RESEARCH ON LEARNING

Learning about Mushrooms Is Influenced by Survival Processing

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Abstract

The human brain is limited by its capacity and incapable of memorizing all information. The memory system evolved to give preference to memory information related to maintaining and increasing individual fitness. We have chosen fungi, a heavily neglected area in science education research, to investigate which kind of information about mushrooms will be better retained by secondary school students. Furthermore, we investigated whether information about mushroom toxicity is better retained when presented only orally or in combination with a written text. The research sample consisted of 160 secondary school students from Slovakia. Pretest/posttest experimental between-subject and within-subject design was used to examine research questions. Data were collected through questionnaires (using a Likert response scale). We found that survival-relevant information (i.e., mushroom toxicity) was retained significantly better than survival-irrelevant information (i.e., mushroom naming and occurrence), but there were no differences in recall between the presentation conditions. Unexpectedly, male students retained information about mushroom toxicity significantly better than female students. Our results suggest that information retention by secondary school students in regard to mushrooms that cause serious poisoning is in accordance with evolutionary predictions and can be utilized by science teachers.

Key Words: *adaptive memory; fungi; science education; secondary school students.*

○ Introduction

The diverse, non-green (lacking chlorophyll) organisms of the kingdom Fungi are a fundamental part of most ecosystems. They influence the natural cycles of various elements, such as carbon, nitrogen, and oxygen (Chang & Miles, 2004; Egli, 2011; Büntgen et al., 2012; Zotti et al., 2013). Fungi are also able to accumulate lead, mercury, and cadmium from the environment (Köppel, 1993; García et al., 2009; Melgar et al., 2009). For humans, fungi can be considered an important food group, with species valued for their characteristic taste, flavor, and nutritional value (Chang, 1996; Chang & Miles, 2004; Halling, 2006; Kalač, 2009; Pacheco-Cobos & Rosetti, 2009). They are a rich source of proteins, carbohydrates, minerals, and vitamins, with a low amount of fat (Chang & Buswell, 1996; Işıloğlu et al., 2001; Gençcelep et al., 2009; Johnsy et al., 2011). Some fungi are economically important crops. For another example, waste from mushroom cultivation is utilized for energy recovery, bioethanol production, and other uses (Maher et al., 1993; McCahey et al., 2003; Lee et al., 2008; Lay et al., 2012; Phan & Sabaratnam, 2012; Zhang et al., 2014; Gupta et al., 2018). (Note: in our usage here, the word *mushroom* most often refers to those fungi that have a stem, or *stipe*; a cap, or *pileus*; and gills, or *lamellae*, on the underside of the cap.)

Humans have difficulty discriminating between edible and non-edible mushrooms (Unluoglu & Tayfur, 2003; Patowary, 2010; Jo et al., 2014), and therefore mushroom poisoning is quite common (Broussard et al., 2001; Chen et al., 2014). Successful mushroom collection requires a good knowledge of the environment; Garibay-Orijel et al. (2012) found that females employed more effective collection strategies than males (Pacheco-Cobos et al., 2010). The fruiting seasons of most mushrooms are in spring and autumn (de Aragón et al., 2011; Boddy et al., 2014), and most cases of mushroom poisoning also occur during these seasons (Unluoglu & Tayfur, 2003; Ahishali et al., 2012; Marinov et al., 2018). Globally, there is an increasing trend in consumption of wild mushrooms (Alonso et al., 2003; Gençcelep et al., 2009), which corresponds to increased mushroom poisoning (Diaz, 2005; Patowary, 2010; Bazzicalupo et al., 2017; White et al., 2019). The incidence of poisonings by mushrooms in Slovakia grew alarmingly, for example, by 30% in the past 10 years (Plačková, 2017).

