MODESTUM
OPEN ACCESS
EURASIA Journal of Mathematics, Science and Technology Education
ISSN: 1305-8223 (online) 1305-8215 (print)
2018 14(4):1397-1406
DOI: 10.29333/ejmste/83677

# Natural Selection Influences the Reactions of Children to Potentially Dangerous Animals

Pavol Prokop [1,2*]

[1] Department of Biology, Faculty of Education, Trnava University, Priemyselná, Trnava, SLOVAKIA
[2] Institute of Zoology, Slovak Academy of Sciences, Dúbravská cesta, Bratislava, SLOVAKIA

Received 22 December 2017 ▪ Revised 28 December 2017 ▪ Accepted 29 December 2017

**ABSTRACT**

Certain animals have represented a danger to humans in terms of a predation and pathogen threat over our evolutionary history. It is therefore adaptive for people to respond to a potential threat faster than to harmless events. Using simple choice tasks, the reaction time of children to predators, disease carriers and aposematically coloured animals were investigated. Children reacted the fastest to predators, followed by disease carriers and finally aposematically coloured animals. Furthermore, children manifested the highest accuracy when distinguishing predators from non-predators, followed by disease carriers and harmless animals, with the most errors occurring when identifying the aposematically coloured from non-aposematically coloured animals. Importantly, children more vulnerable to infectious diseases responded to disease carriers faster than healthier children. These results suggest that children are skilled in distinguishing potential danger from non-danger and that the behavioural immune system influences reaction times in visual contact with the pathogen threat.

**Keywords:** animals, behavioural immune system, predators

## INTRODUCTION

Natural selection shaped the human brain which influences psychology and behaviour. The way we think, feel and respond to external stimuli ultimately influenced the survival and reproductive success of our ancestors in our evolutionary past (Michalski & Shackelford, 2010). Predators, parasites and other harmful animals, which cause human mortality and morbidity (Hart & Sussman 2009; Prokop & Fedor, 2013), could be viewed as the selective forces responsible for perceptual biases in the rapid detection of evolutionary threats (LoBue et al., 2010).

It has been speculated that danger from animals is elicited by certain harmful shapes, such as teeth, claws or spikes (Prokop & Fančovičová, 2017; Souchet & Aubret, 2016; Štefaniková & Prokop, 2015). Indeed, detection of a snake among fear-irrelevant distractors (e.g., flowers, mushrooms) on a touchscreen was consistently faster than vice versa (LoBue & DeLoache, 2008; LoBue & Rakison, 2013; Öhman et al., 2001). Large carnivore predators are tracked by the eyes for a longer time than non-predatory animals (Penkunas & Coss, 2013; Yorzinski et al., 2014) and highly conspicuous, while aposematically coloured animals are detected by humans faster than non-aposematic animals (Bohlin et al., 2012).

Inter-individual behavioural differences often have important fitness consequences (Smith and Blumstein, 2008) and wide-ranging ecological and evolutionary implications (Réale et al., 2010; Sih et al., 2012). Behavioural responses are calibrated according to the presence of pathogens or predators (Hart, 1988, 2011; Lima & Dill, 1990). Humans with a low perceived physical condition, for example, display a stronger fear of large predators (Prokop & Fančovičová, 2010a, 2013a). Those who are more vulnerable to infectious diseases manifest a stronger fear of dangerous animals (Prokop et al., 2010a,b,c), avoid the obese (Park et al., 2007), physically disabled people (Park et al., 2003) and immigrants (Faulkner et al., 2004), because these animals/disfigured people possess the risk of physical injury, disease transmission or death. The ultimate reasons for stronger fear/avoidance can be explained by Error Management Theory (Johnson et al., 2013) suggesting that under uncertainty (i.e., where the true probability of outcomes cannot be precisely predicted), it is more efficient to avoid an object/subject which is *potentially* dangerous in terms of disease transmission, than to risk (potentially deadly) illness.


