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The perception of toxic and non-toxic plants by children and adolescents with regard to gender: implications for teaching botany

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ABSTRACT
Human cognition is influenced by natural selection which results in better information retention related to survival and faster visual recognition of potential threat. Plants are excellent models for studying human preferences because of the long evolutionary connectedness of humans with plants as food sources, although research in this field is scarce. We created visual detection tasks to investigate human responses to toxic and non-toxic plants using a sample of children (N = 80) and adolescents (N = 80). As predicted, toxic plants were detected significantly sooner than non-toxic plants. Children showed faster plant detection times than adolescents and females were faster in identification of plants than males. There were, however, no differences in toxic plant identification skills with respect to age and gender. These results suggest that plant toxicity, as an example of survival-relevant information, meets with increased attention on the part of humans and needs to be incorporated into teaching botany.

KEYWORDS
Botany; information retention; plants; toxicity

Introduction

Plants have served as one of the most important forms of food across human evolutionary history (Ungar and Sponheimer, 2011). The use of plants in traditional medicine is documented in the earliest written records from China, Egypt and Sumeria which suggests that almost all cultures in the world used the therapeutic properties of local flora (Houghton, 1995). According to the WHO (WHO Monographs, 1999, 2002), 80% of the world’s population - primarily those of developing countries - rely on plant-derived medicines for their healthcare (Gurib-Fakim, 2006).

The profound knowledge of medical plants in traditional societies developed through trial and error over millennia, and the most important recipes, were carefully passed on verbally from one generation to another (Gurib-Fakim, 2006). When plants are to be utilized for treatment, however, it is essential to be mindful of their toxic potential (Botha and Penrith, 2008). Plant poisoning in humans usually arises either from unintentional use of toxic plants as food, particularly by inexperienced children (Van Wyk, Van Heerden, and Van Oudthoorn, 2002; Wanzala and Wanjala, 2016) or from the use of poisonous plants for medicinal purposes. In South Africa, for instance, 2% of the people admitted to acute poisoning, compared to 15% of the patients poisoned by traditional plant medicine (Gaillard and Paquin, 1999).

Certain researchers suggest that human dietary dependence on plants throughout our evolutionary history has selectively favoured the evolution of skills enhancing rapid identification of edible plants in early childhood (Wertz and Wynn 2014). Despite this connectedness by humans with plants, teaching
botany still suffers from a basic problem, plants are considered unattractive to learners (Fančovičová and Prokop, 2010; Schussler and Olzak, 2008; Wandersee, 1986; Wandersee and Schussler, 2001) and learning botany is difficult (Prokop, Prokop, and Tunnichiffe, 2007a). One promising explanation for pervasive plant neglect (also termed 'plant blindness', see Balding and Williams, 2016; Wand ersee and Schussler, 1999) is that plants did not pose a physical danger to humans like predatory animals (the animate monitoring hypothesis, see New, Cosmides, and Tooby, 2007). Indeed, predatory animals are detected faster (LoBue and DeLoache, 2008; Öhman, Flykt, and Esteves, 2001) and tracked by eyes for a longer time (Yorzinski et al., 2014) than non-predatory animals. Furthermore, by means of presentation of plant and animal images in rapid succession (10 – 50 ms), Balas and Momsen (2014) demonstrated that detection of animals was significantly higher than plants, suggesting that plant images are harder to detect than animal images.

