding and examining mental models, most studies that analyze drawings rely on qualitative methods such as thematic content analysis (Dove *et al.*, 1999). While qualitative methods are extremely valuable for deriving important insights, quantitative methods are also needed because they offer a more objective approach and are often quicker to implement. Studies that have utilized quantitative methods to analyze drawings provide real insights into student thinking (*e.g.* Bowker, 2007; Diaz, 2009; Libarkin *et al.*, 2015). Previous studies have used drawings to probe mental models of insects in children (Shepardson, 2002; Bartoszeck *et al.*, 2011), college students (Diaz, 2009), and adults (Bartoszeck & Bartoszeck, 2012). For example, Bartoszeck *et al.* (2011) scored children's drawings of insects as belonging to hierarchical levels depending on the features included and their accuracy. In this way, Bartoszeck *et al.* (2011) were able to discern that children build up their mental models of insects starting with the most prominent features (body, wings, etc.). Shepardson (2002) … Diaz (2009) collected insect drawings from college students in an effort to understand their mental models of insects. She scored drawings based on the presence and configuration of salient insect features, with accurate and complete insects receiving the highest scores. This approach was combined with interviews and proved insightful for characterizing aspects of college students' mental models of insects. For example, results showed that students are often unaware that insects such as butterflies possess eyes and legs. We sought to apply a more rigorous quantitative approach, applying the method used by Libarkin et al., (2015), that includes a factor analysis to evaluate student drawings of the greenhouse effect. Similar to Diaz (2009), the authors first deconstructed each drawing into its salient features, and scored them based on presence (1) or absence (0). They then applied exploratory factor analysis, which resulted in the detection of four distinct models that students hold about the greenhouse effect. In our study, we applied this technique to drawings of insects to detect underlying mental models.

Though previous studies have given us insights about mental models of insects in people who do not have much entomology training, what seems to be missing from the literature is an examination of mental models in people who have developed expertise in science and entomology. Comparisons of experts and novices within a discipline are useful for exploring mental models, since experts represent the culmination of the learning process. Thus, experts can be seen as representing maximum knowledge and novices representing minimum. By comparing expert and novice mental models, it is possible to gain insights into the learning process. Experts not only have greater knowledge of their discipline than novices, but they also organize their knowledge differently (Bransford, 2000). For example, experts engage in more efficient "chunking" of information that allows them to hold more information in their working memory (Bransford, 2000). Thus, we would expect insect experts to have mental models of insects that differ from the mental models of novices. Additionally, experts tend to be more abstract in their thinking than novices, and are more effective at solving problems within their discipline. Expert-novice comparisons are frequently collected in studies of conceptual change, since experts, who began as novices at some point, clearly think differently and approach problems in their area of expertise differently than novices (Chi et al., 1981).

This study will shed light on people's ideas of what constitutes or defines an insect. In this study, we attempted to answer the following two research questions:

1) Can factor analysis applied to salient features included in drawings of insects discern underlying model(s) of insects that contain qualities of mental models?

2) How do drawings of insects differ between experts and novices, and do they suggest major differences in their mental models?

We predict that drawings of insects do represent characteristics of underlying mental model(s) of insects, and that drawings created by experts will differ from those created by novices.

METHODS

Participants & data collection

We followed all human subjects protocols as approved by the institutional review board of our university. In order to capture a spectrum of entomological and general science expertise, we collected drawings of insects from three broad populations: 1) Attendees at the conference of a professional entomological society, hereafter referred to as ENTs, 2) Attendees at the conference of a professional geological society, hereafter referred to as GEOs, and 3) Non-Science undergraduate students enrolled in an environmental science course at a large Midwestern university, hereafter NSUs. ENTs and GEOs were assumed to have an equivalent level of general science expertise (Table 3.1). ENTs were assumed to have a higher degree of entomological expertise than either GEOs or NSUs (Table 3.1). NSUs were assumed to have lower degrees of both science and entomological expertise (Table 3.1).

Table 3.1. Relative differences in science and entomological expertise across our three sampled populations.

Population	Science Expertise	Entomological Expertise
ENT	High	High
GEO	High	Low
NSU	Low	Low

The ENT and GEO groups were sampled during the same year, about one month apart. The NSUs who comprised our novice group were sampled the following year. At the time of the NSU data collection, no examination of the ENT or GEO drawings had yet occurred. Participation in this research was voluntary and did not impact the students' grades in any way.

The drawing task consisted of two pages, each with an empty rectangle covering most of an 8.5"x11" page. In order to facilitate a related study (see Chapter 4), participants were originally instructed to make two drawings: One of an insect that they considered *disgusting* on the first page, and one of an insect that they did *not* consider to be disgusting on the second page. Below the rectangle, on the same page, participants were prompted to identify the type of insect they had drawn. Additionally, participants were verbally instructed that they could draw any insect of their choice, and those who inquired as to whether they could draw spiders or other non-insect arthropods were instructed that it was acceptable to do so. This was because these animals are commonly confused with insects, and we assume that other participants who were inclined to draw a non-insect may not have asked. For this current Chapter Three, only the "not disgusting" insect drawings were evaluated, since these drawings included a larger variety of insects than the “disgusting” insect drawings. The disgusting insect drawings will be discussed in an upcoming chapter (see Chapter 4).

For the ENT and GEO groups, the drawing task was administered at one location within the main exhibit hall at each conference. Thus, all ENT and GEO participants were convenience sampled as they passed by the researchers’ stations. Scholars at both conferences were offered a snack as an incentive for participation. Time was not limited for these participant groups, but the drawing task generally took about 2-5 minutes. For the NSUs, the drawing task was administered on the first day of class before any instruction had taken place. Students were given five minutes to complete the drawing task. Since NSU participation occurred during regular class time, students were not offered an incentive, but completed the survey voluntarily.

Coding & frequency of insect features

We followed the method of Libarkin et al. (2015) to code each drawing. This coding scheme was established iteratively by three of the co-authors, and involved breaking the drawing down into its salient features (Fig. 3.1). These salient features were morphological insect features such as legs, antennae, wings, etc. All three raters began by examining a subset of ten randomly selected drawings together and listing prominent features from each drawing. Each feature was given a definition that was mutually agreed upon by all three authors. It should be noted that all insects share a suite of six basic morphological features: legs, antennae, eyes, mouth, head, and body segmentation. Most, though not all, insect species also have wings during the adult stage, but there are some common exceptions, such as earwigs and worker ants. Because of this, we did not include wings as one of the essential features, though we did code for them. Also, though all insects possess a head, a thorax, and an abdomen, with many insects it is difficult to distinguish the division between the thorax and abdomen. For this reason, we coded for the presence of a head, which is usually very easy to distinguish in most insects, separately from thorax and abdomen. The thorax and abdomen we lumped together as one variable that we called "body shape," which had two levels: Oval and elongate.

Another aspect of the insect body that we coded for was segmentation. As mentioned above, it can be difficult to interpret the relative positions of two of the major body segments, the thorax and abdomen. Therefore, we coded a body as being segmented if there was any sort of clear division between thorax and abdomen (Fig. 3.1). In addition, since on insects the individual body parts themselves are divided into segments, we also coded a body as segmented if there were clear divisions between these intra-segment segments.

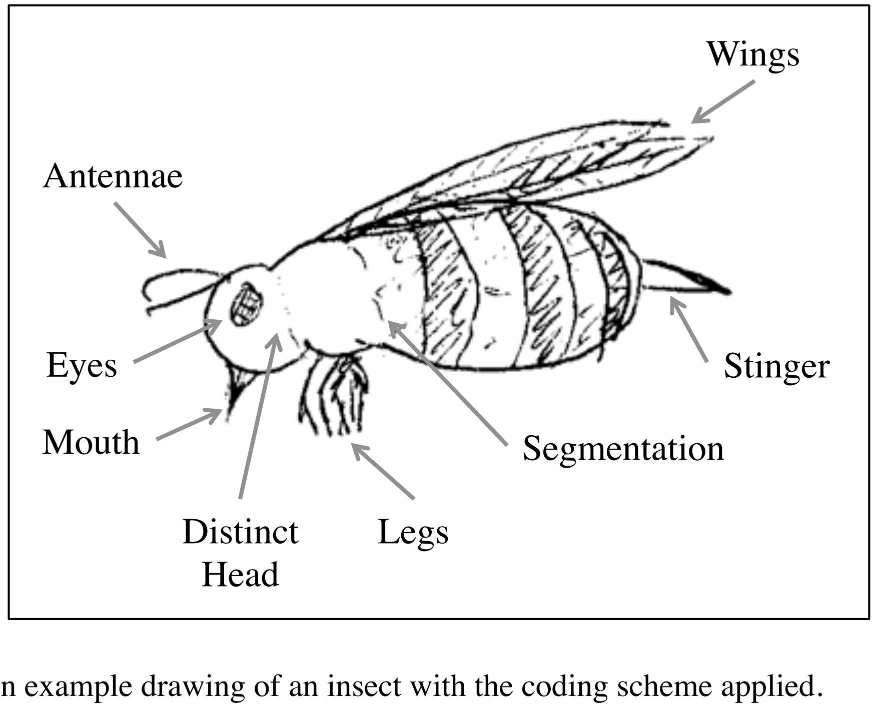

Figure 3.1. An example drawing of an insect with the coding scheme applied.

Through an iterative process, we settled on 11 major morphological features of insects to include in our coding (Table 3.3). These 11 features naturally contain the six basic features that are characteristic of all insects. Once the coding scheme was finalized, each author independently coded 20 drawings, after which an intraclass correlation was conducted. The average measures intraclass correlation across the three raters was 0.92 (min. = 0.91 and max. = 0.93). An intraclass correlation close to 1.0 suggests that each coder's analysis of the drawings is consistent with the others'. Given this high level of agreement, the remaining drawings were coded by one rater. See Figure 3.1 for an example of coding; see Figure 3.2 for a representation of a complete insect as well as example drawings from each participant group. All statistical analyses were performed using SPSS (Version 23.0, SPSS Inc., Chicago, IL).

We calculated the frequency at which each coded feature was drawn within each participant group separately. Since our sample sizes for each participant group were unequal, frequency was calculated as a percentage of the total population for each group.

Total number of features

We compared the mean total number of features included in the drawings (out of a possible 11) for each subject group. Since ENTs are expected to have greater knowledge of insect morphology, we anticipated that on average, their drawings would contain more details (features) than those of novices. For this variable, the highest possible score is eleven, and the lowest possible score is one, since the body-shape variable can be considered here to count as a constant – everyone drew a body on their insect. After satisfying the assumption of normality, we compared the three participant groups using a one-way ANOVA, followed by post-hoc Tukey's HSD.

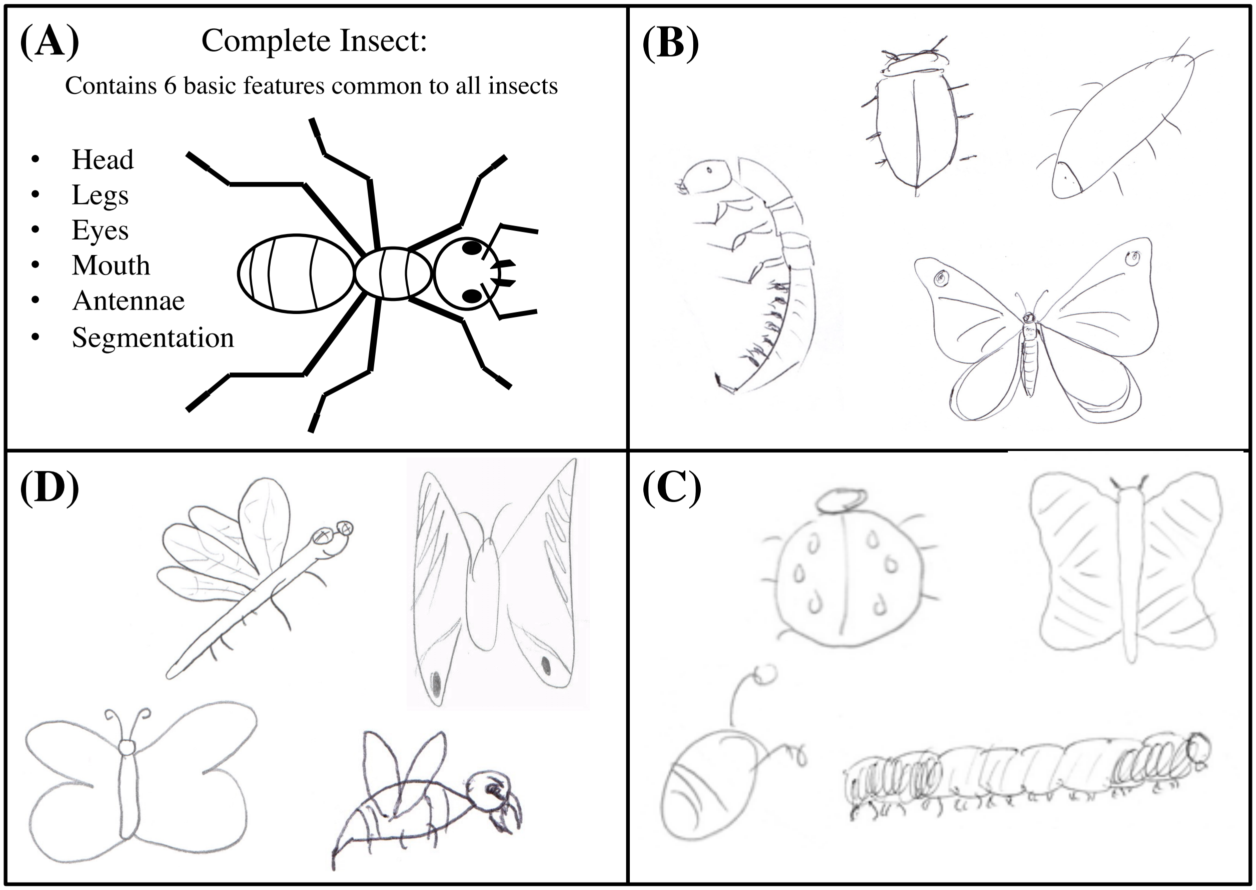

Figure 3.2. Schematic representation of a complete insect (A), along with example drawings from ENTs (B), GEOs (C), and NSUs (D).

Completeness of drawn insects

As part of our analysis, we wanted to explore how often the drawings included an accurate scientific model of an insect. We consider that a drawing of a "complete" insect should include the six major features described above: Legs, eyes, mouth, antennae, head, and segmentation (Fig. 3.2). If we assign one point for including each of these features, we can calculate a "completeness" score for each participant, with the highest possible score being six and the lowest score zero. These data failed the assumption of normality; consequently, we utilized a non-parametric test, the Kruskal-Wallis H test, to determine whether Insect Completeness Score varied across our participant groups.

Correlations between insect features

In order to evaluate whether the data were suitable for PCA, we ran correlational analyses on drawing data from all three expertise levels combined. We conducted Spearman's rank-order correlations between the different insect features, which were coded as dichotomous (1 = feature present, 0 = absent). The intent of the correlational analysis was to determine whether potentially interesting relationships might exist between insect features in the drawings, indicating the possible existence of meaningful patterns that represent underlying mental models. Once relevant criteria had been met, we ran a principal components analysis on all of the drawings.

Principal components analysis

We utilized the technique of principal components analysis (PCA) to reduce dimensionality among the drawings. This analysis was conducted on drawings from all three of the participant groups, which increased the total sample size to a level acceptable for principal components analysis. We did not include a rotation, in order to allow variables to cluster on more than one factor if necessary (Libarkin et al., 2015).