✉ Pavol.Prokop@savba.sk **(*Correspondence)**

**Contribution of this paper to the literature**

- Children are able to identify dangerous animals, particularly predators, from harmless animals
- Children who are more vulnerable to diseases reacted faster to disease carriers than healthier children

Both formal and non-formal learning may benefit from an evolutionary approach examining the ultimate reasons for particular behaviour (Prokop & Kubiatko, 2014; Prokop et al., 2010d, 2016). Animals with a low aesthetic value (Gunnthorsdottir, 2001; Knight, 2008; Prokop & Fančovičová, 2013b), and/or those looking dangerous (Prokop & Fančovičová, 2017) reduce, however, human willingness to protect them. This is particularly important for improving attitudes toward invertebrates, because people's negative attitudes toward a majority of these creatures (Borgi & Cirulli, 2015; Kellert, 1993; Schlegel & Rupf, 2010) are influenced by disgust and fear (Davey, 1994; Gerdes et al. 2009; Lorenz et al. 2014; Prokop & Jančovičová, 2013b; Prokop et al. 2010b). Indeed, invertebrates receive lower conservation support compared with vertebrates (Black et al., 2001; Cardoso et al., 2011) which further emphasizes the importance of a better understanding of human-animal relationships in order to improve people's attitudes toward invertebrates.

Females generally have less positive attitudes toward harmful or disgusting animals than males (Bjerke & Østdahl, 2003; Jimenez & Lindemann-Matthies 2015; Lindemann-Matthies 2005; Prokop et al., 2009a,b, 2010a,c; Prokop & Tunnicliffe, 2010). The rationale for these differences could stem from greater vulnerability to physical harm in females, who are less able to escape and/or defend themselves against predators (Prokop & Fančovičová, 2010a, 2013a; Røskaft et al. 2003; Treves- Naughton Treves 1999). In addition, females appear to be more vulnerable to infectious diseases (Case & Paxson 2005; Duncan et al., 2009; Prokop & Fančovičová, 2013b, Prokop et al., 2010b) which can make their worries regarding potential contamination from animals even more significant.

This study investigated children's perception of animals which pose a possible threat: predators, disease carriers and aposematically coloured animals. First, it was hypothesized that children identify a predator against a non-predator faster than disease carriers or aposematically coloured animals (against controls), because of the harmful shapes associated with the physical threat. Second, it was hypothesized that children who are more vulnerable to diseases react faster to disease carriers than healthier children, due to a heavier risk of being contaminated. Third, females are hypothesized to react to harmful animals faster than males due to their greater vulnerability to physical harm because they are less able to escape and/or defend themselves against predators and females appear to be more vulnerable to infectious diseases.

# MATERIALS AND METHODS

## Participants

A convenience sample of urban kindergarten children aged 5 – 6 years (N = 20, 9 males) and primary school children from two classes (age 8 – 9 years, N = 30, 15 males) participated in this research. Primary school children were tested in the afternoon after finishing school lessons. All the children were Caucasians, because no children of another ethnic group attended schools where the research was carried out. Participation in the research was voluntary.

## Reported Vulnerability to Diseases

Children's parents received a simple question written on A4 paper "How often has your child had an infectious disease in the past 12 months?" There are other methods for obtaining data on perceived vulnerability to diseases from participants (e.g. Duncan et al., 2009; Prokop et al., 2010a), but administering these questionnaires to children of such a young age was clearly impossible. Furthermore, detailed information about children's infectious diseases negatively correlated with the frequency of infectious diseases (if 1 = high frequency and 4 = never) and negatively with the perceived health status of the kindergarten children (if 1 = extremely good and 5 = extremely bad) (Prokop et al., 2016). This simple measure of children's health would therefore seem to be a reliable estimate of his or her actual health.

## Procedure

A within-subject design was used throughout this study meaning that each child participated in all three treatments. The stimulus categories were three predators, three disease carriers and three aposematically coloured animals listed in **Table 1**. The 18 colourful photographs were obtained from the Internet via Google. These animals represent common and typical species for each category. We chose only animals displaying neutral postures to avoid biases in responses to aggressive looking animals (Masataka et al., 2010; Prokop & Fančovičová, 2017). Each

**Table 1.** Correct responses of children who were allowed to decide which of the two animals was a predator, disease carrier or aposematically coloured. The first of the animal pairs was considered the correct response. Numbers for disease-carriers refer to the published reason for inclusion.

| Treatment | Pair of animals | % correct |
|---|---|---|
| Predators | Lion (*Panthera leo*) – Zebra (*Equus quagga*) | 100 |
| | Wolf (*Canis lupus*) – Doe (*Cervus elaphus*) | 100 |
| | Shark (*Carcharodon carcharias*) – Beluga (*Huso huso*) | 80 |
| Disease carriers | Rat (*Rattus rattus*)[1] – Squirrel (*Sciurus vulgaris*) | 78 |
| | Cockroach (*Blatella germanica*)[2] – European cockchafer (*Melolontha melolontha*) | 42 |
| | Mosquito (*Aedes aegypti*)[3] – Damselfly (*Calopteryx splendens*) | 94 |
| Aposematically coloured | European peacock (*Inachis io*) – Knot grass (*Acronicta rumicis*) | 8 |
| | Salamander (*Salamandra salamandra*) – Newt (*Lissotriton vulgaris*) | 38 |
| | Skunk (*Mephitis mephitis*) – Marmot (*Marmota marmota*) | 76 |