Learners, particularly males, have poor plant identification skills (Bebbington, 2005; Dallimer et al., 2012; Fančovičová and Prokop, 2011a; Gatt et al., 2007; Stagg and Donkin, 2013; Palmberg et al., 2015) which may negatively contribute to a connectedness with nature and environmental protection (Palmberg et al., 2015; Robinson, Inger, and Gaston, 2016). Indeed, many students are not willing to learn about plants (Baird et al. 1984) and are not willing to protect them (Greaves et al., 1993; Martin-López, Montes, and Benayas, 2007). Thus, various educational strategies, such as participation in science projects (Stagg and Donkin, 2013), educational programmes (Lindemann-Matthies, 2002, 2005), planting trees with experts (Fančovičová and Prokop, 2011b), hands-on activities (Poudel et al., 2005; Prokop, Majerčíková, and Vyoralová, 2016), or integrating botany with chemistry and art-based activities (Čil, 2015, 2016) have been proposed to increase learners’ interest in botany. This is crucial particularly for males who have a lower interest in plants (Gatt et al., 2007; Prokop, Prokop, and Tunnichiffe, 2007a; b; Schussler and Olzak, 2008) and have poorer plant identification skills (Fančovičová and Prokop, 2011b; Robinson, Inger, and Gaston, 2016) than females. Although hands-on/outdoor activities with plants may promote a learner’s interest in plants (e.g. Lindemann-Matthies, 2002, 2005; Palmberg et al., 2015), they are not applied to everyday school lessons due to practical reasons. There is a consequent need to effectively utilize the potential of plants themselves which can easily be adopted by teachers in various parts of the world, particularly in urban schools where children have more restricted contact with nature compared with rural schools (Zhang, Goodale, and Chen, 2014). Survival-relevant information about an object may promote better information retention (Barrett and Broesch, 2012; Nairne, Thompson, and Pandeirada, 2007). Prokop and Fančovičová (2014) recently demonstrated that secondary school students considered learning about plants and fruits easier if the to-be-learned information was framed around survival-relevant properties (i.e. ripeness or toxicity). Plant toxicity cannot be distinguished according to any common morphological features (Brill and Dean, 1994; Peters, O’Brien, and Drummond, 1992), and thus requires social learning. We hypothesize that toxic plants meet with decreased detection time from humans compared with non-toxic plants (Hypothesis 1). Since toxicity can be deadly to all humans irrespective of their age, we suggest that the same pattern proposed by Hypothesis 1 works with children and adolescents (Hypothesis 2). We further hypothesize that females react more rapidly to toxic plants than males (Hypothesis 3). We hypothesize that females have better toxic plant identification skills than males (Hypothesis 4). Both children and adolescents are expected to be more skilled in identification of toxic plants compared with non-toxic plants, because information about toxicity is related to survival and fitness (Hypothesis 5).

**Methods**

**Participants**

The research was focused on convenience samples of children (46 males, 34 females) from the second level of primary schools (grades 7 and 8) and adolescents (29 males, 51 females). The age of the children was 13 – 14 years (M = 13.5, SE = 0.05, n = 80) and the age of adolescents was 19 – 25 years.
(\(M = 22.03, SE = 0.21, n = 80\)). Children were recruited from six classes belonging to two Slovak urban schools. Written parent consent was received before the research was carried out. Adolescents were university students studying at three universities in Trnava, Slovakia, voluntarily participating in the research. Most of them involved studying laws, healthcare and the humanities. We did not collect information about their permanent residence. Participants were not aware of the hypotheses tested in the research.

**Selection of plants**

We selected common toxic and non-toxic plants occurring in Slovakia according to biology textbooks for 5 and 6 grades (age 10 – 12 years) (for the list of species see Table 1). Slovakia has only one biology textbook for each grade. We further limited plant selection to herbs (i.e. bushes and trees were not included) and those which were shown in textbooks in photographs. A total of 25 non-toxic and six toxic and 16 non-toxic and four toxic plants were presented according to these criteria in textbooks for 5 and 6 grades, respectively. Seven toxic and seven non-toxic plants were selected from this sample due to their common occurrence relative other plants. The number of plants was selected because it seemed to be appropriate for the proposed time for individual examinations (see below). Pictures were accessed through Google. All the plants were uniformly presented with their flowers. We adjusted the picture sizes to a standard body length. Pictures had a similar contrast and brightness.

**Procedure**

The research was carried out between December 2016 and February 2017. All participants were tested individually in a quiet room. Children were tested after teaching finished and adolescents were recruited in the university libraries and halls of residence. Between-subject design was used in this research which means that each participant was tested under one of the two treatments.

Each participant was asked to imagine that he or she was alone in the woods, with a meadow nearby, where there were various plants. Some of these plants are toxic and some are non-toxic to humans. Subsequently, two A4 papers with colourful pictures of seven plant species on each paper were simultaneously shown to the participant for five minutes (Figure 1). This time limit was chosen because longer learning could be tedious for children and, moreover, could produce a low variability in the retained information about the presented plants. One paper contained written information that depicted plants toxic to humans, while the other paper contained written information that depicted plants non-toxic to humans. Common Slovak names were shown below each picture with the plant.

