Journal of Biological Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rjbe20

Seeing coloured fruits: utilisation of the theory of adaptive memory in teaching botany

Pavol Prokop[a] & Jana Fančovičová[a]

[a] Department of Biology, Faculty of Education, Trnava University, Priemyselná 4, 918 43. Trnava, Slovakia.

Published online: 08 Oct 2013.

Journal of Biological Education, 2014
Vol. 48, No. 3, 127–132, http://dx.doi.org/10.1080/00219266.2013.837407

Research paper

Seeing coloured fruits: utilisation of the theory of adaptive memory in teaching botany

Pavol Prokop and Jana Fančovičová

Department of Biology, Faculty of Education, Trnava University, Priemyselná 4, 918 43 Trnava, Slovakia

Plants are characterised by a great diversity of easily observed features such as colours or shape, but children show low interest in learning about them. Here, we integrated modern theory of adaptive memory and evolutionary views of the function of fruit colouration on children's retention of information. Survival-relevant (fruit toxicity) and survival-irrelevant information (naming and occurrence) about twelve plant species that differ in toxicity (toxic and non-toxic) and fruit colouration (red, green and black) were presented to a sample of Slovak high school students. Analyses of surprise retention tests immediately after a plant presentation and one week later showed that participants retained more information about plants with red and black fruits, compared with plants with green fruits. Survival-relevant information was retained significantly better than survival-irrelevant information and fruit's edibleness was associated with the colour red and toxicity was associated with the colour black. This study provides support for the existence of evolved memory mechanisms that enhance retention of survival-relevant information. Furthermore, it highlights the importance of fruit colouration as well as the type of information that children receive about plants on their cognitive processes.

Keywords: adaptive memory; botany; colour; evolution; education

Introduction

When teaching about plants, science educators struggle with several problems in science or botany courses. Learning about plants is perceived to be less interesting than learning about animals (Kinchin 1999; Lindemann-Matthies 2005; Martin-López et al. 2007; Prokop, Prokop, and Tunnicliffe 2007a, b; Schussler and Olzak 2008; Wandersee 1986), photographs of plants in textbooks are less numerous and less diverse than photographs of animals (Link-Perez et al. 2010) and attitudes toward plants are neutral rather than positive (Fančovičová and Prokop 2010, 2011; Selvi 2012). Students also have serious misconceptions about the physiology of plants (Kose et al. 2009; Ozay and Oztas 2003), and their abilities to name plants are limited (Bebbington 2005; Fančovičová and Prokop 2011). There is evidence that females have better knowledge about plants than males (Fančovičová and Prokop 2011; Laiacona, Barbarotto, and Capitani 2006) and that females appreciate plants more than males (Gatt et al. 2007; Hong, Shim, and Chang 1998; Prokop et al. 2007a, b; Schussler and Olzak 2008).

Many plants have colourful flowers that attract pollinators (Glover 2007; Waser and Ollerton 2006) and additionally, a number of species produce often colourful fruits that are consumed by various animals to promote plant dispersion (Ridley 1930; Schmidt et al. 2004). Humans, as well as some non-human primates, have trichromatic vision (Dominy, Svenning, and Li 2003; Jacobs and Deegan 1999; Regan et al. 2001), which allows them to distinguish between blue, green, and red. The innate preference for the colour red was found in humans (Franklin et al. 2010), particularly in females (Hurlbert and Ling 2007). Analyses of children's spontaneous conversation in botanical gardens showed that colours of

Corresponding author: Pavol Prokop, Department of Biology, Faculty of Education, Trnava University, Priemyselná 4, 918 43 Trnava, Slovakia; Institute of Zoology, Slovak Academy of Sciences, Dúbravská cesta 9, 845 06 Bratislava, Slovakia. Email: pavol.prokop@savba.sk

plants attract a child's attention (Tunnicliffe 2001). Because redness is a cue of ripening (due to carotenoids), it is thought that the preference for the colour red evolved to increase the probability of finding ripe fruits (Heerwagen and Orians 1993; Hurlbert and Ling 2007; Prokop and Fančovičová 2012). However, not all coloured fruits are edible; instead strong and contrasting colours (red, yellow, black or brown) often characterise aposematic unpalatable or poisonous species (Edmunds 1974; Gittleman and Harvey 1980; Lev-Yadun 2001).