Model scores & expertise

Based on the groupings suggested by our PCA, we computed scores indicating the degree of alignment of a drawing with the crawling and flying models. Model scores were calculated for each participant for each of the two models by giving one point for the presence of each of the model components. Thus, two scores were computed for each drawing, one for the crawling model and one for the flying model. For the crawling model scoring, a particular drawing could attain a maximum of six points, one for each of the six features which loaded on to the first factor in our PCA (Head, Legs, Eyes, Mouth, Segmented Body, No Wings). Thus, if a drawing included legs, eyes, mouth, and a segmented body, the drawing would receive a score of 4 for the crawling model. For the flying model, a drawing could attain a maximum of 5 points (Segmentation, Eyes, Mouth, Wings, Long Body).

Since participant group is a nominal variable, we utilized dummy coding in order to make the variable more suitable for MANOVA. We chose the ENT group as the baseline for comparison, and thus created two dummy variables: one that we called ENT vs. NSU, which represents the difference between ENT and NSU participants; and one that we called ENT vs. GEO, which represents the difference between the ENT and the GEO participants.

In order to determine whether model scores differed statistically across our three participant groups, we conducted a MANOVA with two dependent variables (Crawling Model Score; Flying Model Score) and one independent variables (participant group).

RESULTS

Participants & data collection

The entomologists we surveyed were mainly undergraduates, graduates, faculty, and professionals in entomology. A total of 97 ENTs participated in the survey, though eight cases were excluded due to missing/incomplete data. In an effort to restrict the sample only to those who had had training in entomology, and thus a high level of entomological expertise, we also excluded those participants who acknowledged having taken fewer than three entomology courses in their lifetime, amounting to 18 total individuals excluded. Thus, we report analyses of drawings from 79 ENTs (Table 3.2).

A total of 104 GEOs participated in the survey. In an effort to restrict the sample to only those individuals who had a science background but no formal instruction in entomology, we excluded six participants who answered “yes” when asked if they had previously taken courses in entomology. In addition, we also excluded two participants who were not either working toward or in possession of a science degree. Finally, four additional participants were excluded from the analysis because they did not complete a drawing. Thus, we report on data from 92 GEOs. These individuals were mainly undergraduates, graduate students, faculty, and professionals in geoscience disciplines (Table 3.2). We surveyed a total of 112 NSUs. Eleven surveys were excluded from the analysis due to missing/incomplete data. Consequently, we report on a total of 101 NSU drawings (Table 3.2).

Table 3.2. Descriptive statistics for each participant group. ENT participants were expert entomologists; GEO participants were expert geologists (non-entomologist scientists); NSU participants were non-science undergraduate students.

Expertise Level	**N**	**Age (M±SD)**	**Gender**	**Highest Degree Held**
ENT	79	38.9 ± 14.1	37.2% Female 62.8% Male	***In Entomology:*** 16% Bachelors’ in progress 26% holding Bachelors’ 18% holding Masters’ 40% holding PhD
GEO	92	34.02 ± 14.7	48.4% Female 51.6% Male	***In Geoscience:*** 29% Bachelors’ in progress 23% holding Bachelors’ 23% holding Masters’ 25% holding PhD
NSU	101	19.81 ± 2.75	53.5% Female 46.5% Male	*All participants working toward Bachelor’s degrees in non-science fields*

Coding scheme and frequency of insect features

The frequencies at which each of our 11 coded features occurred across each participant group are listed in Table 3.3. Eight out of the 11 coded insect features were drawn by greater than 50% of all participants combined – these features are, in order of cumulative percentage from greatest to least: Distinct head, antennae, legs, long-shaped body, wings, segmentation, eyes, and mouth. Oval-shaped body, coded as one variable together with long-shaped body, was also drawn by many participants and is included in Table 3.3.

Seven insect features were drawn by over 60% of ENTs, indicating that these features are most prominent in the mental models of experts: Distinct head, antennae, legs, long-shaped body, wings, eyes, and segmentation. The most commonly drawn feature within the ENT group, as well as when compared to the other two groups, was the distinct head. Within the GEOs, the most commonly drawn variable was legs. GEOs and ENTs both drew legs on their insects more commonly than NSUs. The most commonly drawn variable both within the NSUs and compared to the other two groups was antenna. We also noted that ENTs were twice as likely to include eyes, mouths, and segmentation on their insects than either of the other two groups.

Total number of features

Skewness and kurtosis values divided by their respective standard errors were both less than ±1.96, and the Q-Q plot was normal, leading us to conclude that the data are suitable for parametric analysis (Field, 2013). A one-way ANOVA comparing the total number of features drawn for each group was significant: $F(2,269) = 17.257, p < 0.001$. A post-hoc Tukey's HSD was applied to the data and showed that on average, ENTs differed significantly from both GEOs and NSUs ($p < 0.001$). NSU and GEO participants did not differ significantly from each other (p

= 0.42). The mean (± SD) total number of features drawn by ENTs was 5.29 (±1.78), compared with GEOs at 3.87 (± 1.65) and NSUs at 4.17 (± 1.54). Thus, experts drew one to two more features on average than either of the non-expert groups (Figure 3.3).

Table 3.3. Percentage of individuals from each participant group who drew each morphological insect feature. Features that are part of the basic correct insect are italicized. Features are listed in order of greatest-to-least cumulative frequency.

Coded Feature	NSU	GEO	ENT
1. Distinct head	64.4	66.3	87.3
2. Antennae	78.2	57.6	67.1
3. Body Shape: *Long*	72.3	59.8	65.8
Body Shape: *Oval*	27.7	40.2	34.2
4. Legs	53.5	68.8	68.4
5. Wings	61.4	45.7	64.6
6. Eyes	36.6	34.8	64.6
7. Segmentation	30.7	31.5	64.6
8. Mouth	11.9	16.3	34.2
9. Stinger	5.9	2.2	7.6
10. Hair	2.0	3.3	1.3
11. Pincers / Cerci	0	0	3.8

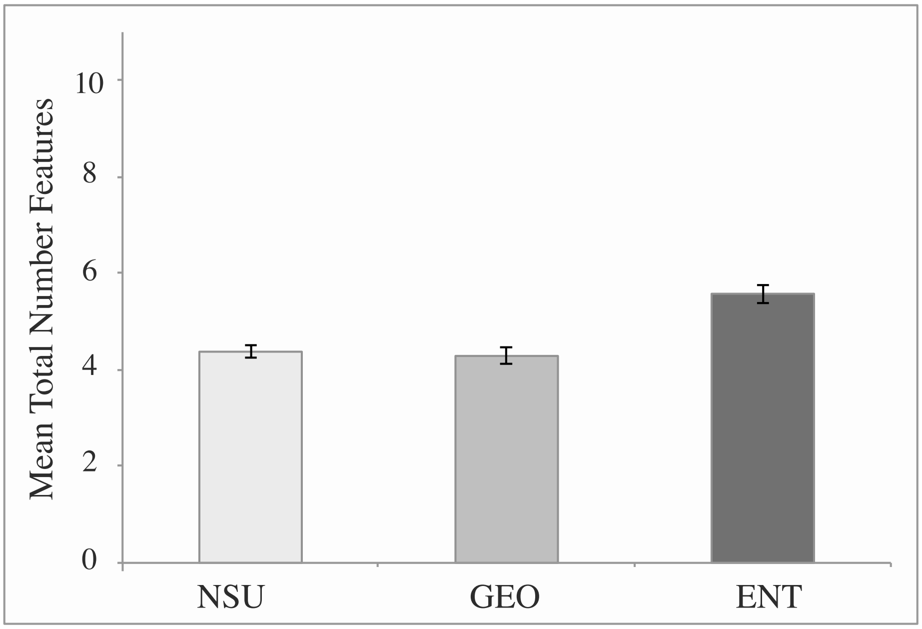

Figure 3.3. Entomologists (ENT) include more features on average than non-science undergraduates (NSU) or non-entomologist scientists (GEO) in drawings of non-disgusting insects.

Completeness of drawn insects

We consider that a drawing of a correct, "complete," insect should include the six major features found on all insects: Legs, eyes, mouth, antennae, head, and segmentation. We calculated an Insect Completeness Score for each participant; scores ranged from zero to six, with one point given for the inclusion of each of the correct features. The mean (± SD) Insect Completeness Score was highest in the ENT participants, at 3.86 (± 1.49), followed by the GEO group (2.79 ± 1.49) and the NSU group (2.75 ± 1.42), which were very similar to each other. The Insect Completeness Score data did not meet the assumption of normality across the three participant groups, thus, we proceeded with non-parametric testing for these data. A Kruskal-Wallis H test was significant, $X^2(2) = 26.81$, $p < 0.001$, indicating that Insect Completeness Score differed across the three groups. The mean rank Insect Completeness Score was highest for ENTs (174.47), followed by GEOs (121.16), followed by NSUs (120.77) (Fig. 3.4).

Though ENT participants drew a greater number of correct insect features than GEO or NSU participants, on average, ENTs created drawings that only contained 64% of a complete insect. Principal components analysis allows us a mechanism for exploring this variability.

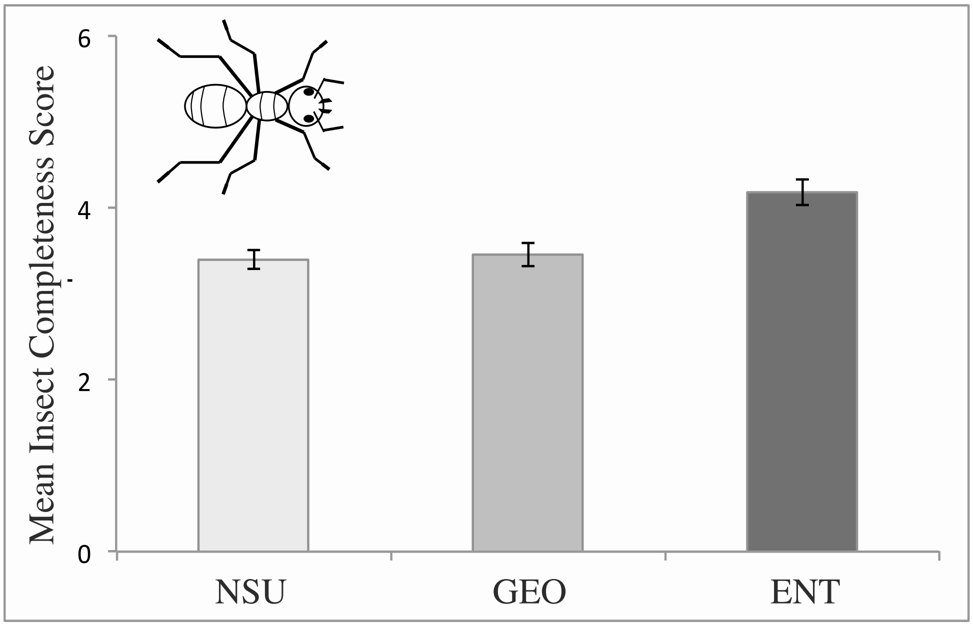

Figure 3.4. Entomologists (ENT) draw insects that are more complete than non-science undergraduates (NSU) or non-entomologist scientists (GEO). Complete Insect Score was calculated by examining all non-disgusting insect drawings and giving one point for each of six features essential to all insects: head, eyes, mouth, antennae, segmentation, and legs. Results from a Kruskal-Wallis H Test showed that Complete Insect Score differed across the three groups ($p < 0.001$). Data are shown as mean ± SEM of Complete Insect Score, representative of drawings by 79 ENT, 92 GEO, and 101 NSU participants.

Correlations between insect features

In order to further investigate relationships between insect features, we conducted point-biserial correlational analyses between the 11 coded features (Table 3.4). Results showed a strong negative relationship between legs and wings ($r = -0.43, p < 0.001$), indicating that an individual who drew legs was less likely to also include wings, or vice versa. Drawing a distinct head on an insect correlated with the inclusion of other features such as legs ($r = 0.5, p < 0.001$), a segmented body ($r = 0.39, p < 0.001$), and eyes ($r = 0.26, p < 0.001$). Additionally, eyes correlated strongly with mouth ($r = 0.45, p < 0.001$), as well as segmentation ($r = 0.33, p < 0.001$). In general, correlational analyses showed that many features were significantly correlated ($p < 0.05$) between features, with many having Pearson coefficients above 0.3 (Table 3.4). We then utilized a PCA in order to explore the variability in the data

Table 3.4. Point-biserial correlations between insect features for all three participant groups combined. One asterisk indicates that the relationship is significant at the level of p < 0.05; two asterisks indicate significance at p < 0.01.

	Head	Legs	Antennae	Wings	Body Shape	Segmentation	Eyes	Mouth	Cerci	Stinger	Hair
Head	1	0.50**	–0.06	–0.18**	–0.14*	0.39**	0.26**	0.13*	0.07	0.04	–0.02
Legs		1	–0.15*	–0.43**	–0.24**	0.28**	0.28**	.25**	0.08	0.11	0.06
Antennae			1	0.22**	0.14*	0.04	–0.15*	–0.11	–0.003	–0.02	–0.11
Wings				1	0.26**	–0.13*	0.04	0.02	–0.12*	0.07	–0.07
Body Shape					1	0.18**	0.07	–0.01	0.001	–0.08	0.002
Segment						1	0.32**	0.21**	0.06	0.13*	–0.02
Eyes							1	0.45**	0.12*	0.20**	0.02
Mouth								1	0.04	0.18**	0.05
Cerci									1	0.14*	–0.02
Stinger										1	0.19**
Hair											1

Principal components analysis

We chose to include the following eight coded insect features in the PCA: Body shape, Segmentation, Head, Eyes, Mouth, Legs, Antennae, and Wings. These variables were chosen because they were included in the drawings of at least 10% of at least one group (*i.e.*, ENT, GEO, NSU) of participants (Table 3.3). The resulting Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.64, which meets the recommended threshold of 0.6 (Costello & Osborne, 2005). Additionally, Bartlett's test of sphericity was significant ($X^2 = 376.53$, df = 28, $p < 0.001$). The diagonals in the anti-image correlation matrix were all above the recommended threshold of 0.5, and communalities after the initial extraction were also all above 0.5, which is above the recommended threshold of 0.3 (Costello & Osborne, 2005). Components were extracted at eigenvalues greater than one, and in addition, we examined the scree plot as an indication of how many components to extract (Catell, 1966). This analysis resulted in three components, accounting for 62.9% of the variation in the data set. However, the eigenvalue for the third component is quite low (1.1), and the scree plot is indicative of a two-factor solution. When we repeated the analysis with two as the set number of components to extract, the antennae variable failed to load on either component, indicating that it does not belong in the solution. For this reason, we decided to drop antennae from the analysis.

We repeated the PCA, using the following seven features: Segmentation, long-shaped body, head, eyes, mouth, wings, and legs. The KMO measure for this analysis was 0.641. Bartlett's test was again significant ($X^2 = 349.4$, df = 21, $p < 0.001$), all anti-image correlation coefficients were above 0.5, and all communalities were above 0.3, with most above 0.5. Two components were extracted with eigenvalues of 2.33 and 1.50. Together, these two components accounted for 54.7% of the variation in the data. The scree plot is shown in Figure 3.5. The component matrix is reported in Figure 3.5; variables with loadings less than ±0.32 are suppressed.

We can consider these two components as two distinct models of insect (Libarkin et al., 2015) (Fig. 3.5). The first model (component) contains segmentation, a distinct head, legs, no wings, eyes, and a mouth. We will refer to this as the crawling model. The second model (component) contains a long-shaped body, segmentation, wings, eyes, and a mouth. We will refer to this as the flying model. We tested the internal consistency of these two models by calculating Cronbach's alpha. For the crawling model (6 features) Cronbach's alpha was 0.66, which implies acceptable internal consistency. For the flying model (5 features) Cronbach's alpha was 0.44, which is less robust.