The participant was then shown a laptop and given a set of three practice trials to teach the participant how to use the touch-screen. This procedure was adopted from LoBue and DeLoache (2008). On the first two trials, a single picture appeared on the screen, and the participant was asked to touch it. The first picture was the toxic plant, and the second the non-toxic plant. In the third trial, a 6-picture matrix without plant names was displayed. The six-picture matrix was

<table>
<thead>
<tr>
<th>Table 1. List of plants used in the research.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toxic plants</strong></td>
</tr>
<tr>
<td>English name</td>
</tr>
<tr>
<td>Herb-paris</td>
</tr>
<tr>
<td>Lily of the valley</td>
</tr>
<tr>
<td>Marsh-marigold</td>
</tr>
<tr>
<td>Henbane</td>
</tr>
<tr>
<td>Devil’s snare</td>
</tr>
<tr>
<td>Greater celandine</td>
</tr>
<tr>
<td>Meadow buttercup</td>
</tr>
</tbody>
</table>
chosen, because in the 9-picture matrix used by LoBue and DeLoache (2008) participants were only asked to find a snake among the distractors (or vice versa), while our research is more based on short-term memory and using more plant species might be overly demanding for the children. The participant was instructed to touch the non-toxic or toxic plant. Between trials, a large smiley face appeared on the screen. The next trial continued after touching a smiley face. All the pictures used in the practice trials were chosen randomly from the original sets of 14 pictures. All the participants readily learned the procedure. Finally, the participant was asked to locate either a single toxic plant target among five non-toxic plant distractors (Treatment 1) or the lone non-toxic target among five toxic plants (Treatment 2) as quickly as possible (Figure 2). A total of 7 trial tests for each treatment followed. Each participant was told to place his or her hands on the handprints after each trial. This ensured that the participant’s hands were in the same place at the start of each trial, which contributed to the validity of collected data. Latency time was automatically recorded from the onset of the matrix to when the participant touched one of the pictures on the screen. If the participant’s answer was incorrect, latency time was not included in the statistical analyses. The validity of the obtained data was further maintained by the selection of the plant species which was obligatory for all learners and by adopting the same research instrument as other authors (Flykt and Caldara, 2006; Hayakawa, Kawai, and Masataka, 2011; LoBue and DeLoache, 2008, 2011; Masataka, Hayakawa, and Kawai, 2010; Öhman, Flykt, and Esteves, 2001)

**Statistical analyses**

Data were not normally distributed (Kolmogorov-Smirnov tests, all \( p < 0.01 \)) and were therefore Box-Cox \( (x + 0.1) \) transformed in order to achieve normality. To evaluate the mean detection time for correct answers (measured in seconds, Cronbach \( \alpha = 0.84 \)) or correct plant identification scores (proportion of correctly identified species, Cronbach \( \alpha = 0.71 \)) (dependent variables), we used a three-way analysis of variance (ANOVA), where plant type (toxic plants versus weeds), age group (students versus adolescents) and gender were categorical between-subject factors. Partial eta-squared \( (\eta^2) \) was used as a measure of: 0.01–0.05 low, 0.06–0.13 moderate, and above 0.14 high effect size (Cohen, 1992).

![Figure 1. A school child learning toxic and non-toxic plants from pictures.](image)
Results

Plant-by plant analysis

An analysis of scores per each plant showed that Herb-paris, Lily of the valley, Marsh-marigold and Henbane (all toxic) showed the fastest mean detection times (Figure 3). In contrast, Common sowthistle, Melde, Saltbush and Whitetop (all non-toxic) showed the slowest mean detection times (Figure 3). This provides support for Hypothesis 1. The toxicity of plants with a moderate detection time was mixed.

Latency time

One participant was removed from the analyses as he failed to correctly identify any of the presented plants. A three-way between subjects ANOVA was conducted to compare the effect of plant type, gender and age on the latency time for the correctly identified plants. The latency time for the correctly identified plants was influenced by all three factors (Table 2). The effect sizes were low for age-related differences and moderate for the influence of plant type and gender (Table 2). Toxic plants among non-toxic plants were detected significantly faster ($M = 3.72, SE = 0.25$) than non-toxic plants among toxic plants ($M = 4.98, SE = 0.25$, Table 2). Hypothesis 1 was confirmed. Importantly, the pattern of performance of young children was the same as that of adolescents: as with adolescents, children located toxic plants more rapidly than non-toxic plants. This confirms Hypothesis 2. The latency time of females and girls was shorter than the latency time of males and boys (Figure 4) which confirms Hypothesis 3. Childrens’ latency time was significantly shorter than those of adolescents (Table 4). The statistically significant interaction Gender $\times$ Age $\times$ Plant type indicates that adolescent males had a significantly longer latency time than boys when detecting non-toxic plants among toxic plants (Figure 4). Additional interactions were not statistically significant (Table 2).