Learning and conceptual processes depend strongly on memory functioning and capacity (Norman 1982; Terry 2005) which consequently influences academic success (Shade 1982). According to modern evolutionary perspective, people show better memory for information processed with respect to ancestral scenarios, such as searching for edible plants or avoiding predators, than for scenarios based purely on the modern environment. That is, our *adaptive memory* and learning systems may be tuned or biased to help us remember information in a survival context (Nairne, Thompson, and Pandeirada 2007). Although the concept of adaptive memory is new (Nairne, Thompson, and Pandeirada 2007), an increasing amount of research has found support for this theory (Nairne 2010). For example, participants who were asked to rate the relevance of unrelated words to a survival scenario, subsequently remembered those words better than participants who processed those same words in several deep-processing control conditions (Nairne, Thompson, and Pandeirada 2007). Barrett and Broesch (2012) found that children from two different cultures remembered information about the dangerousness of selected animals better than other kinds of information. Prokop and Tunnicliffe (2010) showed that school children have better knowledge about predators, disease-relevant animals or pests than about control animals, despite their attitudes toward the former group of animals being less favourable, suggesting that children selectively retain more information about events associated with survival.

In this study, we integrated the modern perspective of adaptive memory with recent theories about colour preference in humans on the grounds of biology education – in this case, to botany lessons. We propose that this interdisciplinary approach that respects evolved psychological mechanisms in humans can be used to examine how to make botany more attractive to children. Specifically, we hypothesise that information about fruits with colours that signal ripeness (particularly red) would be retained better than information about fruits that do not signal ripeness (particularly green) (Hypothesis 1). Second, we hypothesise that information regarding fruits relevant to survival would be better retained than other kinds of information (Hypothesis 2) and that information about toxic plants would be retained better than information about non-toxic plants (Hypothesis 3). We included black fruits in our research to see whether contrasting colours (red and black) are associated more with edibleness or with toxicity of the tested plants. Finally, we hypothesise that females, who appreciate plants more than males, would retain more information about plants than males (Hypothesis 4).

Methods

Participants

The sample of participants (18 males and 53 females) consisted of 16–18-year-olds attending three classes in one Slovak urban high school. The mean age of the participants was 16.4 (SE = 0.06) years and all participants were second year students. A brief open question about the interest in plants (Are you interested in plants?) confirmed that interest in botany was low (only seven participants [10%] reported to have an interest in plants). This variable was not included in statistical analyses due to a low sample of participants interested in plants. In addition, the participants were asked about their experience with each fruit (Have you ever seen this fruit?) and about their identification skills (Do you know the name of this species?). None of the participants reported having had experience with the fruits or any of the names of the presented species. Thus, we conclude that the children were not familiar with the presented fruits and that these two variables were not involved in further statistical tests.

All participants were volunteers, unaware about our hypotheses. After the experiment finished, participants were debriefed about our research goals.

Selection of plants

Stimuli consisted of a set of 12 colour photographs of fruits in lecture halls. All pictures were downloaded from Google. We adjusted the picture sizes to a standard body length. The pictures had a similar contrast and brightness and were presented in a random order. Each picture contained leaves and ripe fruits of particular species. The set of plants was selected so that there would be equal numbers of plants that were toxic and non-toxic to children and equal numbers of plants that have red, green and black fruits. Thus, there was a 2 × 3 design of toxicity (toxic or non-toxic) and colour (red, green black). The full list of presented species is shown in (Table 1).