Working memory, with all its executive functions (inhibition, shifting, and updating), is generally considered a necessary predictor of student performance in the school environment (reviewed by Bos, 2013). Cognitive research is also considering the relatively recent concept of "adaptive memory," which is tuned to remembering information relevant to survival, thereby increasing an individual's fitness (Nairne et al., 2007; Suddendorf et al., 2009; Shohamy & Adcock, 2010). The idea that information processed

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in relation to survival is remembered better than information not processed for its fitness value has been replicated several times (e.g., Bonin et al., 2019a, b). For example, objects described as having been touched by sick people were recalled better, for example, by participants than objects described as having been touched by healthy people (Fernandes et al., 2017). These findings indicate that our memory preferentially stores information about potentially harmful objects over potentially less harmful objects, which ultimately enhances the individual's survival and reproduction (fitness).

Adaptive memory theory has been implemented quite a lot in biology education (Štefaniková & Prokop, 2013), particularly because many topics in biology curricula include potentially harmful organisms that could enhance information retention. Second, humans recall living things more readily than nonliving things (Bonin et al., 2014; Nairne et al., 2017). It was found, for example, that students retained information about dangerous-looking animals more than information about the same animals in a resting position (Prokop & Fančovičová, 2017), probably because such animals enhance visual attention (Yorzinski et al., 2014). When students were asked to learn and then identify toxic (or nontoxic) plants on a touch screen, it was found that toxic plants were retained sooner and more correctly than nontoxic plants (Prokop & Fančovičová, 2019). Interestingly, the female students in the latter study were faster than male students in identifying plants. Additional research showed that red and black fruits showing cues of ripening were better retained by secondary school children than green fruits associated with low edibility (Prokop & Fančovičová, 2014). For both animals and plants, children's memory prioritizes information about toxicity compared with survival-irrelevant information such as naming, diet (in the case of animals), or occurrence (in the case of plants) (Barrett & Broesch, 2012; Prokop & Fančovičová, 2014; Prokop et al., 2016).

Fungi do not currently feature strongly in the Slovak lower secondary biology curriculum (they comprise 3%, 3%, and 6% of teaching hours in grades 5, 6, and 8, respectively) in comparison with animals and plants. Certain aspects of mycology, however, are introduced in the unit "Life in the Woods" (fifth grade), in which students learn (among other things) about basic differences between toxic and nontoxic fungi and acquire basic skills about what to do when poisoning by fungi occurs. Students are further trained to distinguish toxic and nontoxic mushrooms in sixth grade ("Anatomy of Plants and Fungi" unit). This suggests that students in the secondary grades should be skilled in discriminating between common toxic and nontoxic fungi.

In the present study, we investigated whether secondary school students preferentially retain information related to survival in the case of mushrooms. We suggest that mushrooms are relevant for this investigation because they are (1) historically involved in the human diet (Ungar, 2006) and (2) inseparable parts of biology curricula worldwide. First, we hypothesized that information about the toxicity of mushrooms will be better retained than information about the occurrence of mushrooms or their name. Our second hypothesis deals with presentation conditions: Visual and auditory information about mushroom toxicity will be better retained than auditory information alone. Third, because females have better knowledge about plants than males (Laiacona et al., 2006; Fančovičová & Prokop, 2011), we hypothesized that information about mushrooms will be better retained by girls than by boys.

Table 1. List of mushroom species used in the research.

Toxic	Nontoxic
Tricholoma sulphureum	*Lycoperdon perlatum*
Amanita verna	*Russula parazurea*
Gyromitra esculenta	*Leccinum rufum*
Entoloma euchroum	*Tuber aestivum*
Amanita pantherina	*Calvatia gigantea*
Paxillus involutus	*Pleurotus ostreatus*
Lepiota aspera	*Agaricus campestris*

○ Methods

Participants

The study was conducted in June 2017. The participants ($N = 160$) consisted of students (66 males and 94 females) from a local secondary grammar school. The participants' age ranged from 11 to 19 (mean = 16.03; SD = 2.36). The research was carried out in a biology course that is required for all secondary school students in Slovakia. Participants came from randomly selected classes irrespective of the participants' interest in mushrooms.