Identification scores

The mean percentage of the correctly identified plants was 80.1% ($SE = 2.07$, range $0 – 100\%$, $n = 160$). A three-way between subjects ANOVA was conducted to compare the effect of plant type, gender and age on plant identification skills. It was found that females had better plant
identification skills than males ($F(1,152) = 4.6, p = 0.03$, partial $\eta^2 = 0.03$, Figure 5), but we did not find evidence for better identification of toxic plants by females. This provides no support for Hypothesis 4. Other factors as well as interaction terms did not show, however, any influence of the participant’s age and plant toxicity on mean identification scores and effect sizes were low (all $p > 0.21$, all partial $\eta^2 < 0.01$). Hypothesis 5 was therefore not confirmed.

Discussion

This study revealed that toxic plants meet with increased attention than non-toxic plants irrespective of the participant’s age and gender. Plant identification skills were significantly influenced by gender differences, but not by the participant’s age and plant toxicity.

Our principal hypothesis dealt with increased attention on the part of toxic plants compared with non-toxic plants (Hypothesis 1). This hypothesis received strong statistical support with a moderate effect size. Previous research showed that dangerous animals such as snakes and spiders were detected by human participants on touch-screens faster than non-dangerous distractors (LoBue and DeLoache, 2008; Öhman, Flykt, and Esteves, 2001a; Soares et al., 2014) and threatening faces were actually detected by humans more quickly than neutral or friendly faces (for reviews see LoBue and Rakison, 2013; Öhman, 2009). As far as we know, however, no study has examined human speed when detecting potentially threatening plants, i.e. static objects which do not cause an immediate attack. Similarly, as it was found in detecting snakes by LoBue and

Table 2. Results of three-way ANOVA on mean detection time for the correct answers.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>P</th>
<th>Partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>453.3</td>
<td>1</td>
<td>453.3</td>
<td>1067.8</td>
<td>&lt; 0.0001</td>
<td>0.88</td>
</tr>
<tr>
<td>Plant type</td>
<td>6.9</td>
<td>1</td>
<td>6.9</td>
<td>16.3</td>
<td>&lt; 0.0001</td>
<td>0.1</td>
</tr>
<tr>
<td>Gender</td>
<td>4.6</td>
<td>1</td>
<td>4.6</td>
<td>10.8</td>
<td>0.001</td>
<td>0.07</td>
</tr>
<tr>
<td>Age</td>
<td>2.9</td>
<td>1</td>
<td>2.9</td>
<td>6.8</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Gender $\times$ Plant type</td>
<td>0.8</td>
<td>1</td>
<td>0.8</td>
<td>2.0</td>
<td>0.16</td>
<td>0.01</td>
</tr>
<tr>
<td>Age $\times$ Plant type</td>
<td>0.6</td>
<td>1</td>
<td>0.6</td>
<td>1.4</td>
<td>0.23</td>
<td>0.009</td>
</tr>
<tr>
<td>Gender $\times$ Age</td>
<td>0.04</td>
<td>1</td>
<td>0.04</td>
<td>0.1</td>
<td>0.76</td>
<td>0.0006</td>
</tr>
<tr>
<td>Gender $\times$ Age $\times$ Plant type</td>
<td>3.0</td>
<td>1</td>
<td>3.0</td>
<td>7.0</td>
<td>&lt; 0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Error</td>
<td>64.1</td>
<td>151</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DeLoache (2008), the participants in our study were slower to locate non-dangerous plants, in all probability because they spent more time looking at dangerous distractors, a process known as delayed disengagement. This suggests, along with the results of these studies, that humans have evolved a propensity to detect evolutionarily threat-relevant stimuli. In light of the fact that attention enhances learning (Shirey and Reynolds, 1988), stronger attention to toxicity can be utilized in teaching botany, because this information can arguably increase learners’ natural interest in particular plants.