[1]Tollenaere et al. (2010)
[2]Baumholtz et al. (1997)
[3]Tabachnick (1991)

animal filled up the entire display area. The child was seated in front of the experimenter who opened a booklet with one pair of animals each printed with a colour printer (Sharp MX-2614) on an A4 page. Depending on the treatment, children was asked to show which of the two animals was a dangerous predator, disease carrier or an animal with warning (aposematic) colouration. In case of the latter question, we asked children which of the two animals display danger by its colouration, because children in this age group are unaware of what aposematic colouration means. The pairs of pictures were presented in random order. Overall, this task seemed to be easy for children, because 1.) they begin to learn about common animals and plants in kindergarten when they are about 3 years of age and 2.) a preliminary study of a different kindergarten revealed that children had no problems with understanding our questions. A trained student sitting behind the children, unaware of the research questions, examined the reaction time with a stopwatch. The reaction time was defined as the time between the instruction from the experimenter and the touching of the picture by the children's finger(s). Children were not time limited in their choices. The experimenter also noted whether the responses were correct or not, but children were not confronted with the accuracy of their responses.

### Compliance with Ethical Standards

Ethical approval: Written parent consent was received before the research was carried out. All the procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

### Statistical Analyses

The reaction time for three groups of animals (dependent variable) was calculated as the mean time for correct identification of a predator, disease carrier or aposematically coloured animal in a multivariate analysis of covariance (MANCOVA). The reaction time for incorrect responses was not included in the analyses. The categorical predictors were the children's age (kindergarten vs primary school) and gender. We made no specific predictions regarding the children's age, but because older children could be more influenced by knowledge and/or experiences with animals, we investigated possible differences between these two cohorts. Treatment (three groups of animals with mean reaction times) was defined as within-subject variable. Reported vulnerability to diseases (RVD) was defined as the covariate.

Children's correct/incorrect responses (binomial dependent variable) were examined with the Generalized Linear Mixed Model (GLMM) where the children's age (kindergarten vs primary school), gender and treatment were categorical predictors and RVD was the continuous predictor. The children's ID was defined as the random factor in order to take into account the pseudoreplication of the data. Statistical analyses were performed in IBM SPSS ver. 24.

## RESULTS

### Reaction Time

It was hypothesized that children identify a predator against a non-predator faster than disease carriers or aposematically coloured animals (against controls), because of the harmful shapes associated with the physical

**Table 2.** Results of on mean detection time for the correct answers when children identified predators, carriers of diseases and aposematically coloured animals

| | SS | DF | MS | F | P |
|---|---|---|---|---|---|
| Intercept | 94.95 | 1.00 | 94.95 | 48.09 | < 0.001 |
| RVD | 6.79 | 1.00 | 6.79 | 3.44 | 0.07 |
| Age | 31.62 | 1.00 | 31.62 | 16.02 | < 0.001 |
| Gender | 0.31 | 1.00 | 0.31 | 0.15 | 0.70 |
| Age × Gender | 0.80 | 1.00 | 0.80 | 0.41 | 0.53 |
| Error | 88.86 | 45.00 | 1.97 | | |
| Treatment | 22.58 | 2.00 | 11.29 | 14.15 | < 0.001 |
| Treatment × RVD | 6.24 | 2.00 | 3.12 | 3.91 | 0.02 |
| Treatment × Age | 5.45 | 2.00 | 2.72 | 3.41 | 0.04 |
| Treatment × Gender | 0.32 | 2.00 | 0.16 | 0.20 | 0.82 |
| Treatment × Age × Gender | 4.70 | 2.00 | 2.35 | 2.94 | 0.06 |
| Error | 71.82 | 90.00 | 0.80 | | |