Species Selection & Procedure

We gave a 15-minute PowerPoint presentation of 14 color pictures of mushrooms in lecture hall. Each picture depicted one mushroom and was presented individually for approximately one minute. All the pictures were freely downloaded from Google and were manipulated in Adobe Photoshop for high quality. We adjusted the picture sizes to a uniform magnification scale. The pictures had similar contrast and brightness. We presented the pictures in random order. Our selection of mushroom species was based on (1) availability (rare species were not included) and (2) their inclusion in the national biology curriculum. We presented seven images of toxic and seven images of nontoxic mushrooms (Table 1). All participants were experienced with selected species of fungi during their formal biology courses in sixth grade (age 11/12).

All participants received an oral talk from the same experimenter. The talk was supported with a PowerPoint presentation regarding toxicity, occurrence, and the names of 14 mushroom species. In the Toxicity Written (TW) treatment ($N = 80$ students), pictures of mushrooms were accompanied by information about the name, occurrence, and toxicity of each mushroom species. In the Toxicity Introduced (TI) treatment ($N = 80$ students), slides with mushroom pictures contained only information about the name of each mushroom species, but not about its toxicity; toxicity, naming, and occurrence were introduced by the experimenter only

Table 2. Results of MANCOVA on summarized scores for occurrence, toxicity, and names of mushrooms.

Between-Subject Variables	SS	df	MS	*F*	*P*
Intercept	719.81	1	719.8	105.54	<0.001
Age	84.67	1	84.67	12,42	<0.001
Treatment	3.53	1	3.53	0.52	0.47
Sex	26.35	1	26.35	3.86	<0.05
Treatment × Sex	0.84	1	0.84	0.12	0.73
Error	1057.12	155	6.82		
Within-Subject Variables					
Information [a]	106.69	2	53.35	15.33	<0.001
Information × Age	40.78	2	20.39	5.86	<0.01
Information × Treatment	11.41	2	5.7	1.64	0.2
Information × Sex	0.75	2	0,37	0.11	0.9
Information × Treatment × Sex	5.82	2	2.91	0.84	0.43
Error	10791	310	3.48		

[a] Naming, occurrence, and toxicity.

orally (separately for each slide). Students did not record any information, but only listened carefully.

Pretest & Posttest Session

One week before and again immediately after the oral talk in the TW and TI treatments was completed, each participant was asked to participate in the pretest and posttest session, respectively. These sessions were identical. Because we found no apparent differences in pretest scores with respect to treatment, it was not necessary to control statistical analyses with pretest scores. The posttest session was identical for students from the TW and TI treatments. It contained the same mushroom species (presented in random order) as in the TW and TI treatments, but information about toxicity, occurrence, and species name were missing.

Each picture was presented for approximately one minute. During this time, the students answered simple questions investigating (1) students' skill in identifying mushrooms ("Write the name of the mushroom"), (2) the perceived toxicity of the mushrooms ("Do you think that the mushroom in the picture is toxic or nontoxic?"), and (3) their knowledge of the occurrence of the mushroom ("Please select the appropriate place where this mushroom occurs: deciduous forest, coniferous forest, or meadow"). The order of these questions was based on each picture. In the first picture, for example, respondents first spelled the name, then picked out the toxicity, and then the occurrence. In the second image, attention was first attracted to the occurrence, then the name of the mushroom, and finally the toxicity. Correct identification was coded as 1 and incorrect as 0. We calculated the individual scores for each subscale with high values referring to better knowledge. The completion of the posttest took approximately 30 minutes.

Statistical Analyses

Summarized scores from toxicity, occurrence, and the names of all presented species were used for the statistical analyses. These scores were treated as dependent variables, while treatment and gender were independent categorical predictors. The participant's age was defined as covariate in multivariate analysis of covariance (MANCOVA). Pairwise comparisons were made with Wilcoxon matched-pairs tests.