Procedure

Each picture was presented for up to 2 minutes. During this time, the participants received oral information about the Slovak name of the plant,

Table 1. Plant species used in PPT presentation

Toxicity	Colour	Latin name	English name	Slovak name
Toxic	Red	*Nertera granadiensis* L.	Coral bead plant	Nertera granadská
		Ilex aquifolium L.	Common holly	Cezmína ostrolistá
	Green	*Lantana camara* L.	Spanish flag	Lantana menlivá
		Solanum carolinense L.	Carolina horsenettle	'Divoká paradajka'
	Black	*Hyoscyamus niger* L.	Henbane	Blen čierny
		Hedera helix L.	Common ivy	Brečtan popínavý
Non-toxic	Red	*Eugenia uniflora* L.	Pitanga	Pitanga
		Malpighia glabra L.	Barbados cherry	Barbadoská čerešňa
	Green	*Macadamia integrifolia* Maiden, Betche	Macadamia nut	Makadámia celolistá
		Baccaurea motleyana Muell.Arg.	Rambai	Rambai
	Black	*Aristotelia chilensis* L.	Chilean wineberry	Maqui
		Euterpe oleracea L.	Acai palm	Acai

occurrence, and toxicity (toxic or non-toxic). The presentation was made by their biology teacher (25-year-old female), who was trained by the authors of this paper, but was not aware of our specific research goals to avoid any bias during data collection. The oral presentation lasted approximately 20 minutes and was repeated three times (each class received the same presentation). Each class, however, received only one oral presentation. Immediately after the presentation finished, a surprise retention test was given to participants. The surprise retention test (hereafter test) consisted of three questions: (1) Naming (Do you remember the name of this species?); (2) Toxicity (Are fruits of this plant toxic or not?); and (3) Occurrence (Where does this species occur?). The teacher presented the twelve plants in a PPT presentation again, and students responded to the three questions on each species that was shown for 90 seconds. One week later, a retest was given to participants in the same way as the test. The order of plants presented in PPT presentation was randomised across trials.

Statistical analyses

A 2 (gender: between-subject) × 2 (test/retest: within-subject) × 3 (type of question: within-subject) × 2 (toxicity: within-subject) × 3 (colour: within-subject). General Linear Model was performed using STATISTICA ver. 10. Partial η^2 was used in order to measure the effect size (0.01 was considered small, 0.04 moderate, and 0.1 large; Huberty 2002).

Results

Colour

Participants' mean scores were significantly influenced by fruit colour both in test and retest conditions ($F(2,138) = 29.2$, $p < 0.0001$, $\eta^2 = 0.30$, Figure 1). Information about red and black fruits were better retained than information about green fruits (Tukey post hoc test, both $p < 0.001$), but there was no difference in the mean scores for red and black fruits (Tukey post hoc test, $p = 0.2$). This provides support for Hypothesis 1.

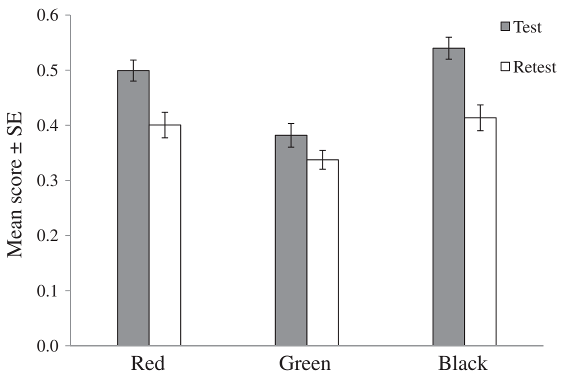

Figure 1. Differences in retention scores across fruit colour and conditions

Type of question

Participants' mean scores did significantly differ with respect to the three questions, both in test and retest conditions ($F(2,138) = 284.9$, $p < 0.0001$, $\eta^2 = 0.81$, Figure 2). Information about fruit's toxicity was better remembered than naming and occurrence of plants (Tukey post hoc test, $p < 0.001$). Hypothesis 2 was supported.