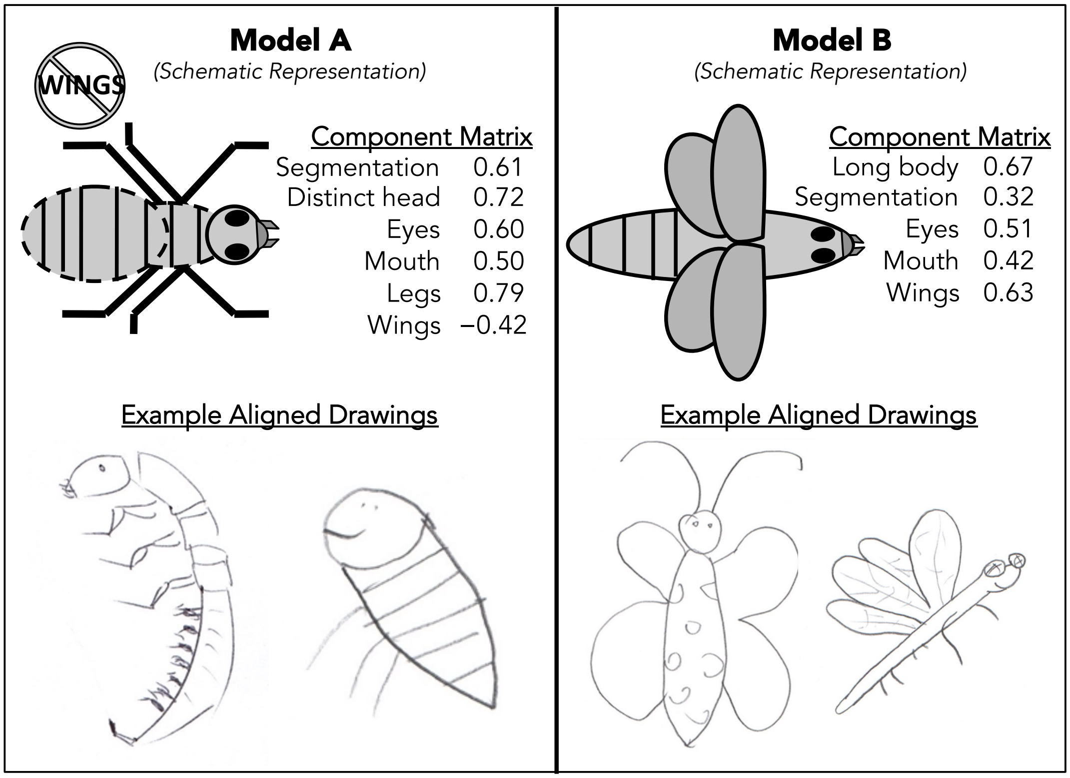

Figure 3.5. Schematic and drawn representations of the crawling model and flying model based on the results of our PCS. Factor loadings for each feature are also given; loadings below ±0.32 are suppressed.

Model scores & expertise

In order to address our second research question and determine whether a relationship existed between alignment with the models and expertise, we conducted a MANOVA. Our independent variable was participant group, which is coded as nominal. Our two dependent variables were Crawling and Flying Model Scores, both of which were ratio/interval. Skewness and kurtosis values over respective standard errors were mostly below ±1.96 for all combinations of dependent and independent variables, indicating a normal or near-normal distribution. Levene's test was not significant for scores for either model, thus satisfying the assumption of homogeneity of variance. In addition, Box's test was non-significant (Box's M = 2.496, $F(6,1407046.4) = 0.411$, $p = 0.872$), satisfying the assumption of homogeneity of covariance matrices. The MANOVA examined the relationship between the scores for each model and participant group. Overall, the MANOVA was significant (F (2,268) = 11.01, $p < 0.001$, Roy's Largest Root = 19.175, partial $\eta^2 = 0.125$). Participant group had a significant main effect on both the Crawling Model Score ($F(2,269) = 11.538$, $p < 0.001$, partial $\eta^2 = 0.079$) and the Flying Model Score ($F(2,269) = 16.445$, $p < 0.001$, partial $\eta^2 = 0.109$). Given the significant results of this test, we proceeded with Tukey's HSD post hoc test (Field, 2013).

Mean scores for the crawling model were significantly higher in ENT participants than in either NSUs ($p < 0.001$) or GEOs ($p = 0.004$). NSU participants had slightly lower scores but did not differ statistically from GEU participants for the crawling model ($p = 0.269$) (Table 4, Figure 5). For the flying model, post-hoc testing showed that ENT participants again had significantly higher scores than either NSU ($p < 0.001$) or GEO participants ($p < 0.001$). GEO and NSU participants did not differ statistically in their mean alignment with the flying model ($p = 0.352$), though NSUs had slightly higher scores (Table 3.5, Figure 3.6).

Table 3.5. Mean model scores, correctness score, and total number of features for each subject group.

	Crawling Insect Score (M±SE)	Flying Insect Score (M±SE)	Correctness Score (M±SE)	Total Features (M±SE)
ENT	3.54 ± 0.188	2.94 ± 0.153	3.86 ± 0.175	5.29 ± 0.201
GEO	2.73 ± 0.174	1.88 ± 0.126	2.76 ± 0.156	3.87 ± 0.172
NSU	2.36 ± 0.165	2.13 ± 0.117	2.75 ± 0.142	4.17 ± 0.153

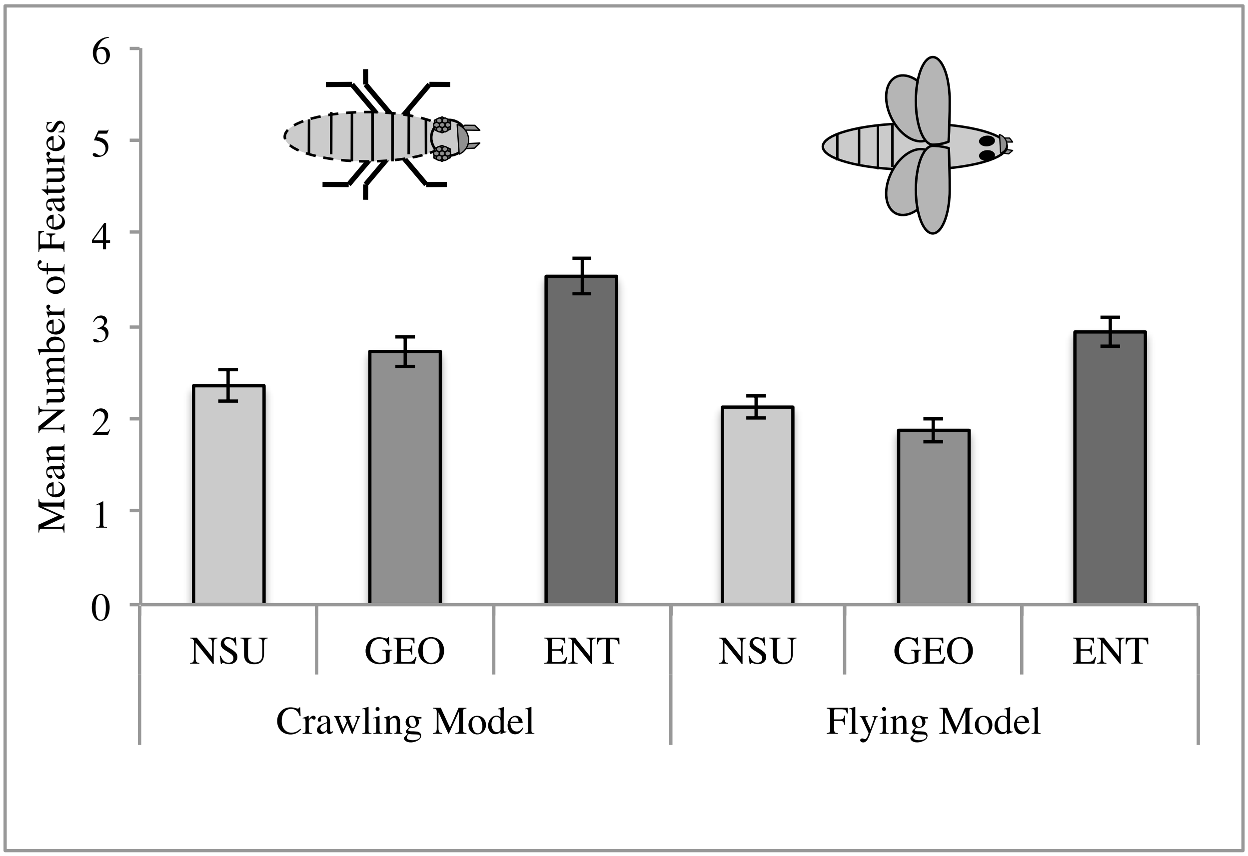

Figure 3.6. Mean model score for each of the two models from participants from each group. Error bars denote standard error.

DISCUSSION

In the present study, we analyzed drawings in order to shed light on the content and organization of mental models of insects. We also investigated how mental models differ between people with advanced training in entomology (ENTs), people with advanced training in science but not entomology (GEOs), and people with minimal or no training in entomology or other science (NSUs). Mental models are employed when a person thinks and reasons about a topic (Jones et al., 2011). When constructing a mental model, one must select which components to include, incorporate those components together, and organize them into a coherent framework (Van Meter & Garner, 2005; Quillin & Thomas, 2014). Drawings capture aspects of mental models, since the act of making a representational drawing requires soliciting a mental image. Thus, drawings can be thought of as imperfect external representations of dynamic internal representations. Drawings are commonly used in science education research to study how people think about explanatory processes, such as the greenhouse effect. The results of the present study support previous works that have indicated that drawings can also be used to study how people think about objects or entities, such as insects (*e.g.* Shepardson, 2002; Diaz, 2009). In addition, this study demonstrates the utility of quantitative analyses for detecting patterns in drawings from many individuals.

Two underlying models emerged from our PCA: (1) A crawling model with legs and specifically without wings, and (2) a flying model with wings. Individuals from all three participant groups created drawings that aligned with the two models. This suggests that these basic means of characterizing insects – as crawling or flying – may represent two distinct mental models of insect. These two models are interesting because they represent the two spaces that people primarily observe and interact with insects – on surfaces and in the air. Experts (ENTs) had higher scores for each model than either of the novice groups (GEO or NSU). This is likely due to the fact that entomologists drew more features on their insects than the other groups.

Beyond the importance to insect education, this result also shows that breaking down drawings into salient features and conducting PCA is a useful method for determining underlying relationships between variables.

The discovery of the two insect models lends support to previous findings indicating that flying and crawling are useful distinctions for characterizing insects to the public. For example, Baldwin et al. (2008) surveyed Florida residents about their use of pesticides, and utilized the categories of “flying” and “crawling” to specify different categories of pests. Crawling pests were cockroaches and ants; flying pests were mosquitoes, wasps, and flies. Results showed that participants viewed flying pests as being more harmful to human health than crawling pests, but cited crawling pests as the larger issue in terms of prevalence and the cost of control. Interestingly, the authors suggest in their discussion that the reason crawling insects were perceived as an actionable threat by the majority of participants was “probably due to a low tolerance for crawling insects, rather than actual damage caused by the pests” (p. 77, Baldwin *et al.*, 2008). Furthermore, many of the flying insects drawn by NSUs were butterflies; likely not perceived as threatening or damaging.

A similar computer-based analysis of children’s drawings of insects (see Appendix I) also yielded two models, one of which is a crawling model, the other of which is a flying model. This is extremely interesting because it indicates that crawling and flying insects are seemingly distinct from each other not only across levels of knowledge, but also across the life span. Additionally, the flying versus crawling dichotomy also emerged in a recent analysis of children’s comments regarding various different types of insects (Breuer *et al.*, 2015). Cluster analysis of the comments revealed a divide between insects that traveled mainly by crawling or were perceived to crawl, and insects that were mainly perceived in flight, with the flying insects receiving more positive comments and inspiring less disgust than the crawling insects (Breuer *et al.*, 2015). This lends support to the idea that insects' different modes of travel (flying vs. walking) may be a useful way to characterize them in educational settings rather than traditional taxonomy-based classification. Though it seems clear from both Baldwin et al. (2008) and Breuer et al. (2015) that crawling insects in general are more negatively regarded than flying insects, the role of affect is outside the scope of the current study. Chapter Four of this dissertation addresses this relationship.

Though the PCA allows us to reduce dimensionality in our data, we also gleaned important insights about how expert and novice mental models of insect morphology differ by examining correlations between features and frequency of features. Both correlational and PCA showed an overall negative relationship between the inclusion of legs and wings in the drawings. Novice (GEO or NSU) participants who drew one were more likely than experts to not include the other. Interestingly, uniquely among NSU participants, wings were more frequently included than legs. We noted that many of the drawings with prominent wings were butterflies, which are an entrée point into the world of insects for many people. Diaz (2009) collected drawings of insects from a similar population of college students and interviewed a subset of those students about the contents of their drawings. Qualitatively, Diaz (2009) makes note of the fact that students who drew insects with wings but not legs, usually butterflies and lady beetles, did so because they believed that these insects do not possess legs. She also notes that some students did not draw eyes or a mouth on their insects because they believed that insects also do not possess those features. This result was also apparent in our data set – frequency of eyes and mouths was much lower for the two novice groups than for experts. In addition, the occurrence of eyes and mouth was positively correlated with expertise. One of the most defining characteristics of insects is their segmentation. Diaz (2009) reported that most students drew their insect with distinct segments (including the head). Segmentation was positively correlated with expertise in our data, and experts drew segmentation more frequently than novices. We suggest that eyes, mouths, and segmentation are more advanced concepts that become more commonly integrated into mental models of insects upon the achievement of expertise. Experts included a greater number of features, on average, than novices. One simple explanation for this is that experts possess greater knowledge of insect morphology than novices. For example, the majority of extant insects possess both eyes and mouths, and all insects have segmented bodies – we would expect entomologists to know that.

Drawings of insects created by people who had expertise in entomology differed in several important ways from drawings created by novices. Drawings of insects by trained entomologists (ENTs) were more detailed and more complete than drawings made by people who did not have this training. Interestingly, participants with general training in science (GEOs) but who lacked expertise in entomology created drawings that were similar in both completeness and the amount of detail to drawings made by college students who had neither science nor entomology training (NSUs). This implies that experience specifically in entomology, rather than science in general, is responsible for changes to mental models of insects. Previous studies also acknowledge that expertise development changes the way one connects with content – experts organize and process information within their discipline differently than non-experts do, and their knowledge is much greater (Chi et al., 1981). One possible reason that entomologists included more features in their drawings than novices is concerned with working memory. Working memory is the site of interaction between attention, perception, and memory. It "temporarily stores information as part of the performance of complex cognitive tasks"

(Baddeley, 1992). The contents of working memory, including mental models, are used in completing cognitive tasks. Thus, working memory is engaged when creating a drawing because the individual must rely on what they already know. In children, working memory capacity was found to be a significant predictor of the number of dog-like features included in drawings of dogs (Panesi & Morra, 2016). Previous work has shown that experts have greater and more complex working knowledge within their discipline than novices (Chi et al., 1981; Peters, 2000).

Though entomologists drew insects that were more accurate than novices, their drawings largely fell short of the full six features that we designated as defining a correct and complete insect: Head, segmentation, eyes, mouth, antennae, and legs. Does this mean that the entomologists we surveyed were not aware that insects possess all of these features? If the drawings are reflective of mental models, and mental models encompass one's knowledge, then does it follow that features missing from the drawing are also missing from the individual's knowledge? Though previous research has shown that even seasoned experts may hold misconceptions about certain aspects of their field (Lewis & Linn, 1994), we feel that this is unlikely in this case. The six essential insect features are extremely important to the functioning of an insect and are covered even in the most basic of introductory entomology courses. Why else might it be that drawings by ENTs are not all perfectly correct and complete representations of insects? We suggest that experts do know that insects have all of these features but for some reason do not include all of them at once. This could be either the result of a conscious decision not to include certain features in the drawing, or an unconscious choice. Because we did not interview our subjects, we cannot go back and ask them if they made a conscious decision not to draw all the features, or whether they were not aware of it at the time.