○ Results

Toxicity vs. Occurrence vs. Name

MANCOVA with treatment (predictor), age (covariate), and summarized scores from occurrence, toxicity, and name (dependent variables) indicated that there were no differences in scores with respect to treatment (Table 2 and Figure 1), but the influence of gender was statistically significant (Figure 2). Detailed analyses showed that male students retained more information about mushroom toxicity than female students ($F_{1,\ 155} = 7.57$; $P = 0.007$) while no gender differences were found in the domain of name and occurrence ($F_{1,\ 155} = 0.99$ and 1.82, $P = 0.32$ and 0.18, respectively). As students' age increased, their naming and occurrence scores also increased ($\beta = 0.27$ and 0.16, $P = 0.0007$ and 0.04, respectively). There were no associations between the age of the participants and information retention regarding toxicity ($\beta = 0.12$, $P = 0.13$).

Within-subject analyses showed that information about toxicity was better retained than information regarding naming and occurrence ($F_{2,\ 53.4} = 15.33$, $P < 0.001$). The Scheffé post hoc test revealed that mushroom toxicity was followed by the occurrence

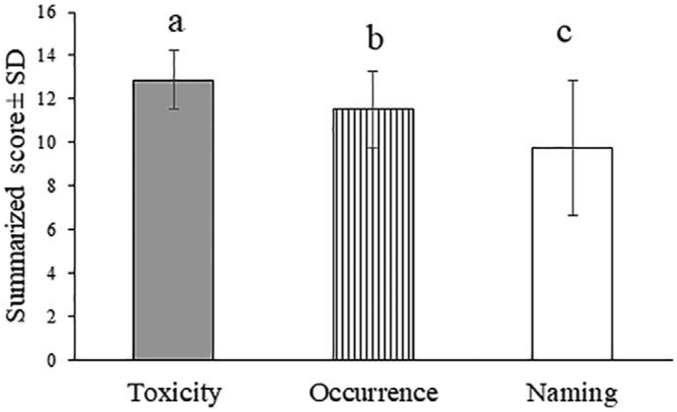

Figure 1. Mean performance with respect to the effect of treatment.

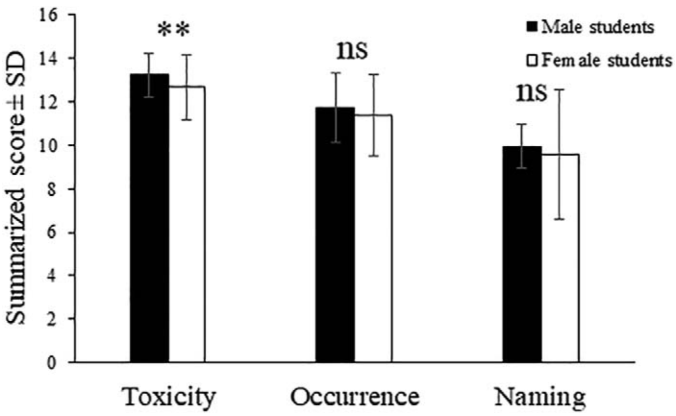

Figure 2. Gender differences in retention tests.

and then by the naming (Figure 3). Other differences were not statistically significant.

Additional Results

Pairwise comparisons of pooled data irrespective of the effect of treatment showed that information regarding naming, occurrence, and toxicity of nontoxic mushrooms were retained significantly better than information about toxic mushrooms (Wilcoxon $Z =$ 8.34, 2.13, and 2.38; $P < 0.001$, $P < 0.05$, and $P = 0.05$, respectively).

○ Discussion

This study primarily investigated whether information regarding mushrooms differing in survival relevance and sensory modality influence information retention in secondary school students. In line with the theory of adaptive memory, survival-relevant information was recalled better than survival-irrelevant information. Information retention regarding mushroom toxicity was not, however, influenced by written information, which was used as a supplement to oral information. Surprisingly, male students demonstrated better information retention with respect to toxic mushrooms than female students.