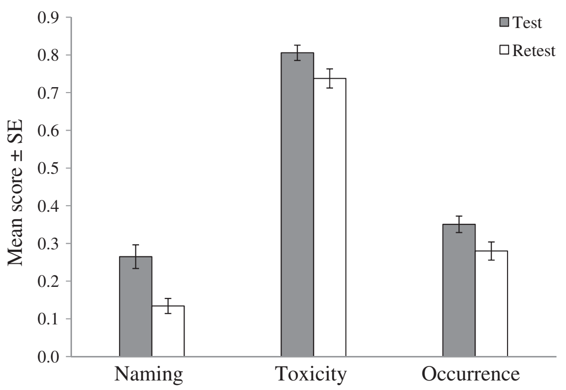

Figure 2. Mean performance across conditions

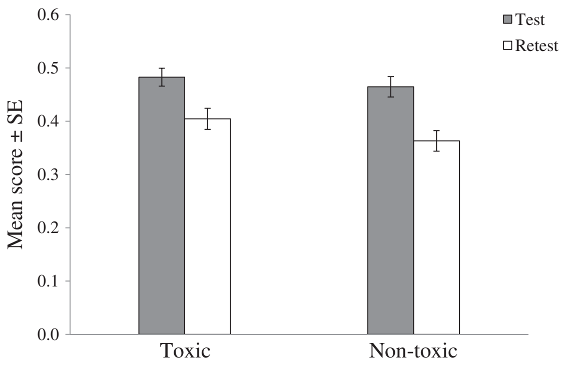

Figure 3. Gender differences in retention tests

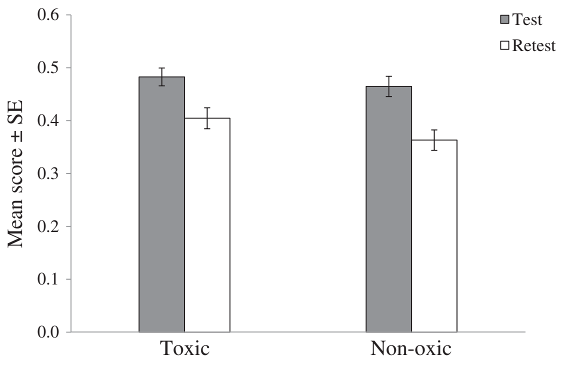

Figure 4. Differences in retention tests with respect to plant toxicity

Type of test

Participants' mean scores were significantly lower in retest compared with test ($F(1,69) = 36.5$, $p < 0.001$, $\eta^2 = 0.34$, Figure 2). Decreasing retest scores supports reliability of obtained data.

Gender

Females tended to score better than males, but this difference was not statistically significant ($F(1,69) = 1.99$, $p = 0.16$, $\eta^2 = 0.02$, Figure 3). Hypothesis 4 was not supported.

Poisonousness

Toxic fruits tended to received significantly higher mean scores than non-toxic fruits ($F(1,69) = 5.07$, $p = 0.03$, $\eta^2 = 0.06$, Figure 4). This supports Hypothesis 3.

Interaction terms

Fruit colour × toxic/non-toxic interaction ($F(2,138) = 85.4$, $p < 0.0001$, $\eta^2 = 0.55$) suggests that red, but non-toxic fruits received higher mean scores than red, but toxic fruits, while the reverse was true for black fruits. Mean scores for green fruits were similar with respect to toxicity.

Type of question × fruit colour × toxic/non-toxic interaction ($F(4,276) = 21.5$, $p < 0.0001$, $\eta^2 = 0.24$) means that participants best answered the question about non-toxic red fruits, but toxicity was associated with green and black fruits. The naming and occurrence of plants was best answered for edible red fruits, while poisonous plants were best remembered when their fruits were of black colour. No similar differences were observed for plants with green fruits. This provides support for Hypothesis 3.

Discussion

Plants are viewed as 'lifeless' organisms (Lindemann-Matthies 2005) most probably because they lack movement like most animals (Kinchin 1999). Here, we attempted to utilise fruit colouration that enhances aesthetic value of fruits (Prokop and Fančovičová 2012), fruit's toxicity (Fančovičová and Prokop 2011) and information about these plants that differ in survival value (Nairne, Thompson, and Pandeirada 2007) to examine whether these variables influence plant information retention.