An additional interesting finding is that the majority of the drawings we analyzed depicted insects in their adult (mature) life stage; this was true across all three participant groups. Life stage was not referred to in the survey prompt. Anecdotally, we did notice the presence of larvae such as maggots when participants were prompted to draw an insect that they thought was disgusting, though again depictions of adults far outnumbered depictions of larvae. This suggests that mental models of insects are primarily composed of adult insects, rather than larval forms. In addition, larval forms seem to be associated with negative affect, in this case, disgust. In support of this is Wagler and Wagler's (2012) study, which documented more negative attitudes toward larval forms than adult forms. Another explanation for the paucity of larval insects depicted in our study is that people are simply less aware of larval insects. This makes sense because immature insects are more likely to be found hidden within or underneath objects, since their exoskeletons are less hardened than in adulthood, and thus they need more protection. It is unclear whether the relative lack of immatures in our sample is due to lack of awareness or dislike. Perhaps ontologically, adult insects are viewed as the most important because they are the most visible in our world. We suggest that educational programs should place more emphasis on teaching the immature forms of insects. Insects are most vulnerable in the larval stage, particularly larval stages that occur in water, which are often utilized as bioindicators (Merritt *et al.*, 2008). Larval forms of insects are also important food sources for human populations across the globe. If people are not aware of the existence of larval insects, they may be less inclined to protect and conserve them.

Limitations

One important thing to note is that though we collected drawings, which are representative of knowledge, we did not quantify nor experimentally manipulate the amount, relevance, or complexity of our participants' knowledge of insects and other arthropods. Rather, we assumed that the experts' greater formal training, as indicated by their considerable amount of undergraduate- and/or graduate-level entomological coursework, would be a satisfactory indicator of expertise. Precisely defining expertise levels poses a challenge to researchers since there is much variation in how expertise levels are defined across the literature (see Hoffman, 1998). In general, scholars tend to group those who have had significant formal education in their fields toward the expert end of the continuum, and those who have had little or no formal training toward the novice end (Chi et al., 1981; Lewis & Linn, 1994). We acknowledge that this is a grossly oversimplified classification, since there are additional factors that contribute to expertise other than coursework (Hoffman, 1998). Our three participant groups were sampled from three diverse populations (non-science college students, non-entomologist scientists, and entomologist scientists) and are different enough from each other that a valid comparison across expertise levels is warranted.

Conclusions

Individuals enter a learning environment with their own unique pre-existing mental models that they use to interpret their experiences and plan their behavior (Jones *et al*., 2011). Teaching and learning in the sciences must be thoughtfully planned with attention paid to facilitating positive attitudes, since positive interest and motivation are important for effective learning (Schiefele, 1991). Evidence suggests that fact-based science learning is not adequate in regards to improving attitudes (Koballa & Crawley, 1985). Thus, it is important to assess students' existing attitudes and knowledge prior to instruction. For instance, in the field of entomology, learners may be constrained by negative conceptions of insects. Our study suggests that people organize their mental models of insects based on whether they are observed to primarily crawl or fly. We believe that this may be a more approachable way to characterize insects to the public, rather than emphasizing traditional taxonomic classifications. In addition, we found that experts' mental models are more likely to include fine-grained features such as segmentation, eyes, and mouths; with novices' mental models generally sticking to large-grained features such as wings. One final major insight from this study is that, across the spectrum of expertise we sampled, mental models of insects tend to include the mature/adult life stage rather than the immature stage.

REFERENCES

REFERENCES

Baddeley, A. (1992) Working Memory. *Science, 255*(5044): 556.

Baldwin, R. W., Koehler, P. G., Pereira, R. M., and Oi, F. M. (2008) Public perceptions of pest problems. *American Entomologist, 54*(2): 73–79.

Bartoszeck, A., and Bartoszeck, F. K. (2012) Educação de jovens e adultos: Estudo exploratório do conceito de insetos. *Estação Científica (UNIFAP), 2*(1): 33–41.

Bartoszeck, A., da Silva, B. R., and Tunnicliffe, S. D. (2011) Children’s concept of insect by means of drawings in Brazil. *The Journal of Emergent Science, 2*: 17-24.

Bixler, R. D., Carlisle, C. L., Hammitt, W. E., and Floyd, M. F. (1994) Observed fears and discomforts among urban students on field trips to wildland areas. *The Journal of Environmental Education, 26*(1): 24–33.

Bixler, R. D., and Floyd, M. F. (1997) Nature is scary, disgusting, and uncomfortable. *Environment and Behavior, 29*(4): 443–467.

Breuer, G. B., Schlegel, J., Kauf, P., and Rupf, R. (2015) The importance of being colorful and able to fly: Interpretation and implications of children’s statements on selected insects and other invertebrates. *International Journal of Science Education, 37*(16): 2664–2687.

Chi, M. T. H. (2008) Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), *Handbook of research on conceptual change* (pp. 61-82). Hillsdale, NJ: Erlbaum.

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981) Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*(2): 121–152.

Diaz, A. E. (2009) Undergraduates’ mental models about insect anatomy and insect life cycles. M.S. Thesis, California State University, Fullerton. Retrieved 27, January, 2017 from http://search.proquest.com.proxy1.cl.msu.edu/docview/305177877/abstract/51ACC4349EF94C3APQ/1.

Gerdes, A. B. M., Uhl, G., and Alpers, G. W. (2009) Spiders are special: Fear and disgust evoked by pictures of arthropods. *Evolution and Human Behavior, 30*(1): 66–73.

Hinkle, N. C. (2000) Delusory parasitosis. *American Entomologist, 46*(1): 17–25.

Hoffman, R. R. (1998) How can expertise be defined? Implications of research from cognitive psychology. In *Exploring expertise* (pp. 81-100). Palgrave Macmillan UK.

Holstermann, N., Grube, D., and Bögeholz, S. (2009) The influence of emotion on students' performance in dissection exercises. *Journal of Biological Education, 43*(4): 164–168.

Jones, N., Ross, H., Lynam, T., Perez, P., & Leitch, A. (2011) Mental models: An interdisciplinary synthesis of theory and methods. *Ecology and Society, 16*(1): 46.

Kellert, S. R. (1993) Values and perceptions of invertebrates. *Conservation Biology, 7*(4): 845–855.

Koballa, T. R., and Crawley, F. E. (1985) The influence of attitude on science teaching and learning. *School Science and Mathematics*, *85*(3): 222-232.

Leather, S. R. (2013) Institutional vertebratism hampers insect conservation generally; not just saproxylic beetle conservation. *Animal Conservation, 16*(4): 379–380.

Lewis, E. L., and Linn, M. C. (1994) Heat energy and temperature concepts of adolescents, adults, and experts: Implications for curricular improvements. *Journal of Research in Science Teaching, 31*(6): 657–677.

Libarkin, J. C., Thomas, S. R., and Ording, G. (2015) Factor analysis of drawings: Application to college student models of the greenhouse effect. *International Journal of Science Education, 37*(13): 2214-2236.

Lord, C. G., Ross, L., and Lepper, M. R. (1979) Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of Personality and Social Psychology, 37*(11): 2098–2109.

Losey, J. E., and Vaughan, M. (2006) The economic value of ecological services provided by insects. *BioScience, 56*(4): 311–323.

Martín-López, B., Montes, C., and Benayas, J. (2007) The non-economic motives behind the willingness to pay for biodiversity conservation. *Biological Conservation, 139*(1-2): 67–82.

Merritt, R. W., Cummins, K. W., & Berg, M. B. (2008) *Introduction to the Aquatic Insects of North America: Text*. Dubuque, IA: Kendall Hunt Publishing.

Osborne, J. W., & Costello, A. B. (2005) Best practices in exploratory factor analysis. *Practical Assessment, Research & Evaluation, 10*(7): 1-9.

Panesi, S., & Morra, S. (2016) Drawing a dog: The role of working memory and executive function. *Journal of Experimental Child Psychology,* 152: 1–11.

Peters, H. P. (2003) From information to attitudes? Thoughts on the relationship between knowledge about science and technology and attitudes toward technologies. In M. Dierkes & C. von Grote (Eds.) *Between Understanding and Trust. The Public, Science and Technology* (pp 265–286). The Netherlands: Harwood Academic Publishers.

Potter, M. F., & Bessin, R. T. (1998) Pest control, pesticides, and the public: Attitudes and implications. *American Entomologist, 44*(3): 142–147.

Quillin, K., & Thomas, S. (2015) Drawing-to-learn: A framework for using drawings to promote model-based reasoning in biology. *CBE-Life Sciences Education*, *14*(1): es2.

Rowe, A. L., & Cooke, N. J. (1995) Measuring mental models: Choosing the right tools for the job. *Human Resource Development Quarterly, 6*(3): 243—255.

Schiefele, U. (1991) Interest, learning, and motivation. *Educational Psychologist, 26*(3-4): 299–323.

Shepardson, D. P. (2002) Bugs, butterflies, and spiders: Children's understandings about insects. *International Journal of Science Education, 24*(6): 627–643.

Smithsonian Institution Office of Policy and Analysis. (2007) The buzz on insects: a study of attitudes and knowledge among visitors to the National Museum of Natural History. Retrieved 15, January, 2017 from https://www.si.edu/content/opanda/docs/Rpts2007/07.09.Insects.Final.pdf.

Thompson, F., & Logue, S. (2006) An exploration of common student misconceptions in science. *International Education Journal*, *7*(4): 553-559.

Wagler, R., & Wagler, A. (2011) Arthropods: attitude and incorporation in preservice elementary teachers. *International Journal of Environmental and Science Education, 6*(3): 229–250.

Van Meter, P., & Garner, J. (2005) The promise and practice of learner-generated drawing: Literature review and synthesis. *Educational Psychology Review, 17*(4): 285–325.

CHAPTER FOUR

IMPACTS OF AFFECT AND EXPERTISE ON DRAWINGS OF DISGUSTING AND NOT-DISGUSTING INSECTS

ABSTRACT

Negative attitudes toward insects are very common among the public. Attitudes have behavioral, cognitive, and affective components. The goal of this study was to explore the affective response to insects, disgust, in the context of mental models of insects in drawings. We collected drawings of "disgusting" and "not disgusting" insects from individuals across different levels of entomological and general scientific expertise, ranging from non-science undergraduate students to professional entomologists. Insect features included in the drawings were indexed and a principal components analysis was applied to find underlying variation in patterns of features. This analysis resulted in the emergence of two components that each resembled a distinct insect – a legged but wingless "crawling" insect, and a winged but legless "flying" insect. In addition, all participants completed a disgust survey indicating their relative level of disgust stimulated by insects and non-insect arthropods. We utilized a multiple linear regression in order to determine if insect-associated disgust could be predicted by the combination of insect features included and subject group of the individual participants. The analysis indicated that approximately 35% of the variation in disgust was attributable to subject group (expertise) and the degree to which drawings aligned with the crawling insect model. We conclude that crawling insects may be regarded as being more disgusting than flying insects, that educational and professional backgrounds play a role in mediating disgust toward insects, and that examining drawings of insects can be a useful tool to shed light on affect associated with insects.

INTRODUCTION

Emotions, or affective responses, play an important role in cognition, in that they provide information in addition to semantic knowledge (Clore & Huntsinger, 2007). Affective reactions are important to the formation of attitudes (Breckler, 1984). For example, people tend to assign higher values to objects that inspire positive emotions and lower values to objects that inspire negative emotions (Clore & Huntsinger, 2007). Insects are invertebrate animals that stimulate a variety of emotions in humans, ranging from awe and happiness to disgust and fear. Though insects are intrinsically valuable to human beings due to their important positions in the world's food chains and the ecosystem services (Losey & Vaughan, 2006), multiple studies show that negative attitudes toward insects are very common among the public (Kellert, 1993; Bixler et al., 1994; Bjerke et al., 1998; Schlegel & Rupf, 2010). In order to encourage public valuation of insects, it is important to challenge negative attitudes toward insects.

Previous studies indicate that people with greater knowledge of something are less likely to perceive it as harmful (Boete & Moran, 2016). For example, professionals who work with bats are less likely to perceive them as dangerous (Boete & Moran, 2016). Along this line, comparisons of experts and novices within the same discipline have also shown that experts perceive their object of study differently than novices (Chi et al., 1981). Both visual processing (Tanaka & Curren, 2001) and knowledge organization (Chi et al., 1981) differ between experts and novices. Evidence from brain-imaging studies suggests that experts become emotionally habituated to their object of expertise (Cheng et al., 2007). This means that experts exhibit more muted emotional responses to their object of study than non-experts.

In this study, we explored the representation of emotion in drawings of insects from individuals with different levels of insect and scientific expertise. Examining drawings has been shown to be a useful way to probe understanding about a topic of interest (Dove et al., 1999; Ainsworth et al., 2011; Libarkin et al., 2015, etc.). In addition, drawings can also be used to detect or evaluate emotion (e.g. Oster & Crone, 2004; Löfström & Nevgi, 2012), though this is much less common in the literature than using drawings to evaluate understanding. Drawings of insects have previously been utilized in studies of children's understandings about insects (Shepardson, 2002; Snaddon & Turner, 2007), though to our knowledge, no prior studies exist that utilize drawings of insects created by adults.

In particular, we focused on the emotion of disgust. Disgust is a negative reaction that is both emotional and physiological, and is associated with a characteristic facial expression that involves scrunching one's nose and raising the upper lip (Haidt et al., 1994). Disgust activates regions of the brain associated with hunger and eating, and the word disgust itself means "bad taste" (Phillips et al., 1997). Disgust is thought to be an evolutionary mechanism to promote avoidance of potential disease-causing agents such as feces, blood, and rotten meat (Oaten et al., 2009), though disgust is also elicited in response to moral transgressions and violation of sexual norms (Tybur et al., 2009). Disgust associated with the perception of insects is linked to pathogen avoidance (Lorenz et al., 2014). Sensitivity to disgust is usually measured using a scale (Likert-type survey) (Haidt et al., 1994; Tybur et al., 2009; Lorenz et al., 2014).

Research questions

This study builds off the previous chapter of my dissertation, Chapter Three, in that it utilizes data from the same participants. Chapter Three describes an investigation in to mental models of insects using principal components analysis (PCA) of salient features included in drawings of regular (not disgusting) insects. The PCA resulted in the characterization of two major models of insects that occurred in the drawings: a crawling model, and a flying model.

This present work investigates the same set of drawings as Chapter Three, but considers an additional dimension of cognition: affect. In addition to the drawings of regular (not disgusting) insects that were explored in Chapter Three, this current work also reports on an additional set of drawings in which the same participants drew an insect they considered disgusting.

The main goal of this chapter is to examine how disgust influences people's internal representations of insects in the context of expertise. Drawings created by insect experts, professional entomologists, were compared to drawings created by insect novices, who were non-science major undergraduates. In addition, both were compared to a third group of individuals who were professional scientists outside of the field of entomology. In Chapter Three, it was found that drawings of experts aligned more closely with the crawling and flying models than the drawings of non-experts. Building off this finding, this current Chapter is framed around the following research questions:

1) Do insect experts differ in their reported level of insect-associated disgust from insect novices?
2) How do drawings of disgusting insects differ from drawings of not disgusting insects?
3) Can disgust toward insects be predicted by examining drawings of insects?