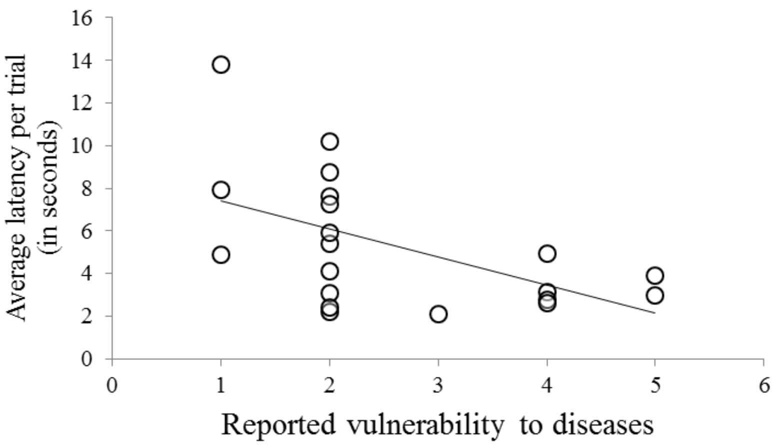


**Figure 1.** The relationship between reported vulnerability to diseases and average latency to detect disease carriers among kindergarten and school children

threat. In line with this hypothesis, children's reaction time when an animal was correctly identified as a predator, disease carrier or an animal with aposematic colouration varied between 1.51 and 18.60 sec (M = 5.88, SD = 3.15, N = 150). MANCOVA revealed that the reaction time was significantly influenced by the children's age, reported vulnerability to disease and treatment; gender differences were not statistically significant (**Table 1**).

According to the second hypothesis, children who are more vulnerable to diseases react faster to disease carriers than healthier children, due to a heavier risk of being contaminated. An analysis of the Treatment × RVD interaction revealed that RVD negatively correlated with the reaction time of disease carriers (β = -0.52, P = 0.02, **Figure 1**), but not with the reaction time of predators and aposematically coloured animals (β = -0.07 and -0.11, P = 0.8 and 0.4, respectively). This provides support for the second hypothesis. Animals × Age interaction suggest that the reaction time for correct identification of predators was similar with kindergarten and primary school children, but the former group of children was faster in identifying disease carriers and animals with aposematic colouration.

Predators were identified most rapidly (M = 3.8 sec, SD = 1.4, N = 50), followed by aposematically coloured animals (M = 6.6, sec, SD = 3.3, N = 50) and finally by disease carriers (M = 7.2, SD = 3.2 sec, N = 50) (Tukey's post-hoc test, P < 0.001 for all combinations) (**Figure 2**). Kindergarten children showed a shorter reaction time than primary school children (**Table 1**, **Figure 2**). Additional ANOVA with RVD as a dependent variable and children's age and gender as predictors showed no differences in RVD with respect to gender (mean RVD for males vs females, M = 2.2, SD = 1.22, N = 24 and M = 2.15, SD = 1.1, N = 26, respectively, $F_{1,46}$ = 0.006, P = 0.94). Younger children appeared to be more frequently ill (M = 2.6, SD = 1.3, N = 20) than older children (M = 1.9, SD = 0.96, N = 30) ($F_{1,46}$ = 4.59, P = 0.04) and interaction between the variables was not significant ($F_{1,46}$ = 0.93, P = 0.34). This suggests that males and females manifested a similar RVD and therefore the hypothesized gender difference in RVD (Hypothesis 3) did not influence the reaction time.