Our second hypothesis suggested that both children and adolescents show similar patterns in detecting toxic plants faster as compared with non-toxic plants. This hypothesis was confirmed, but, notably, children revealed faster detection times compared with adolescents. In contrast, LoBue and DeLoache (2008) demonstrated that adults were faster in detecting snakes among distractors than their children. It can be argued that children are more vulnerable to plant toxins (Lewis and Elvin-Lewis, 2003) than adults and, thus, need to be more cautious in contact with
toxic plants. We argue, however, that a non-significant Age × Plant type interaction instead suggests that children were faster in detections of any plant, not specifically toxic ones, compared with adolescents. There is the possibility that certain differences in children’s touch interaction patterns from those of adults (Vatavu, Cramariuc, and Schipor, 2015) and/or higher interest in science (Bennett and Hogarth, 2009) were responsible for faster detection times.

The two hypotheses were concerned with gender differences in both latency time (Hypothesis 3) and plant identification skills (Hypothesis 4). Of these, only Hypothesis 3 received statistical support. Females showed faster latency times than males when searching for toxic as well as for non-toxic plants. This result can be generalized with research indicating that females more readily associate dangerous animals with fearful stimuli (Rakison, 2009) and are more accurate as well as more sensitive to threatening (i.e. potentially dangerous) facial expressions than males (Montagne et al., 2005). Textbooks were in all probability the primary source of knowledge of the tested plants. As a result, younger children who were actually using biology textbooks were able to recall them better. Adolescent males, who are less interested in botany than females (Hong, Shim, and Chang, 1998; Schussler and Olzak, 2008), might have stronger difficulties remembering non-toxic plants which do not amount to a health threat. Further research might investigate whether interest in plants impacts latency time.

Although females did not score better in identification of toxic plants than males, which provides no support for Hypothesis 4, our results suggest that females, more than males, respond faster to plant images and are more accurate in identifying plant species. These gender differences could stem from evolutionary pressures where sexual division of foraging labour favoured fruit/plant collection by females (Krasnow et al., 2011). Indeed females, but not males, excel at tasks appropriate to the gathering of immobile plant resources (Laiacona, Barbarotto, and Capitani, 2006).

We further hypothesized that participants will be more skilled in identification of toxic plants compared with non-toxic plants, because information about toxicity is related to survival and fitness (Barrett and Broesch, 2012; Nairne, Thompson, and Pandeirada, 2007; Otgaar and Smeets 2010) (Hypothesis 5). Surprisingly, this hypothesis was not confirmed. In general, these results seem to be compatible with Fančovičová and Prokop (2011a) who did not find any difference in children’s toxic and non-toxic plant identification skills. Although these results are in sharp contrast with evolutionary predictions, we hypothesize that null results can be attributable to genuine costs and benefits from the presented plants. Prokop and Fančovičová (2014) found, for example, that students retained more information about plants with red and black fruits (associated with ripening and edibility), compared with plants with green fruits. Similarly, hands-on activities with plants resulted in better information retention scores compared with treatment focused on more traditional lectures when only plant fruits were present (Prokop, Majerčíková, and Vyoralová, 2016). Flowers have, in contrast, an aesthetic rather than survival-relevant value for humans (Hůla and Flegr, 2016). Although further research in this field is necessary, we suggest that the presence of fruits on plants can have a stronger influence of information retention than the presence of flowers.

Conclusions and educational implications

This study highlights the importance of survival-relevant information, i.e. plant toxicity, in information processing amongst humans of various ages. Both children and adolescents detected toxic plants more rapidly than non-toxic plants and females, but not males, showed a superior speed in detecting and identifying plants (albeit the identification success of toxic plants was similar between males and females). Several implications follow for the teaching of botany. First, plant toxicity captures the learner’s attention and this needs to be utilized in botany lessons. Introducing survival-relevant information may be advantageous for teachers in terms of enhancing learner’s interest and information retention. Teachers may introduce the importance of particular plants for humans, their medical use, and lethal dosages or first aid in case of toxic plants. This information can be applied during formal lessons as well as during determination of common plants on the school campus and/or room plants cultivated in schools or students’
homes. Second, it seems that the use of plant fruits can be more convincing in creating survival-relevant scenarios compared with flowers. We therefore recommend introducing plant samples along with their fruits in botany lessons if possible. Third, special attention should be paid to males who are less interested in plants and have poorer plant identification skills than females.

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Disclosure statement

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