METHODS

Participants & data collection

We collected drawings from three populations of individuals at three levels of insect expertise: non-science undergraduate students (NSUs), scientists with no specialized training in entomology (GEOs), and scientists with extensive training in entomology (ENTs). ENTs were individuals participating in the annual meeting of a major American professional entomological society, and thus were mainly students and professionals in entomology. We assume that our ENT population has greater expertise about insects than either GEOs or NSUs, and approximately equivalent general science expertise as our GEO participants. GEOs were individuals participating in the annual meeting of a major American professional geological society, and thus were mainly students and professionals in the geosciences. GEOs were assumed to have greater expertise in general science than NSUs, but similar expertise about insects. Both ENTs and GEOs were presumed to have greater expertise in general science than NSUs. Descriptive statistics for our participants can be found in Table 1 (reproduced from Chapter Three of this dissertation). Participants were asked to draw one insect they did not find disgusting, and on a separate page, one insect that they did find disgusting. Participants were also asked to record the type of insect they had drawn. In addition, we collected demographic data such as gender and highest degree held.

Insect disgust survey

In addition to the two drawings, participants also completed a brief Likert-scaled survey of insect-associated disgust (Lorenz et al., 2014; Chapter Two of this dissertation). Participants ranked their disgust level in response to each survey item on a 4-point Likert scale with the following rankings: “Not at all disgusting,” “Somewhat disgusting,” “Very disgusting,” and “Extremely disgusting.” The disgust survey consisted of the following nine survey items:

(1) Finding a scorpion in your shoe.

(2) Seeing an ant crawl across the floor.

(3) Finding a bug in your shirt.

(4) Watching a spider make its web.

(5) Eating a chocolate-covered cricket.

(6) Feeling a mosquito bite you.

(7) Accidentally touching a spiderweb.

(8) Watching a centipede crawl across your leg.

(9) Seeing a cockroach run across a countertop.

Insect disgust scores were calculated for each participant by weighting the different response options from one (not at all disgusting) to four (extremely disgusting), and taking the sum of all responses from each participant. Thus, the lowest possible disgust score was nine, and the highest possible score was 36. We calculated Cronbach's alpha on all nine items for all participants together in order to confirm the reliability of the survey. The disgust survey showed good reliability with Cronbach's $\alpha = 0.866$. We conducted a Kruskal-Wallis H test in order to determine whether disgust differed significantly across our participant groups.

Previous studies on disgust report higher mean disgust levels for females relative to males (e.g. Davey, 1994). Since the gender data did not ascribe to a normal distribution, we used a non-parametric test to determine whether disgust differed between the genders. Another suggestion from the literature (e.g. Curtis et al., 2004) is that disgust sensitivity declines with age. We collected data from GEO and ENT participants across the lifespan, from age 19 to age 78. In contrast, NSU participants all reported their ages as between 18 and 25 years, as was expected because NSU participants were undergraduate students. We compared mean insect disgust score for each participant group in four age categories: 18-25, 26-40, 41-55, and 56-78 years. Due to severely unequal sample sizes as well as the absence of NSU data for ages over 25, we were unable to perform a statistical analysis to determine whether age affects insect disgust outside of expertise. Thus, we created a graph of the data in order to make a qualitative comparison.

Drawings, insect models, & insect model scores

Both sets of drawings were coded by breaking each drawing into salient insect features and recording their presence or absence. A detailed description of our sampling and coding methodology can be found in Chapter Three. Eleven distinct insect features were coded: head, antennae, legs, body shape (oval vs. elongate), wings, eyes, segmentation, mouth, stinger, hair, and pincers/cerci. The average frequency at which each feature occurred for both the disgusting and not disgusting drawings was calculated and compared between disgusting and not disgusting drawings across all participants, in order to gain an idea of overall trends.

In the previous analysis of the non-disgust drawings (Chapter Three), PCA was utilized without rotation in order to reduce dimensionality in the data. From this analysis, two components emerged. These two components each reflected a distinct model or type of insect. The first component represents a crawling insect, and the second component represents a flying insect (Fig. 4.1). These two components can be considered to represent common themes in people's representations of insects. Scores were calculated for each model for each participant, indicating the degree to which the features included in the model were present in each drawing. For example, the crawling model contains six features: head, segmentation, eyes, mouth, legs, and wings lacking. Thus, for their crawling model score, each participant was given one point for the inclusion of all six features. Note that for this model, the inclusion of the "wings absent" feature means *not* drawing wings. Thus, it is possible for a drawing to score a maximum of six points if they drew a head, segmentation, legs, eyes, and a mouth, and no wings. The minimum possible score for the crawling model is negative one. For the flying model, the maximum score is five since the model contains five features: Long-shaped body, segmentation, wings, eyes, and mouth. Thus, the maximum possible score is five, and the minimum is zero. In addition, a "complete insect score" was calculated for all drawings. The complete insect score estimates the degree to which a drawing represents an accurate scientific model of an insect (or other arthropod). A complete insect should possess a distinct head, legs, eyes, mouth, antennae, and segmentation.

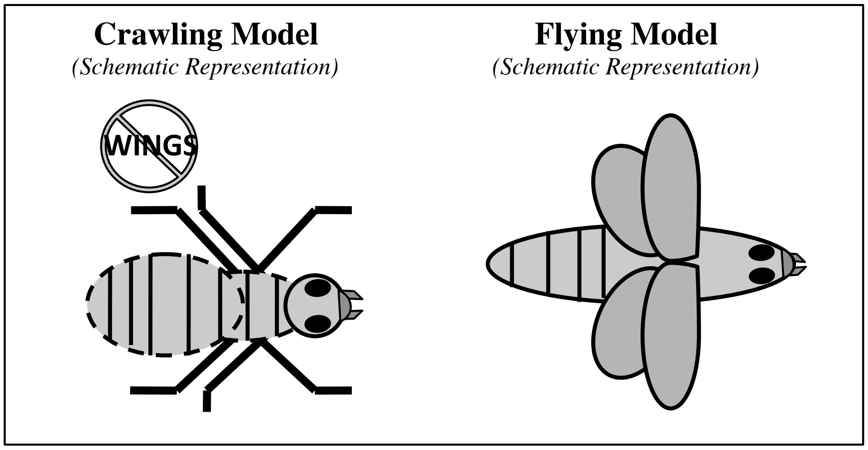

Figure 4.1. Crawling and flying insect models as detected through principal components analysis (Chapter Three).

Correlational analysis

In order to explore potential relationships between insect disgust and the drawings, point-biserial Pearson correlations were conducted between disgust score, gender, crawling model score, flying model score, and participant group for both the disgusting and not disgusting drawings. Participant group, as a nominal variable representing relative expertise, was dummy-coded in order to be appropriate for the analysis. The ENT group, the experts, was chosen as the baseline with which to compare the other participants, the non-experts. Thus, two dummy variables were created, ENT vs. NSU (compares ENTs to NSUs), and ENT vs. GEO (compares ENTs to GEOs).

Multiple regression

A multiple linear regression analysis was conducted in order to determine whether expertise and model scores could predict insect-associated disgust. This test was run for the *not-disgusting* insect drawings only. This is because a greater variety of insects was represented in the not-disgusting drawings than in the disgusting drawings. Thus, the not-disgusting drawings were more representative of a typical insect. In addition, sample size for the not-disgusting drawings was greater than for the disgusting drawings. Before conducting the regression, tests were performed to verify normality, linearity, homogeneity of variances, homoscedasticity, outliers, and influential points (Field, 2013). We conducted a multiple linear regression to predict Insect Disgust Score from Subject Group (ENT, GEO, NSU) and Crawling Model Score. The Crawling Model Score was included because it correlated significantly with Insect Disgust Score in the not-disgusting drawings. Flying Model Score also correlated significantly with Insect Disgust Score in the not-disgusting drawings, but the correlation coefficient was relatively low; thus, it was not included in the regression model. Crawling Model Score is considered to be continuous, since it is a quantitative measure of the number of features that align with the model. Age was not included as a predictor in the analysis since our participant groups were different in terms of age distribution. Subject Group, as a categorical variable, was dummy-coded into the same two dummy variables utilized in the correlational analyses. Again, the ENT group was selected to use as a baseline.

RESULTS

Participants & data collection

Full descriptive statistics for our participants are reproduced in Table 4.1. A total of 294 individuals were surveyed. Two hundred and forty-one drawings of disgusting insects, and 272 drawings of not-disgusting insects were analyzed. For the drawings of disgusting insects, out of a total of 112 NSUs, 100 completed an applicable drawing. Twelve individuals either did not complete a drawing, or their drawing was not applicable to the study (*e.g.* drawing does not depict an insect or other arthropod). Out of a total of 96 GEOs, 80 completed a drawing; and out of a total of 87 ENTs, 65 completed an applicable drawing. ENTs numbers are lower because many did not complete a drawing, instead writing in that they did not find any insects to be disgusting. For the drawings of not-disgusting insects, out of the total 112 NSUs, 101 completed an applicable drawing. For GEOs, 92 completed an applicable drawing; for ENTs, 80 individuals completed an applicable drawing.

Table 4.1. Descriptive statistics for each participant group (ENT, GEO, NSU). Reproduced from Chapter Three of this dissertation.

Expertise Level	**N**	**Age (M±SD)**	**Gender**	**Highest Degree Held**
ENT	79	38.9 ± 14.1	37.2% Female 62.8% Male	***In Entomology:*** 16% Bachelors' in progress 26% holding Bachelors' 18% holding Masters' 40% holding PhD
GEO	92	34.02 ± 14.7	48.4% Female 51.6% Male	***In Geoscience:*** 29% Bachelors' in progress 23% holding Bachelors' 23% holding Masters' 25% holding PhD
NSU	101	19.81 ± 2.75	53.5% Female 46.5% Male	*All participants working toward Bachelor's degrees in non-science fields*

Insect disgust survey

Out of a total of 294 participants, 285 completed the disgust survey. Disgust scores declined with entomological expertise, with the mean disgust score (± SD) for ENTs at 14.25 (± 4.15), for GEOs at 18.37 (± 5.24), and for NSUs at 22.76 (± 5.73) (Fig. 4.2).

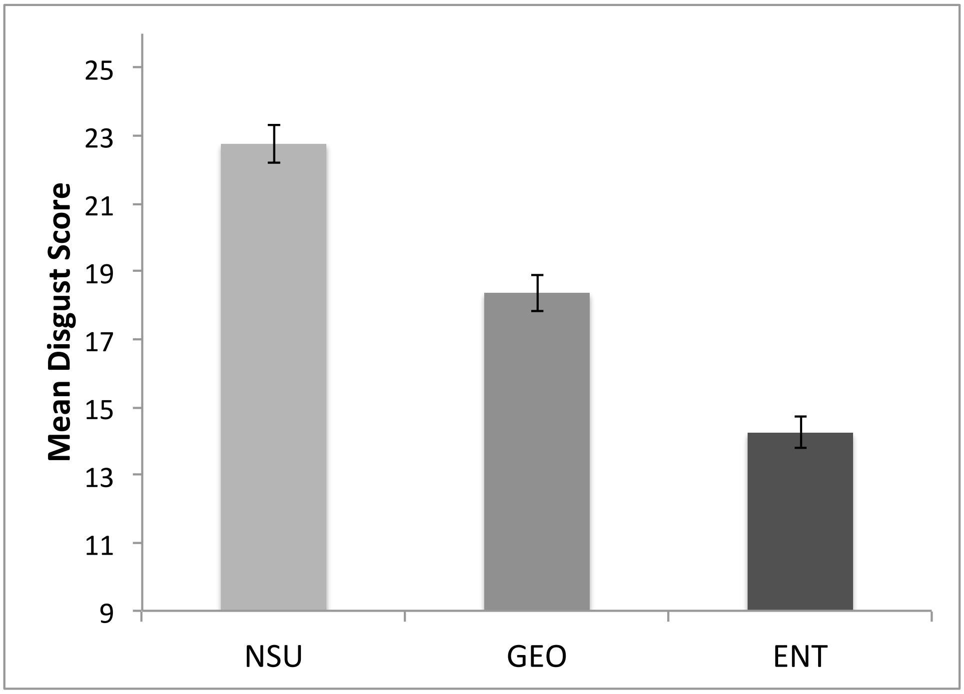

Figure 4.2. Mean insect disgust score (± SE) across our three sampled populations. The y-axis begins at 9 because the lowest possible disgust score was 9. NSUs had the highest mean score, followed by GEOs, with ENTs having the lowest perceived disgust associated with insects.

Since the disgust data for each gender did not conform to a normal distribution, in order to determine whether reported disgust differed by gender, a Mann-Whitney U test was utilized, combining data from all three participant groups. This test was significant ($U = 5346.5$, $p < 0.001$), indicting that males and females differ in their reported levels of disgust across all three participant groups. Mean rank score was higher for females (167.19) than males (109.15).

All NSU participants reported their age as between 18 and 25 years. In comparison, GEO and ENT participants between the ages of 18 and 25 generated mean disgust scores well under that of NSU participants. Thus, the higher mean insect disgust score exhibited by the NSU group cannot be attributed solely to their collective lower age. However, greater age may still be confounding because older ENT and GEO participants have more career experience. Expertise level was not explicitly measured, though it is likely safe to assume that expertise increases with age/experience. However, note from the graph (Fig. 4.3) that for the ENT group, mean disgust is greatest in the 18-25 years group, with the next three age groups (26-78 years) scoring similarly to each other. So, it would appear from this graph that insect disgust is present in experts at every age, but is relatively constant after age 25.

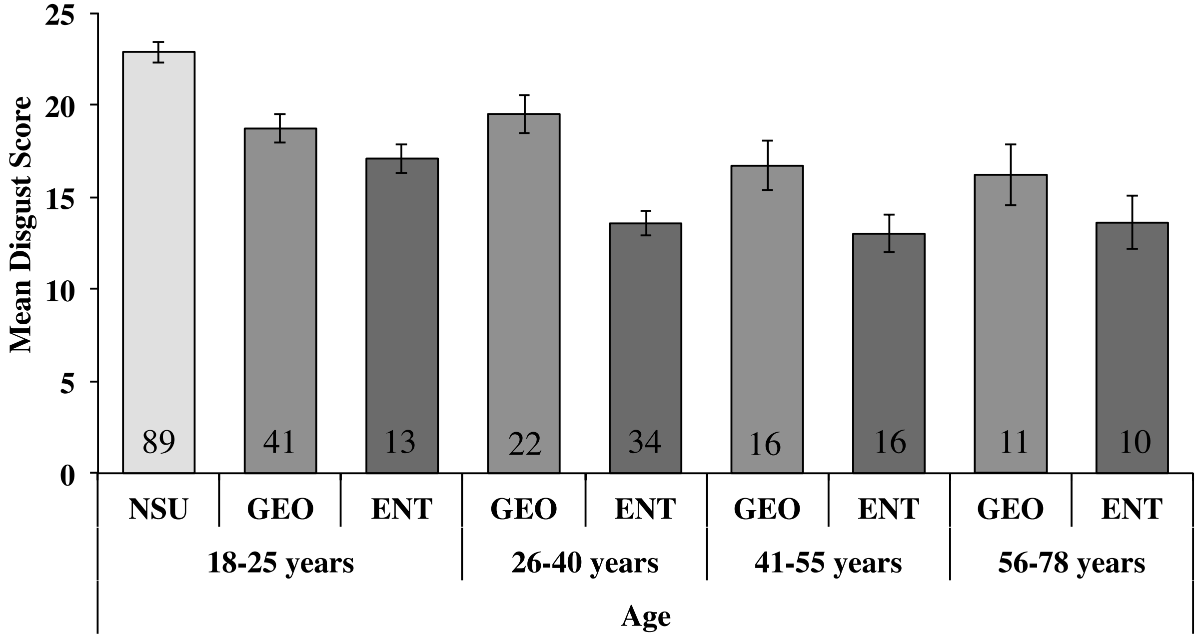

Figure 4.3. Mean disgust score plotted by age category for each participant group. NSU = non-science undergraduates; GEO = non-entomologist scientists; ENT = entomologists. The quantity of participants reporting age in each category for each group is indicated within the bottom of

Figure 4.3 (cont'd)
each bar. Note that all NSU participants reported their age as between 18 and 25 years. GEO and ENT participants between the ages of 18 and 25 generated mean disgust scores well under that of NSU participants.