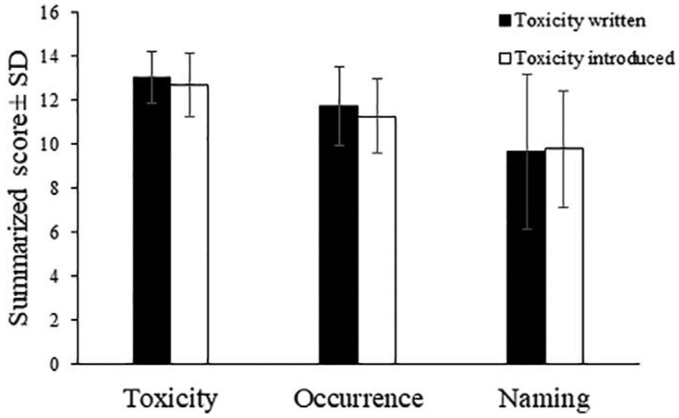

Figure 3. Mean performance across conditions.

Guided by an evolutionary perspective, we assumed that respondents would retain information about mushroom toxicity better than their occurrence or their names. The established assumption has been confirmed. Similar patterns were observed in research with both animals and plants, where potential dangerousness or toxicity was better retained than naming, occurrence, or diet (Barrett & Behne, 2005; Štefaniková & Prokop, 2013). Overall, these results support the idea that survival-relevant information is better retained than survival-irrelevant information, thereby increasing an individual's fitness (Nairne et al., 2007; Suddendorf et al., 2009; Shohamy & Adcock, 2010).

Interestingly, however, previous research showed no differences in information retention regarding occurrence or naming of animals and plants (Štefaniková & Prokop, 2015; Prokop et al., 2016). All nontoxic mushrooms in the present research were edible, however, and edibility is associated with better information retention (Fančovičová & Prokop, 2011; Prokop & Fančovičová, 2014). Indeed, nontoxic mushrooms scored better than toxic mushrooms in all three investigated domains (occurrence, naming, and toxicity). We suggest that the occurrence of mushrooms could be prioritized over naming because information on occurrence would ultimately improve an individual's foraging success, while naming would not.

The present experiment did not reveal a significant preference for retention in the visual modality, because students retained information about toxicity regardless of the effect of the treatment. These results are in accordance with previous work (Taub & Kline, 1976; Mahendra et al., 2005; Morris et al., 2015) in which no differences in recall between presentation conditions (auditory, written, combined) were found. Our results suggest that oral presentation is enough for retaining information about toxicity. It should be acknowledged that we did not investigate all possible experimental combinations (e.g., written information without auditory, the effects of conditions on mushroom naming and occurrence); thus, these results should be considered preliminary, and further research is required before a definite conclusion will be reached.

Traditionally, men were primarily in charge of hunting, wood processing, and/or family protection (Ungar & Teaford, 2002). The division of labor associated with hunting also explains sexual differences in cognitive abilities. Men were capable of excellent spatial orientation, whereas women were better at recognizing new objects. Research in Mexico has shown that women are able to harvest more types of mushrooms at the same time because they visit different places and do not use as much energy as men (Pacheco-Cobos et al., 2010). We hypothesized that information about toxicity of mushrooms would be better retained by female students than by male students, but this hypothesis was not supported. Instead, male students showed significantly better information retention regarding toxic mushrooms than female students. Previous research is still inconclusive in regard to information retention and gender differences; for instance, using the visual detection task, female students displayed faster latency times than male students when searching for toxic as well as for nontoxic plants (Prokop & Fančovičová, 2019). Female students, however, showed no better information retention than male students when researchers asked certain questions regarding plants presented one week earlier (Prokop & Fančovičová, 2014). More research on gender differences in information retention is required.

In conclusion, although mushrooms account for significant numbers of poisonings every year, little emphasis has been placed on using science education to address this. Guided by the theory of adaptive memory, we found that information retention in secondary school students follows evolutionary predictions, suggesting that survival-relevant information is prioritized over survival-irrelevant information. Science educators should utilize these findings by introducing toxicity of mushrooms as an important and survival-relevant topic that enhances students' recall. Teachers should select for biology lessons those mushroom species that could be found by students when visiting natural areas where they live. We also recommend the use of visual stimuli to depict basic differences between toxic and nontoxic species along with health implications of ingesting toxic mushrooms. Future research would benefit from the investigation of personal experiences and students' interest in mycology when searching for edible mushrooms in natural settings.

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