Our first hypothesis dealt with the association between fruit colouration and information retention. As predicted, information about red and black fruits was better retained than information about green fruits. In an experimental study with 4–5-month-olds, children preferred red over green colour (Franklin et al. 2010). Here we supported the superiority of the colour red over the colour green because information about red fruits was retained significantly better than information about green fruits. Prokop and Fančovičová (2013) recently showed that when animals were presented to students in contrasting, aposematic colours, willingness to protect them was higher than when animal colours were cryptic. We suggest that contrasting colours increase aesthetic value (Prokop and Fančovičová 2012) and attention toward these stimuli and this enhances learning/memory processes. Ultimately, stronger attention toward red fruits would be influenced by their value as food in our ancestral past, as well as today (Heerwagen and Orians 1993; Hurlbert and Ling 2007). The mean scores for black fruits were similar to those for red fruits, but our results suggest that the information retention about plants with black fruits would be enhanced by their association with toxic, rather than non-toxic fruits (see below).

Secondly, we hypothesised that information regarding fruits relevant to survival would be better retained than other kinds of information. This hypothesis received statistical support, because survival-relevant information (ie whether the fruit is toxic or non-toxic) was retained significantly better than survival-irrelevant information. This finding corroborates current research by Nairne, Thompson, and Pandeirada (2007) and Barrett and Broesch

(2012) who similarly showed that survival-relevant information (*eg* dangerousness of an animal) is retained better than survival-irrelevant information (*eg* naming of an animal). It would be argued that the information about fruit's toxicity is simply easier to retain than information about naming or occurrence. While this alternative is viable and cannot be ruled out without additional research, the participant's mean scores significantly differed from chance (Figure 2), suggesting that the participant's scores were not a product of random choice.

Our third hypothesis tested the idea that survival-relevant information about the toxicity of the presented plants would be retained better than information about non-toxic plants. This hypothesis, again, received statistical support. In addition, black fruits were associated with toxicity, and red fruits with ripening of presented fruits. Previous research showed that children are unable to discriminate between toxic and non-toxic fruits according to colour (Prokop and Fančovičová 2012) and their knowledge about toxic fruits is limited (Fančovičová and Prokop 2011), probably because contrasting colours can advertise both ripening and toxicity (Edmunds 1974; Gittleman and Harvey 1980; Lev-Yadun 2001). However, additional senses such as olfaction (Hoover 2010) and taste in all probability influenced the definitive decision as to whether a chosen fruit or seed would be consumed or not (for a review, see Birch 1999).

Our final hypothesis dealt with gender differences in information retention about plants. Previous research showed that females have better knowledge about plants than males (Fančovičová and Prokop 2011; Laiacona et al. 2006), which could be explained by their higher interest in plants (*eg* Hong, Shim, and Chang 1998; Schussler and Olzak 2008). We did not find significant differences in retained information about plants between the sexes. It is possible that the sample size of males was not large enough to detect these differences (note that mean scores favoured females, but this difference did not reach significance) or that these differences are more pronounced in adults, who were responsible for collecting fruits more than children in our evolutionary past. Further research with more diverse samples is required before a definite conclusion can be made.

Implications for teaching botany

This study provides several implications that should be taken into consideration in botany lessons. First, visual, colourful presentations of plants should include exposure of their fruits or seeds that promote information retention. In particular, contrasting colours of fruits may increase children's attention, interest and consequently information retention about these plants. We speculate that the same implications would be applied to colourful flowers, but we have no data to support this claim. Second, talking about plants should contain survival-relevant information. This information includes plant edibility, the presence of toxic substances, medical importance of plants and incidences that can cause human death. For example, the hemlock (*Conium maculatum*) lacks any attractive seeds or other features potentially attractive to children, but the story of Socrates who was given a potent infusion of the hemlock and died (Brickhouse and Smith 2002) can positively influence retention of information about this species. Finally, there was some evidence that the children involved in the research associated red colour with a fruit being edible and black or green colours with toxic fruits, although this was not conclusive. Teachers should teach children that plants, similar to animals, possess aposematic, warning colours, and unknown fruits (with contrasting colour) should not be consumed.

Acknowledgement

We thank Alex Lovejoy who kindly improved the English and an anonymous referee for helpful comments.

References

Barrett, H. C., and J. Broesch. 2012. "Prepared Social Learning about Dangerous Animals in Children Dangerous." *Evolution and Human Behavior* 33 (5): 499–508.

Bebbington, A. 2005. "The Ability of A-level Student to Name Plants." *Journal of Biological Education* 32 (2): 62–67.