Drawings, insect models, & insect model scores

There were both differences and similarities in the frequency of inclusion of the different insect features between the disgusting and not disgusting insect drawings (Table 4.2). Non-disgusting drawn insects were nearly 30% more likely to have wings, 18% more likely to have antennae, 13% more likely to have a long-shaped body, and 8% more likely to have a distinct head than the disgusting drawings. Disgusting drawings were 20% more likely to have legs, 13% more likely to have an oval-shaped body, nearly 10% more likely to have a mouth, and 6% more likely to have pincers/cerci. By contrast, features that were included at similar rates in both types of drawings (within 5% of each other) were eyes, segmentation, stinger, and hair. In order to qualitatively explore the types of insects drawn, we created word clouds (www.tagul.com) composed of all recorded insects drawn for both the disgusting and not disgusting insects (Figure 4.4). Common among the not disgusting insects were butterflies, lady beetles, dragonflies, ants, bees, and praying mantids. Common among the disgusting insects (though some are non-insect arthropods) were cockroaches, ticks, maggots, centipedes, mosquitoes, flies, and spiders. Note that bees and ants were common among both disgusting and not disgusting entries.

Calculated scores for both the crawling model and flying model, along with complete insect score, were higher among experts (Table 4.3). This was found to be significant for the not disgusting drawings in the previous chapter. Since higher scores are indicative of having more features in common and thus greater alignment with the models, this suggests that ENTs as a group drew insects that were more closely aligned to the models than either GEOs or NSUs.

Model scores were tested between disgusting and not disgusting drawings, with the crawling model scores generally larger for disgusting than not-disgusting drawings across all three participant groups (Table 4.3).

Table 4.2. Frequencies of coded insect features (all participant groups combined). In the Difference (ND – D) column, positive values indicate that the feature was more common in the not disgusting drawings; negative values indicate that the feature was more common in the drawings of disgusting insects.

Insect Feature	Not Disgusting Drawings (ND)	Disgusting Drawings (D)	Difference (ND – D)
1. Distinct Head	71.7%	63.8%	7.9
2. Antennae	68.0%	49.2%	18.8
3. Legs	63.0%	83.5%	-20.5
4. Wings	57.0%	27.8%	29.3
5. Body Shape: Long	66.2%	52.4%	13.8
Body Shape: Oval	33.8%	47.6%	-13.8
6. Eyes	44.1%	47.6%	-3.5
7. Segmentation	40.8%	41.7%	-0.9
8. Mouth	19.9%	29.5%	-9.6
9. Stinger	5.1%	5.5%	-0.4
10. Hair	2.2%	4.7%	-2.5
11. Pincers/Cerci	1.1%	7.1%	-6.0

Table 4.3. Mean model scores (±SD) for disgusting and not disgusting drawings across participant groups.

	Not Disgusting		**Disgusting**	
	Crawling Model	**Flying Model**	**Crawling Model**	**Flying Model**
NSU	2.36 (±1.66)	2.13 (±1.18)	3.37 (±1.09)	1.89 (±1.11)
GEO	2.73 (±1.66)	1.88 (±1.21)	3.14 (±1.23)	1.86 (±1.14)
ENT	3.54 (±1.67)	2.94 (±1.36)	3.71 (±1.40)	2.34 (±1.43)

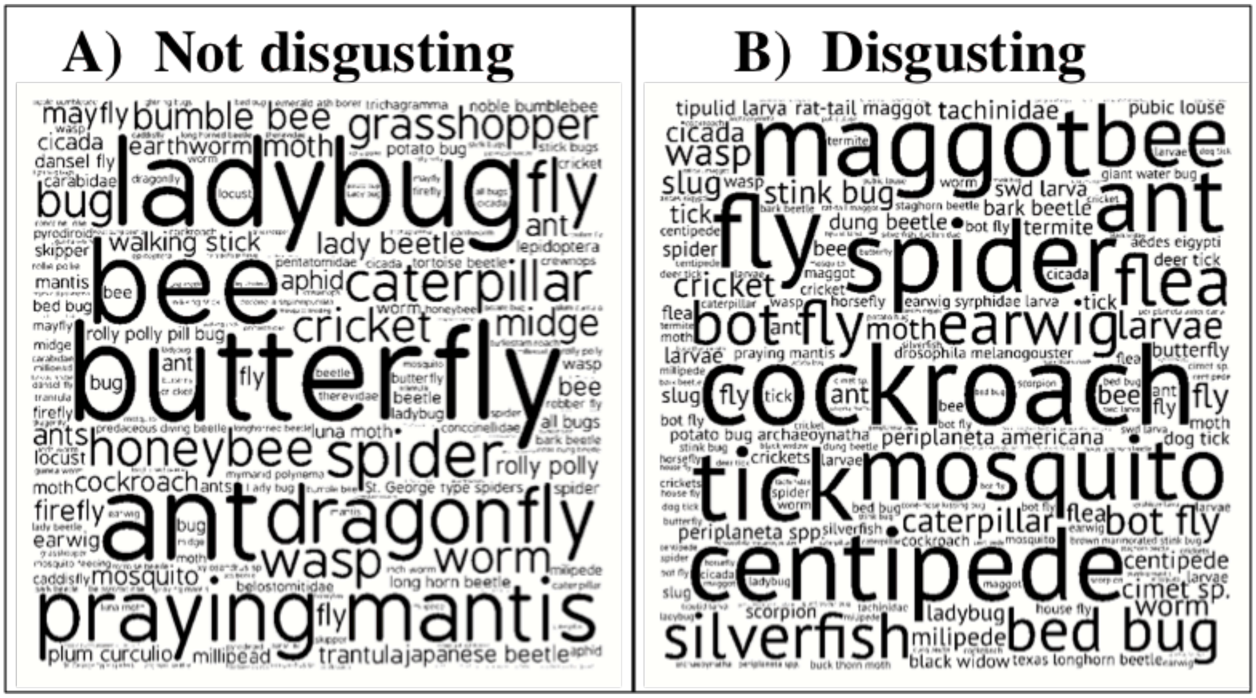

Figure 4.4. Two word clouds based upon participants' recordings of the type of insect they had intended to portray, showing dominant types of (A) not-disgusting (left) and (B) disgusting (right) insects drawn. The relative sizes of the words indicate their frequency in the dataset.

Correlational analysis

Point-biserial Pearson correlations were conducted between Insect Disgust Score, Crawling Model Score, Flying Model Score, as well as the dummy-coded participant group variables, ENT vs. NSU and ENT vs GEO. For the not-disgusting insect drawings, Insect Disgust Score was negatively correlated with Subject Group and the Crawling Model Score (Table 4.4). In addition, the analyses showed that Insect Disgust Score correlated significantly with the Crawling Model Score in the not-disgusting insect drawings only. Insect Disgust Score did not correlate with the Crawling Model Score in the disgusting insect drawings. Disgust score correlated weakly with Flying Model Score for both the disgusting and not disgusting drawings.

Table 4.4. Pearson correlations between disgust score and model scores calculated from drawings of (A) not-disgusting insects, and (B) disgusting insects. * Significant correlation at level of 0.05. **Significant correlation at level of 0.01.

(A) NOT DISGUSTING	Disgust Score	ENT vs NSU	ENT vs GEO	Gender	Crawling Model Score	Flying Model Score
Disgust Score	1	0.50**	-0.01	0.37**	-0.32**	-0.16**
ENT vs. NSU		1	-0.55**	0.10	-0.21**	-0.09
ENT vs. GEO			1	0.02	-0.04	-0.22**
Gender				1	-0.18**	-0.18**
Crawling Model Score					1	0.41**
Flying Model Score						1

(B) DISGUSTING	Disgust Score	ENT vs. NSU	ENT vs. GEO	Gender	Crawling Model Score	Flying Model Score
Disgust Score	1	0.50**	-0.04	0.37**	-0.10	-0.17**
ENT vs. NSU		1	-0.55**	0.09	-0.01	-0.08
ENT vs. GEO			1	0.03	-0.14*	-0.07
Gender				1	-0.04	-0.02
Crawling Model Score					1	0.57**
Flying Model Score						1

Multiple regression

A multiple linear regression was conducted using the forced entry method to predict Insect Disgust Score from Subject Group and Crawling Model Score. In this analysis, *only the not-disgusting insect drawings were utilized*. Prior to the analysis, participant group, a nominal variable, was dummy-coded in to two dichotomous variables, ENT vs. GEO and ENT vs. NSU. In this way, the regression will compare these two groups to the ENT group, who represent a high level of expertise. In order to avoid issues with missing data, missing cases were deleted listwise.

Despite the fact that females on average scored higher than males on the Insect Disgust Survey, gender was not utilized as a predictor of insect-associated disgust in the regression analysis. This is because, though females tend to report stronger emotions than males, brain-imaging studies have revealed similar activity for males and females during emotional processing (Schienle et al., 2005; Bluhm, 2013). The tendency of females to report greater emotion thus may be a product of culture rather than a biological difference between the genders (Bluhm, 2013). In addition, the purpose of this study, as stated in the research questions, is to determine whether disgust can be predicted from relative expertise about insects and drawings of insects, not about effects of gender. For these reasons, gender was not included in the regression model.

Before conducting the regression, in order to make sure the data were suitable for the analysis, test were conducted to verify the assumptions of linearity, outliers and influential points, normality, multicollinearity, independent errors, homogeneity of variances, and homoscedasticity (Field, 2013).

Linearity between the Insect Disgust Score and Crawling Model Score was examined utilizing a scatterplot. The scatterplot suggested that a linear relationship exists between Insect Disgust Score and Crawling Model Score, meeting the assumption of linearity. The dummy variables were not tested for linearity because as dichotomous variables the relationship is automatically linear. In testing for outliers and influential points, two individual cases had standardized residuals that were >2.5. Field (2013) states that as long as the total number of cases with standardized residuals > 2.5 is less than one percent of the total data set, then these cases should not unduly influence the model. In support of this, Cook's distance was 0.004, which is less than 1, and the mean Mahalanobis distance was 3.0, which is less than the critical values of alpha for chi-square analysis for two degrees of freedom (Field, 2013). The correlation matrix was examined for multicollinearity issues. Crawling Insect Score correlated significantly with the NSU dummy variable ($r = -0.21$, $p < 0.001$). Though these two predictor variables correlated significantly with each other, the correlation coefficient is relatively small, and thus, issues with collinearity are unlikely. Crawling Score did not correlate with the GEO dummy variable ($r = -0.041$, $p = 0.501$). In addition, VIF values were all less than 10, and Tolerance values were greater than 0.2 (Field, 2013), again indicating no problems with multicollinearity. The Durbin-Watson statistic was utilized to test for independence of errors. The Durbin-Watson value was 1.951; since this number was close to two, independence of errors was assumed (Field, 2013).

Continuing to explore the data to determine if all assumptions of multiple linear regression are met, the data were tested for normality. When the skewness and kurtosis values were divided by their standard error, the result was less than ±1.96 for most combinations of variables, indicating a near-normal distribution. In addition, the histogram and P-P plot were also indicative of a normal distribution. Homogeneity of variances in Insect Disgust Scores was tested using Levene's test. For the ENT vs. NSU (dummy variable) disgust scores, variances based on means were equal for both ENT and NSU participants, $F(1,264) = 2.003$, $p = 0.158$. For the ENT vs. GEO (dummy variable) disgust scores, variances based on means were significantly different for ENT and GEO participants, $F(1, 264) = 7.876$, $p = 0.005$. However, the variance ratio between ENT and GEO participants was 1.538, which is fairly low, indicating that the significance is likely an artifact of large and unequal sample sizes (Field, 2013). For the Crawling Model Score, variances based on means were equal, $F(6, 269) = 1.626, p = 0.140$. We conclude from this analysis that the assumption of homogeneity of variances is acceptably met by our data. Finally, we tested for homoscedasticity by examining the scatter plot of zpred vs. zresid. The resulting plot resembled an overall random array, indicating no issues with homoscedasticity.

The linear regression was conducted to determine whether Crawling Model Score and Subject Group could predict Insect Disgust Score. The result of this analysis yielded a significant model, ($F(3, 262) = 47.873$, $p < 0.001$, $R^2 = 0.354$, $R^2_{\text{Adjusted}} = 0.347$). This indicates that approximately 35% of the variation in Insect Disgust Scores is predicted by differences in Crawling Model Score and Subject Group. Each of the three predictor variables were significant additions to the model, as indicated by their standardized beta values. For Crawling Model Score (standardized $\beta = -0.181$, $p < 0.001$), this value indicates that as the Crawling Model Score increases by one standard deviation (1.73), the Insect Disgust Score decreases by -0.181 standard deviations (-0.181×6.12), or 1.11.

The dummy variable of ENT vs. NSU had a standardized β of 0.616 ($p < 0.001$). This indicates that the difference in disgust score for a person in the NSU group compared to a person in the ENT group was significant. The GEO vs. ENT dummy variable had a standardized β of 0.283 ($p < 0.001$), thus, the difference in disgust score for a person in the GEO group compared to a person in the ENT group was also significant.

Table 4.5. Linear model of the predictors of Insect Disgust Score.

	b	**SE b**	**β**	**p**
Constant	16.327	0.853	-	$p < 0.001$
Crawling Model Score	–0.639	0.182	0.616	$p < 0.001$
ENT vs NSU	7.836	0.781	0.283	$p < 0.001$
ENT vs GEO	3.640	0.774	–0.181	$p = 0.001$

DISCUSSION

The results of this study clearly indicate that insect experts differ in their reported level of insect-associated disgust from insect novices. This finding is in line with a trend, documented in previous literature, that experts perceive their object of expertise differently from novices (Chi et al., 1981; Boete & Moran, 2016). However, we are not able to discern from our results whether this lower disgust is truly the result of the process of developing expertise, or whether the individuals who choose to become entomologists tend to have lower disgust toward insects at the outset. Nevertheless, the possibility that having knowledge and experience with insects acts to reduce one's negative emotions associated with them is still a plausible one. This is because experimental studies have found that habituation can indeed influence affect toward a stimulus (Rozin, 2008; Viar-Paxton & Olatunji, 2012), and that experts are known to become emotionally habituated to disgusting stimuli (Cheng et al., 2007). In addition, exposure to a disgusting stimulus across multiple contexts has been found to be more effective at reducing disgust than exposure in one context (Viar-Paxton & Olatunji, 2012). Therefore, it seems very likely that the ENTs greater experience and exposure to insects caused them to feel less disgust associated with insects. Training in science, regardless of exposure to insects, appears to also mediate insect-associated disgust, as our GEO participants scored approximately mid-way between NSUs and ENTs on the Insect Disgust Survey.

Another goal of this study was to determine whether drawings of disgusting insects differ from drawings of not disgusting insects. That is, are there qualities of insects that particularly evoke disgust? What does a disgusting insect look like, in comparison to a non-disgusting insect? From analysis of the drawings, we noted a clear trend that had to do with the inclusion of legs versus wings; legs were more commonly included on disgusting insects, wings were more commonly included on not disgusting insects, and the two features are strongly negatively correlated with each other (Chapter Three). Though *all* insects have legs, save for those in their larval or pupal life stages, participants were more likely to include them when evoking disgusting insects. This may indicate that people are more likely to label an insect as disgusting when they perceive it to be crawling on its legs. These results could be related to the fact that parasites like fleas and lice are crawling pests – they do not possess wings. Disgust as an emotion is associated with aversion to potentially damaging stimuli, thus, it is possible that people in general have a greater aversion to crawling insects in order to facilitate avoidance of these types of macroparasites. Disgust is very relevant to disease; in fact, disgust has been postulated to be evolutionarily driven by the desire to avoid pathogens and other undesirable stimuli (Curtis et al., 2004; Oaten et al., 2009; Tybur et al., 2009). We noted that the insects (and other arthropods) that were drawn most often in the disgusting category were insects that were associated with disease and pathogens. This aligns with a trend in the literature of disease-relevant insects being perceived as more disgusting than disease-irrelevant insects (Curtis et al., 2004; Prokop & Fančovičová, 2010). Curtis et al. (2004) asked people to rate the disgustingness of contrasting pairs of disease-relevant and irrelevant stimuli. They found that disease-irrelevant insects (tent caterpillars, wasp) were rated similarly to disease-relevant animals (parasitic worms, louse). Curtis et al. (2004) attribute this similarity to the fact that the insects are also "biologically relevant" (p. S132), in that they represent danger. The authors state, "Further work should reveal whether the response pattern to disgust-relevant insects varies with the exposure that people have had to different species in different ecological zones" (p. S132). In this current study, we did not test or ask about participants' actual behaviors associated with disgusting versus not disgusting insects, however, one study found that people were more likely to take action such as using pesticides upon finding a crawling pest than a flying one (Baldwin et al., 2008).

There was no relationship between crawling model score and disgust score for the disgusting drawings, despite the fact that some features of the crawling model (legs, mouth, segmentation) were more common among disgusting drawings than not disgusting drawings, and crawling insect model scores were higher for disgusting than not disgusting drawings. This may indicate that people included these features regardless of their reported level of disgust toward insects. A logical conclusion here is that despite individual differences in reported disgust, there seems to be a consensus (lack of variation) in that everyone thinks the same insect features (or same types of insects) are disgusting. This suggests that educators and researchers can better assess levels of insect-associated disgust by asking people to draw insects that they do not consider disgusting.

The third research question addressed in this study is, can the intensity of an individual's disgust toward insects be predicted by examining their drawings of insects? We tested this for the not-disgusting drawings only. We found that participants' crawling model scores were a significant predictor of insect-associated disgust, in that higher crawling model scores predicted lower disgust scores, though this effect was relatively small. Subject group, and thus, expertise, was a stronger predictor of insect-associated disgust than crawling model score. Being either a NSU or GEO were significant predictors of disgust score; each were associated with greater disgust than the ENT participants. It is worth noting that being an NSU was the strongest predictor of insect disgust.

We conclude that educational and professional backgrounds play a role in mediating disgust toward insects, and that examining drawings of insects can be a useful tool to shed light on affect associated with insects.

REFERENCES

REFERENCES

Ainsworth, S., Prain, V., and Tytler, R. (2011) Drawing to learn in science. *Science, 333*(6046): 1096–1097.

Baldwin, R. W., Koehler, P. G., Pereira, R. M., and Oi, F. M. (2008) Public perceptions of pest problems. *American Entomologist, 54*(2): 73–79.

Bixler, R. D., Carlisle, C. L., Hammltt, W. E., and Floyd, M. F. (1994) Observed fears and discomforts among urban students on field trips to wildland areas. *The Journal of Environmental Education, 26*: 24–33.

Bluhm, R. (2013) Self-fulfilling prophecies: the influence of gender stereotypes on functional neuroimaging research on emotion. *Hypatia, 28*(4): 870–886.

Boëte, C., and Morand, S. (2016) Bats and academics: how do scientists perceive their object of study? *PLOS ONE, 11*(11): e0165969.

Breckler, S. J. (1984) Empirical validation of affect, behavior, and cognition as distinct components of attitude. *Journal of Personality and Social Psychology, 47*(6): 1191–1205.

Cheng, Y., Lin, C. P., Liu, H. L., Hsu, Y. Y., Lim, K. E., Hung, D., and Decety, J. (2007) Expertise modulates the perception of pain in others. *Current Biology, 17*(19): 1708–1713.

Chi, M. T. H., Feltovich, P. J., and Glaser, R. (1981) Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*(2): 121–52.

Clore, G. L., and Huntsinger, J. R. (2007). How emotions inform judgment and regulate thought. *Trends in Cognitive Sciences*, *11*(9): 393-399.

Curtis, V., Aunger, R., and Rabie, T. (2004) Evidence that disgust evolved to protect from risk of disease. *Proceedings of the Royal Society of London B: Biological Sciences, 271*(Suppl 4): S131–33.

Davey, G. C. L. (1994) Self-reported fears to common indigenous animals in an adult UK population: the role of disgust sensitivity. *British Journal of Psychology, 85*(4): 541–554.

Dove, J. E., Everett, L. A., and Preece, P. F. W. (1999) Exploring a hydrological concept through children's drawings. *International Journal of Science Education, 21*(5): 485–497.

Field, A. (2013) *Discovering statistics using IBM SPSS statistics*. Fourth ed. Sage.

Haidt, J., McCauley, C., and Rozin, P. (1994) Individual differences in sensitivity to disgust: a scale sampling seven domains of disgust elicitors. *Personality and Individual Differences, 16*(5): 701–713.

Kellert, S. R. (1993) Values and perceptions of invertebrates. *Conservation Biology, 7*(4): 845–855.

Lorenz, A. R., Libarkin, J. C., and Ording, G. J. (2014) Disgust in response to some arthropods aligns with disgust provoked by pathogens. *Global Ecology and Conservation, 2*: 248–254.

Losey, J. E., and Vaughan, M. (2006) The economic value of ecological services provided by insects. *BioScience, 56*(4): 311–323.

Löfström, E., and Nevgi, A. (2014) Giving shape and form to emotion: using drawings to identify emotions in university teaching. *International Journal for Academic Development, 19*(2): 99–111.

Oaten, M., Stevenson, R. J., and Case, T. I. (2009) Disgust as a disease-avoidance mechanism. *Psychological Bulletin, 135*(2): 303–21.

Oster, G. D., and Crone, P. G. (2004) *Using drawings in assessment and therapy: A guide for mental health professionals*. Psychology Press.

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., Bullmore, E. T., Perrett, D. I., Rowland, D., Williams, S. C. R., Gray, J. A., and David, A. S. (1997) A specific neural substrate for perceiving facial expressions of disgust. *Nature,* 389(6650): 495–498.

Prokop, P., and Fančovičová, J. (2010) The association between disgust, danger and fear of macroparasites and human behaviour. *Acta Ethologica, 13*: 57–62.

Rozin, P. (2008) Hedonic 'adaptation': specific habituation to disgust/death elicitors as a result of dissecting a cadaver. *Judgment and Decision Making; Tallahassee,* 3(2): 191.

Schienle, A., Schäfer, A., Stark, R., Walter, B., and Vaitl, D. (2005) Gender differences in the processing of disgust- and fear-inducing pictures: an fMRI study. *Neuroreport, 16*(3): 277–280.

Shepardson, D. P. (2002) Bugs, butterflies, and spiders: children's understandings about insects. *International Journal of Science Education, 24*(6): 627–643.

Snaddon, J. L., and Turner, E. C. (2007) A child's eye view of the insect world: perceptions of insect diversity. *Environmental Conservation, 34*: 33–35.

Tanaka, J. W., and Curran, T. (2001) A neural basis for expert object recognition. *Psychological Science, 12*: 43–47.

Tybur, J. M., Lieberman, D., and Griskevicius, V. (2009) Microbes, mating, and morality: individual differences in three functional domains of disgust. *Journal of Personality and Social Psychology, 97*: 103–22.

Viar-Paxton, M. A., and Olatunji, B. O. (2012) Context effects on habituation to disgust-relevant stimuli. *Behavior Modification, 36*(5): 705–722.

Wilcove, D. S., and Master, L. L. (2005) How many endangered species are there in the United States? *Frontiers in Ecology and the Environment, 3*: 414–420.

APPENDIX

INTRODUCTION

Public attitudes toward insects and other arthropods are overwhelmingly negative, despite the fact that both ecologically and economically arthropods are among the most important creatures on the planet. The exact origin of negative attitudes toward insects remains somewhat mysterious. In particular, childhood seems to be an important time for the formation of lasting beliefs and values pertaining to wildlife (Deruiter & Donnelly, 2002). For example, one study suggested that the most effective time for building empathy and appreciation toward wildlife is between the first and fifth grade (ages 6-10 years) (Kellert, 1985). In addition, Shepardson (2002) surveyed elementary school students from kindergarten through the fifth grade about their perceptions of insects, and noted that the emergence of negative attitudes toward insects started around first grade (ages 6-7 years).

The experience of keeping an animal as a pet can enhance an individual's sense of empathy (Daly & Morton, 2006; Daly & Suggs, 2010). Children who keep pets are better informed about their pets' biology than children who do not keep pets (Prokop et al., 2008). Keeping pet animals in an educational context has been reported by teachers to be beneficial for children's socio-emotional development (Daly & Suggs, 2010). In addition, exposure to animals which formerly were negatively perceived has been shown to enhance children's' appreciation for those animals (Lindemann-Matthies, 2005).

A previous study by Korte et al. (2005) introduced live Madagascar Hissing Cockroaches (*Gromphadorhina portentosa*) as pets in a first grade classroom, and observed the children as they "got to know" the cockroaches and made observations about their behavior. The children were interviewed at two time points – just before the cockroaches were first introduced to the class, and again after several weeks had passed and the children had studied the cockroaches and handled them several times. The children reacted positively to the roaches by the end of the study.

In order to challenge negative perceptions toward insects, it is important to habituate individuals as children to the diverse forms, functions, modes of living, and beneficial services provided by the insect world. Habituation has been shown to be an effective means of developing positive interest in items that were previously regarded as distasteful (Holstermann et al., 2012). In the following study, we introduced live pet insects to elementary school classrooms and collected drawings from students in order to detect changes in the children's mental models of insects.

METHODS

Study Design and Data Collection

As part of a larger series of surveys designed to assess elementary school students' attitudes and knowledge towards insects, students in three 1st/2nd (combined) grade classrooms and three 3rd/4th (combined) grade classrooms at a local public school completed a drawing task. The task was administered to students pre- and post-participation in a series of targeted lessons structured around interactions with live pet insects (hissing cockroaches, blue death-feigning beetles, and superworms). Thus, each student made two drawings, with the exception of some who were absent on the days that the surveys were given. Drawings were completed in the students' regular classrooms during normal class time. Students were instructed not to talk to each other as they completed the task, so as not to influence one another's drawings. The students were instructed by the first author that the insect they were to draw could be of any kind that they wished, but should be a "real" type of insect (*i.e.*, not imaginary). In a few circumstances students asked, "Can I draw a spider?" and were instructed that that would be acceptable despite the fact that spiders are not insects. The reason for this is that children tend to classify spiders as insects, and children commonly draw spiders when they are asked to draw insects (Shepardson, 2002). The pre-participation surveys were given between September 30 and October 6, 2015, before the start of the insect lessons. The post-participation surveys were given between December 9-11, 2015, after the lessons had finished. Topics covered in the insect lessons included external insect morphology, sociality, defense mechanisms, and life cycles.

Participants

One hundred and sixty three students from six classrooms (three 1st/2nd grade combined and three 3rd/4th grade combined) at public elementary school in Michigan, U.S., participated in this study during the autumn and early winter of 2014. Participants ranged from 6 to 10 years of age. We report on the analysis of 140 pre- and 161 post-lesson drawings. Sample size differed between the two treatments mainly due to differential student attendance during sampling days. In addition, an illustration that decorated the front of the pre-participation survey may have influenced some students in their drawings. In an attempt to eliminate this potential confound, we removed from our analysis all pre-participation drawings (n=21) that bore strong similarity to the cover illustration and removed the cover illustration for the post-survey.

Table A.1. Age and gender of participants.

	n	**Mean Age (SD)**	**% Male**
Pre	140	7.69 (1.18)	43.6
Post	161	7.71 (1.2)	47.2

Coding of drawings

Several methods for interpreting drawings quantitatively have been utilized in previous analyses of children's drawings, such as indexing of salient features (Libarkin et al., 2015), computer-based pattern analyses (Forbus et al., 2011) and grouping drawings into pre-defined categories (Dove et al. 1999; Shepardson, 2002). In our study, each child's drawing was analyzed by coding the individual features of each insect. An iterative process was used to develop the coding scheme. All three raters began by examining a subset of ten randomly selected drawings together and listing prominent features from each drawing. Each feature was given a definition that was mutually agreed upon by all three authors. Once the coding scheme was finalized, each author independently coded the same 20 drawings, after which an intraclass correlation was conducted.

Data analysis

Data were analyzed using SPSS 21.0 (IBM, Inc., Chicago, IL, U.S.A.). We calculated the frequencies of all coded variables from both of our two sampling periods. In order to determine whether the frequency of coded features changed pre to post, we compared the pre and post frequencies of each feature in paired-samples t-tests. In addition, we conducted a correlation analysis between all coded variables to determine whether the data were likely to contain underlying models. After the method of Libarkin et al. (2015), who utilized principal components analysis (PCA) to identify underlying models in undergraduates' drawings of the greenhouse effect, we wanted to determine whether children's representations of insects contained discernible patterns that could be elucidated via PCA. We then utilized point-biserial correlations in order to determine the relationship between alignment of drawings with models (the factor score) and the use of descriptive codes (e.g. two eyes, six legs, etc.), as well as the relationship between factor score and the demographic variables gender and grade level.

RESULTS

Coding of drawings

The average measures intraclass correlation across the three raters was 0.92 (min. = 0.91 and max. = 0.93). An intraclass correlation close to 1.0 suggests that each coder's analysis of the drawings is consistent with the others'. Given this high level of agreement, the remaining drawings were coded by one rater. Coding of the children's drawings resulted in the identification of 22 distinct insect features that existed in the drawings collectively (Table A.2). Several of these features, or codes, were automatically related to each other. For example, we coded for the presence or absence of some of the most common and obvious insect features such as eyes, mouth, etc., and additionally, we coded for descriptors of those features (should they be present) such as number of eyes, shape of the mouth, decoration on the wings, etc. (see Table A.2). Thus, the presence of some of the major codes (eyes, mouth, etc.) automatically guaranteed the use of an additional descriptive code. Because these major features are related to their descriptors, but coded separately, we utilized only the major codes such as "mouth" and "eyes" in our factor analysis.

The drawings in our sample were created by children representative of a range of age levels (from 6 to 10 years of age). Not surprisingly, we noted quite a bit of variation within the drawings across the sample. However, there were some consistently obvious patterns that are reflected in our coding scheme. For example, all of the children drew some sort of "body" for their insect. The precise shapes of the bodies differed to an extent, but all could be classified as either more *rounded* or *elongate* in shape. To reflect this pattern, we coded body shape as one dichotomous variable with the two mutually-exclusive conditions *round* and *long*. In the results section, a positive factor loading for the variable "body shape" indicates a round body as part of the model, and a negative loading indicates a long body. If the variable does not load, that indicates that body shape was variable and is not essential to the model.

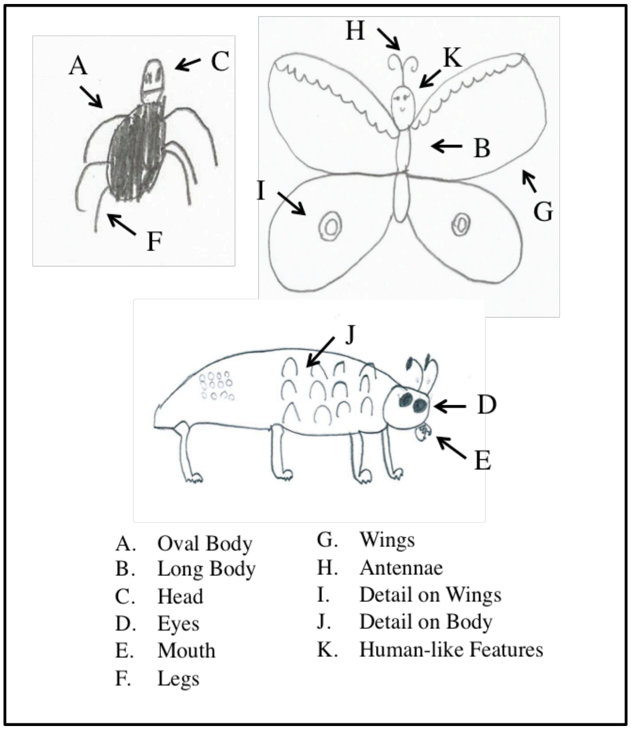

Figure A.1. Examples of coded features.