Birch, L. L. 1999. "Development of Food Preferences." *Annual Review of Nutrition* 19: 41–62.

Brickhouse, T. C., and N. D. Smith. 2002. *The Trial and Execution of Socrates: Sources and Controversies*. New York: Oxford University Press.

Dominy, N. J., J. C. Svenning, and W. H. Li. 2003. "Historical Contingency in the Evolution of Primate Color Vision." *Journal of Human Evolution* 44 (1): 25–45.

Edmunds, M. 1974. *Defense in Animals. A Survey of Anti-predator Defenses*. Harlow: Longman Group.

Fančovičová, J., and P. Prokop. 2010. "Development and Initial Psychometric Assessment of the Plant Attitude Questionnaire." *Journal of Science Education and Technology* 19 (5): 415–421.

Fančovičová, J., and P. Prokop. 2011a. "Children's Ability to Recognise Toxic and Non-toxic Fruits: A Preliminary Study." *Eurasia Journal of Mathematics, Science and Technology Education* 7 (2): 115–120.

Fančovičová, J., and P. Prokop. 2011b. "Plants have a Chance: Outdoor Educational Programmes Alter Student's Knowledge and Attitudes towards Plants." *Environmental Education Research* 17 (4): 537–551.

Franklin, A., L. Bevis, Y. Ling, and A. Hurlbert. 2010. "Biological Components of Colour Preference in Infancy." *Developmental Science* 13 (2): 346–354.

Gatt, S., S. D. Tunnicliffe, K. Borg, and K. Lautier. 2007. "Young Maltese Children's Ideas about Plants." *Journal of Biological Education* 41 (3): 117–122.

Gittleman, J. L., and P. H. Harvey. 1980. "Why are Distasteful Prey not Cryptic?" *Nature* 286 (5769): 149–150.

Glover, B. 2007. *Understanding Flowers and Flowering: An Integrated Approach*. Oxford: Oxford University Press.

Heerwagen, J. H., and G. H. Orians. 1993. "Humans, Habitats, and Aesthetics." In *The Biophilia Hypothesis*, edited by S. R. Kellert and E. O. Wilson, 138–172. Washington, DC: Island Press.

Hong, J. L., K. C. Shim, and N. K. Chang. 1998. "A Study of Korean Middle School Students' Interests in Biology and their Implications for Biology Education." *International Journal of Science Education* 20 (8): 989–999.

Hoover, K. C. 2010. "Smell with Inspiration: The Evolutionary Significance of Olfaction." *American Journal of Physical Anthropology Supp*. 143: 63–74.

Huberty, C. J. 2002. "A History of Effect Sizes Indices." *Educational and Psychological Measurement* 62 (2): 227–240.

Hurlbert, A. C., and Y. L. Ling. 2007. "Biological Components of Sex Differences in Color Preference." *Current Biology* 17 (16): 623–625.

Jacobs, G. H., and J. F. Deegan. 1999. "Uniformity of Colour Vision in Old World Monkeys." *Proceedings of the Royal Society of London* 266 (1432): 2023–2028.

Kinchin, I. M. 1999. "Investigating Secondary-School girls' Preferences for Animals or Plants: A Simple 'Head-to-head' Comparison Using Two Unfamiliar Organisms." *Journal of Biological Education* 33 (2): 95–99.

Kose, S., M. Usak, and M. A. Bahar. 2009. "Cross-age Study of students' Understanding and their Misconceptions about Plant Nutrition." *Didactica Slovenica-Pedagoska Obzorja* 24 (1): 109–122.

Laiacona, M., R. Barbarotto, and E. Capitani. 2006. "Human Evolution and the Brain Representation of Semantic Knowledge: Is there a Role for Sex Differences?" *Evolution and Human Behavior* 27 (2): 158–168.

Lev-Yadun, S. 2001. "Aposematic (Warning) Coloration Associated with Thorns in Higher Plants." *Journal of Theoretical Biology* 210 (3): 385–388.

Lindemann-Matthies, P. 2005. "'Loveable' Mammals and 'lifeless' Plants: How children's Interest in Common Local Organisms can be Enhanced through Observation of Nature." *International Journal of Science Education* 27 (6): 655–677.

Link-Perez, M. A., V. H. Dollo, K. M. Weber, and E. E. Schussler. 2010. "What's in a Name: Differential Labelling of Plant and Animal Photographs in Two Nationally Syndicated Elementary Science Textbook Series." *International Journal of Science Education* 32 (9): 1227–1242.

Martín-López, B., C. Montes, and J. Benayas. 2007. "The Non-economic Motives behind the Willingness to Pay for Biodiversity Conservation." *Biological Conservation* 139 (1–2): 67–82.

Nairne, J. S., S. R. Thompson, and J. N. S. Pandeirada. 2007. "Adaptive Memory: Survival Processing Enhances Retention." *Journal of Experimental Psychology: Learning, Memory and Cognition* 33 (2): 263–273.

Nairne, J. S. 2010. "Adaptive Memory: Evolutionary Constraints on Remembering." In *The Psychology of Learning and Motivation*, edited by B. H. Ross, 1–32. Burlington, VT: Academic Press.

Norman, D. A. 1982. *Learning and Memory*. W. H. Freeman & Company.

Ozay, E., and H. Oztas. 2003. "Secondary students' Interpretations of Photosynthesis and Plant Nutrition." *Journal of Biological Education* 37 (2): 68–70.

Prokop, P., and J. Fančovičová. 2012. "Beautiful Fruits Taste Good: The Aesthetic Influences of Fruit Preferences in Humans." *Anthropologischer Anzeiger* 69 (1): 71–83.

Prokop, P., and J. Fančovičová. 2013. "Does Colour Matter? The Influence of Animal Warning Colouration in Human Emotions and Willingness to Protect them." *Animal Conservation* 16 (4): 458–466.

Prokop, P., M. Prokop, and S. D. Tunnicliffe. 2007a. "Is Biology Boring? Student Attitudes toward Biology." *Journal of Biological Education* 42 (1): 36–39.

Prokop, P., G. Tuncer, and J. Chudá. 2007b. "Slovakian Students' Attitude toward Biology." *Eurasia Journal of Mathematics, Science and Technology Education* 3 (4): 287–295.

Prokop, P., and S. D. Tunnicliffe. 2010. "Effects of Keeping Pets at Home on Children's Attitudes toward Popular and Unpopular Animals." *Anthrozoös* 23 (1): 21–35.

Regan, B. C., C. Julliot, B. Simmen, F. Viénot, P. Charles-Dominique, and J. D. Mollon. 2001. "Fruits, Foliage, and the Evolution of Primate Colour Vision." *Philosophical Transactions of the Royal Society of London* 356: 220–283.

Ridley, H. N. 1930. *The Dispersal of Plants throughout the World*. Ashford, England: Reeve.

Schussler, E., and L. A. Olzak. 2008. "It's not Easy Being Green: Student Recall of Plant and Animal Images." *Journal of Biological Education* 42 (3): 112–119.

Schmidt, V., H. M. Schaefer, and H. Winkler. 2004. "Conspicuousness, not Colour as Foraging Cue in Plant-animal Interactions." *Oikos* 106 (3): 551–557.

Selvi, M. 2012. "Adaptation into Turkish of the Plant Attitude Questionnaire." *Journal of Baltic Science Education* 11 (2): 175–183.

Shade, B. J. 1982. "Afro-American Cognitive Style: A Variable in School Success?" *Review of Educational Research* 52 (2): 219–244.

Terry, W. S. 2005. *Learning and Memory: Basic Principles, Processes, and Procedures (3rd Edition)*. Allyn & Bacon.

Tunnicliffe, S. D. 2001. "Talking about Plants-comments of Primary School Groups Looking at Plant Exhibits in a Botanical Garden." *Journal of Biological Education* 36 (1): 27–34.

Wandersee, J. H. 1986. "Plant or Animals - Which do Junior High School Students Prefer to Study?" *Journal of Research in Science Teaching* 23 (5): 415–426.

Waser, N. M., and J. Ollerton. 2006. *Plant-Pollinator Interactions: From Specialization to Generalization*. University of Chicago Press.