Frequency of coded features

The most commonly drawn insect features, both pre- and post-lessons, were legs, eyes, head, and antennae, respectively. Table A.2 gives the frequencies, as well as the results of significance testing between the pre- and post-participation occurrence of each coded feature.

Only a few features significantly differed in their frequency pre v. post. Of the major codes, only head (p=0.005) and mouth (p=0.037) showed significant increases. Of the other coded features, the frequency-of-use of antennae (p=0.005), stinger (p=0.004), and detail/decoration on the body (p=0.013) increased significantly. The frequency of drawings with eight legs decreased significantly (p=0.023). There was also a marginally-significant decrease in insects with long, pointed mouthparts (p=0.059).

Table A.2. Frequencies of the presence of each variable and also significance of differences pre/post using paired-samples t-tests.

Characteristics	**Before Instruction (n=140)**	**After Instruction (n=160)**	**Sig.**
	% Present	***% Present***	
Body Shape			
Oval	49.3	41	0.79
Long	50.7	59	
Head	66.4	75.2	0.005
Eyes	69.3	75.2	0.09
Mouth	42.9	45.3	0.037
Legs	71.4	66.5	0.502
Wings	37.1	46.6	0.205
Antennae	52.1	58.4	0.005
Cerci	2.9	1.2	0.158
Stinger	5	13	0.004
Hair	5	6.2	0.809

Correlational analysis

We investigated correlations between all coded characteristics prior to factor analysis. Sample sizes consisted of 140 pre-participation drawings and 160 post-participation drawings. Pre- and post-participation data were tested in two separate correlations. We noted that many of the most commonly drawn coded features correlated with other features with coefficients above

0.3 (Tables A.3), indicating the potential presence of underlying latent factors in the data (Field, 2013). In light of this result, we continued with our investigation of whether the pre- and post-participation data met the qualifications for factorability.

Also of note is the strong negative correlation, both pre- and post-, between legs and wings. We can infer from this that children who drew legs on their insect were unlikely to also include conspicuous wings, and vice versa. This relationship is also reflected in the following analyses, and is expanded upon in the discussion section.

Table A.3. Pearson correlations between major coded variables before and after the instructional period. $*p < 0.01$; $**p < 0.05$.

PRE	**Head**	**Shape**	**Legs**	**Wings**	**Eyes**	**Mouth**
Head	1		.187*		.281**	
Shape		1	.370**	-.344**	.192*	
Legs	.187*	.370**	1	-.528**	.333**	
Wings		-.344**	-.528**	1		
Eyes	.281**	.192*	.333**		1	.389**
Mouth			.		.389**	1
POST	**Head**	**Shape**	**Legs**	**Wings**	**Eyes**	**Mouth**
Head	1	.187*	.261**	-.183*	.301**	.264**
Shape	.187*	1	.271**	.272**		
Legs	.261**	.271**	1	-.655**		
Wings	-.183*	-.272**	-.655**	1		
Eyes	.301**				1	.408**
Mouth	.264**				.408**	1

PCA of pre-participation drawings

To analyze the pre-data, we ran a PCA with no rotation and latent factors extracted at eigenvalues greater than one, which is Kaiser's criterion (Field, 2013). In addition, examination of the point of inflection of the scree plot was also utilized as a criterion for determining the number of latent factors (Catell, 1960; Costello & Osborne, 2005). We employed the major codes of head, mouth, eyes, legs, wings, and body shape as (oval vs. long) in our statistical model, as these characteristics were the most frequently drawn major features of insects across the sample. We report a Kaiser-Meyer-Olkin measure of sampling adequacy of 0.645, which is above the recommended threshold of 0.5, and in addition Bartlett's test of sphericity was significant (χ^2 (15) = 124.829, $p < 0.001$) (Field, 2013). Furthermore, the anti-image correlation matrix revealed that correlation coefficients on the diagonal were all above 0.5, and communalities for the five variables utilized in our model were all above 0.3, further indicating the validity of factor analysis as an analytical approach to these data (Field, 2013).

Two factors emerged from the analysis with eigenvalues greater than one, with the first factor explaining 35.8% of the variance, and the second factor explaining 21.9%, for a total of 57.7% of variation in the data explained by two latent factors. In addition, examination of the point of inflection of the scree plot also indicated the presence of two factors, hereafter referred to as *models*. Un-rotated loadings for coded features on each model are given in Table A1.4. A hypothetical illustration of each model is included in Figure A1.2, along with examples of drawings that appear to fit each model.

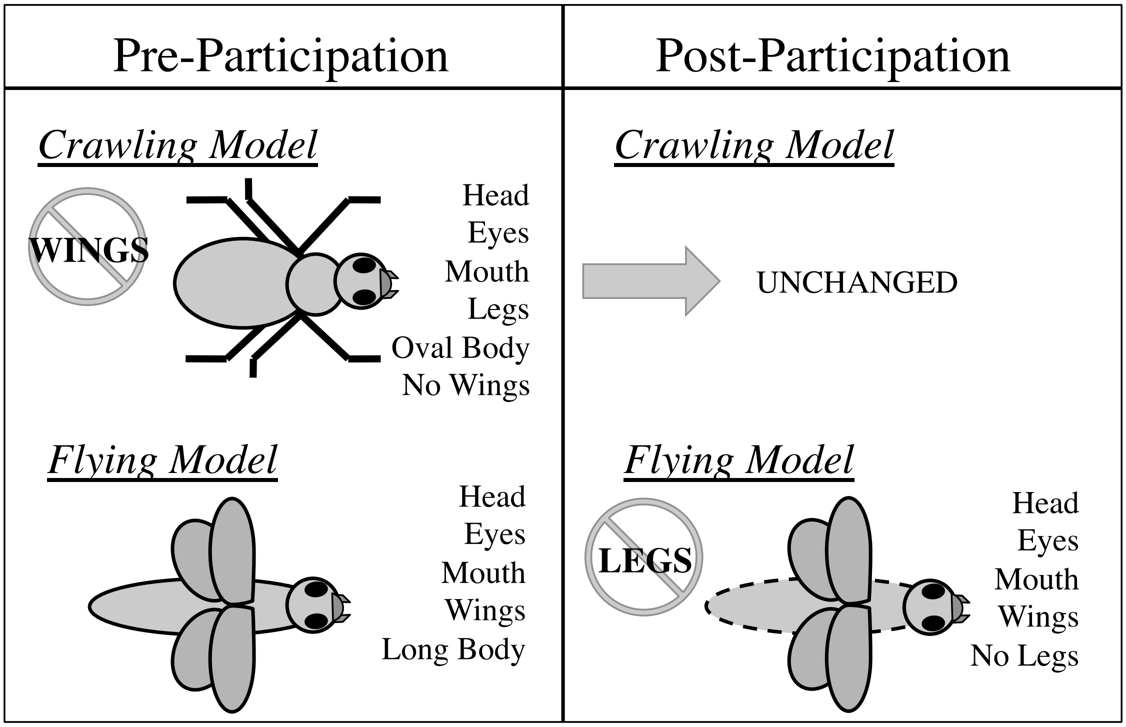

Figure A.2. Schematic illustration of both emergent insect models from the PCA of the pre- and post-instruction drawings. The crawling model did not change pre- and post-participation. The flying model changed in that long body was dropped and no legs was adopted.

The analysis suggests the presence of two separate constructs underlying the drawings. To determine the internal consistency of the two models, we calculated Cronbach's α for each model. Negatively-loading items were reverse-coded before conducting the analysis (Field, 2013). We report that Cronbach's $\alpha = 0.621$ for the Crawling Model (Oval Body, Legs, Eyes, Mouth, Head, No Wings), and $\alpha = 0.238$ for the Flying Model (Long Body, Eyes, Head, Wings, Mouth). Note that these two models are similar to the models of insects from Chapters three and four. In alignment with previous literature (Field, 2013), we interpret these alpha values to suggest that the Crawling Model is a reliable construct. However, the low alpha achieved by the Flying Model suggests it is not truly representative of underlying constructs.

Table A.4. Factor loadings for drawings pre-participation. Loadings below ±0.3 are suppressed.

Coded Feature	Crawling Model	Flying Model
Body Shape (+ Oval, – Long)	0.624	-0.312
Head	0.460	0.357
Eyes	0.624	0.522
Mouth	0.371	0.682
Legs	0.783	-
Wings	-0.636	0.613

PCA of post-participation drawings

For the post drawings, we also conducted a separate PCA with no rotation and factors extracted at eigenvalues greater than one. We utilized the same coded features as in the pre-data for our analysis, in order to determine whether the models changed or remained the same pre- to post-participation in the insect lessons. The Kaiser-Meyer-Olkin measure of sampling adequacy for the post-data was 0.62, which again is above the recommended threshold of 0.5, and Bartlett's test of sphericity was significant ($\chi^2(15) = 166.0$, $p < 0.001$) (Field, 2013). Communalities were above 0.3 for all variables, and diagonals in the anti-image correlation matrix were all above 0.5.

Similar to the pre-participation results, our analysis of post-participation drawings revealed two latent factors with eigenvalues greater than one. The first factor explains 34.64% of the variation, and the second factor explains 24.63%. Together these two latent factors account for 59.27% of the variance in the data. In addition, the scree plot was also indicative of the presence of two factors. Loadings for the post-data are given in Table A.5. The Crawling Model remains the same. Post-participation, the Flying Model changes in that body shape falls out of the model and not-legs is added. Please see Figure A.2 for visual depictions of these changes.

Analysis of the internal consistency of each model indicates that, post-participation, Cronbach's $\alpha = 0.605$ (acceptable) for the Crawling Model, and $\alpha = 0.361$ (low) for the Flying Model.

Table A.5. Factor loadings for post-participation drawings. Loadings below ±0.3 are suppressed.

Coded Feature	Crawling Model	Flying Model
Body Shape (+ Oval, – Long)	0.518	-
Head	0.611	0.331
Eyes	0.432	0.675
Mouth	0.373	0.696
Legs	0.777	-0.370
Wings	-0.711	0.492

DISCUSSION

The two insect models that emerged from the analysis are particularly interesting because they represent the two locomotory modalities by which children experience insects – crawling on the ground or other surface, and flying through the air. Another interesting finding is the mutually exclusive nature of legs and wings in the drawings, as indicated by our correlational and factor analyses. In short, factor loadings indicated that drawings of flying insects generally showed the wings but not the legs, and drawings insects with legs generally did not have wings. In nature, the vast majority of insects have both legs and wings, and thus this tendency to draw one but not the other is incongruent with reality and may be an especially important area to target during instruction about insects.

Breuer et al. (2015) documented a similar result in their investigation of children's conceptions of insects. Breuer et al. (2015) analyzed children's comments in response to exposure to images of different types of insects. Using a cluster analysis, Breuer et al. (2015) determined that the children's comments about the different insects that had or appeared to have wings grouped separately from comments about the insects (and other invertebrates) that did not have wings. It appears, then, that locomotory modality may be particularly important to children's conceptions of insects.

Though we did not explicitly investigate the relationships between children's attitudes toward insects and their drawings of them, it is very likely that a relationship exists (Jolley, 2010). The exact origins of negative attitudes toward insects are murky and have not been fully explicated. It has been postulated that humans are evolutionarily adapted to avoid insects because some species pose dangerous threats to humans (Ohman et al., 1985). Cultural environment, parental attitudes toward insects, and personal experiences of insects also play important roles that influence the strength and valence of attitudes toward insects (Breuer et al., 2015; Prokop et al., 2010).

It is quite striking how similar these models and relationships between features are to models that emerged from an analysis of adults' drawings of insects (Chapter 3). This suggests that flying and crawling – legs and wings – are perceived as distinct from each other from childhood through the lifespan.

REFERENCES

REFERENCES

Barraza, L. (1999) Children's drawings about the environment. *Environmental Education Research 5*: 49-66.

Bjerke, T., and Østdahl, T. (2004) Animal-related attitudes and activities in an urban population. *Anthrozoos, 17*: 109–129.

Breuer, G. B., Schlegel, J., Kauf, P., and Rupf, R. (2015) The importance of being colorful and able to fly: interpretation and implications of children's statements on selected insects and other invertebrates. *International Journal of Science Education, 37*(16): 2664–2687.

Cardoso, P., Erwin, T., Borges, P. and New, T. (2011) The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation*, *144*(11): 2647-2655.

Cattell, R. B. (1966) The scree test for the number of factors. *Multivariate Behavioral Research 1*: 629-637.

Daly, B., and Morton, L. L. (2006) An investigation of human-animal interactions and empathy as related to pet preference, ownership, attachment, and attitudes in children. *Anthrozoös*, *19*(2): 113-127.

Daly, B., and Suggs, S. (2010) Teachers' experiences with humane education and animals in the elementary classroom: implications for empathy development. *Journal of Moral Education, 39*: 101-112.

De Winter, J. C. F., and Dodou, D. (2016) Common factor analysis versus principal component analysis: A comparison of loadings by means of simulations. *Communications in Statistics – Simulation and Computation, 45*: 299-321.

Dove, J. E., Everett, A., and Preece, P. F. W. (1999) Exploring a hydrological concept through children's drawings. *International Journal of Science Education, 21*(5): 485-497.

Field, A. (2013) *Discovering statistics using IBM SPSS statistics*. Sage.

Forbus, K., Usher, J., Lovett, A., Lockwood, K., & Wetzel, J. (2011). CogSketch: Sketch understanding for cognitive science research and for education. *Topics in Cognitive Science*, *3*(4), 648-666.

Jolley, R. P. (2010) *Children & Pictures: Drawing and understanding*. Wiley-Blackwell.

Kidd, A.H., and Kidd, R. M. (1990) Social and environmental influences on children's attitudes toward pets. *Psychological Reports, 67*: 807-818.

Kellert, S.R. (1993) Values and perceptions of invertebrates. *Biological Conservation, 7*(4): 845-855.

Losey, J.E., and Vaughan, M. (2006) The economic value of ecological services provided by insects. *BioScience, 56*(4): 311-323.

Martín-López, B., Montes, C., and Benayas, J. (2007) The non-economic motives behind the willingness to pay for biodiversity conservation. *Biological Conservation, 139*: 67-82.

McLean, M., Henson, Q., and Hiles, L. (2003) The possible contribution of student drawings to evaluation in a new problem-based learning medical programme: a pilot study. *Medical Education, 37*(10): 895-906.

Ohman, A., Dimberg, U., and Ost, L.-G. (1985) Animal and social phobias: Biological constraints on learned fear responses. In S. Reiss & R. R. Bootzin (Eds.), *Theoretical issues in behavior therapy* (pp. 123-178). New York: Academic Press.

Prokop, P., A. Tolarovičová, A., Camerik, A. M., and Peterková, V. (2010) High school students' attitudes towards spiders: A cross‐cultural comparison. *International Journal of Science Education, 32*(12): 1665-1688.

Sallam, M. Eds. Mejia, D., and Lewis, B. 1998. Insect damage: damage on post-harvest. International Centre of Insect Physiology and Ecology. Food and Agriculture Organization of the United Nations.

Shepardson, D. (2002) Bugs, butterflies, and spiders: children's understandings about insects. *International Journal of Science Education, 24*(6): 627-643.

Snaddon, J. and Turner, E. (2007) A child's eye view of the insect world: perceptions of insect diversity. *Environmental Conservation, 34*: 33-35.