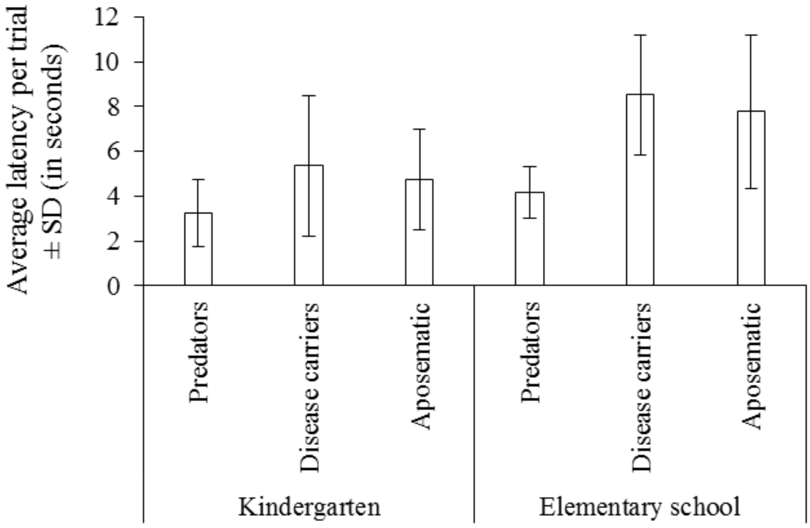


**Figure 2.** Average latency time with respect to children's age and treatment

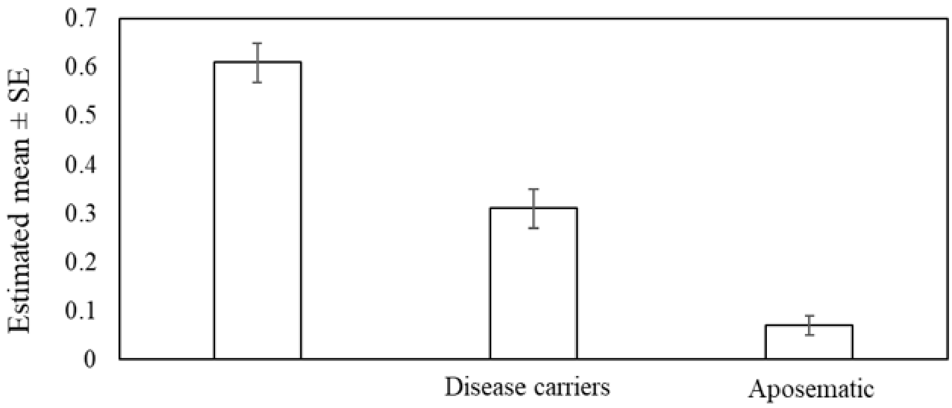


**Figure 3.** Differences in correct responses with respect to treatment

## Accuracy of Children's Responses

Children displayed significant differences in identifying animals (GLMM, entire model: $F_{12,415} = 16.9$, $P < 0.001$). Treatment was the only variable which influenced the frequency of the correct responses ($F_{12,415} = 68.3$, $P < 0.001$). A pair-wise comparison of contrasts revealed that predators were identified most correctly, followed by disease carriers and animals with aposematic colouration (**Figure 3**). All the differences between these three groups were statistically significant (all P's < 0.001). The influence of other variables (age, gender, RVD and interaction terms) was not statistically significant (all P's > 0.14).

A detailed analysis of the pairs of animals presented in each treatment demonstrated that lions and wolves were perfectly recognized as predators. Belugas were, in all probability due to their large size, sometimes misinterpreted as a predator instead of a shark. Mosquitoes and rats were identified as disease-carriers by a majority of children, while the harmless European cockchafer was often misclassified as a disease carrier instead of a cockroach. Considering animals with warning colouration, the colours of the European peacock were not considered a "warning" in comparison with moths. The body colouration of the harmless newt was, similarly, considered to be more dangerous than the colouration of a salamander. Only the colouration of a skunk was recognized by most children as more dangerous compared with a marmot (**Table 2**).

## DISCUSSION

This study investigated children's reaction time in a series of simple tasks, where predators, disease carriers and aposematically coloured animals were identified against control, harmless animals. Children's reaction time, as well as their correct identification of animals, differed across treatments and certain associations were found with children's RVD. No differences were identified between males and females.

The first hypothesis dealt with the reaction time of children when they were asked to identify animals from three treatments where it was expected that predators would be identified faster than disease carriers, followed by aposematically coloured against controls. Although previous research also found certain associations between perceived vulnerability to diseases and avoidance of potential disease carriers (Faulkner et al., 2004; Park et al., 2003, 2007), no study had investigated these relationships with a reaction time. In line with the hypothesis, identification of the predators was accompanied by faster reaction times than identification of the remaining two groups of animals. This result is in accordance with research indicating that dangerous predators such as snakes are identified by humans among fear-irrelevant distractors faster than vice versa (LoBue & DeLoache, 2008; LoBue & Rakison, 2013; Öhman et al., 2001). Furthermore, predators not only increase the visual attention of humans (Penkunas & Coss, 2013; Yorzinski et al., 2014), but young children seem to understand the harmful influences of predators on prey (Kubiatko, 2012). Barrett (2005), for example, demonstrated that when 4 – 5-year-old children were asked to simulate an encounter between a predator and prey using plastic models, a majority of them correctly reported that "The lion eats the zebra" or "The zebra runs away from the lion". Finally, children seem to be well predisposed to learn which animal presents a dangerous threat to humans (Barrett & Broesch, 2012; Štefaniková & Prokop, 2015). Children in the present study showed significantly lower numbers of errors when identifying predators compared with disease carriers and aposematically coloured animals providing further support for fast learning about dangerous animals in early childhood.

According to the second hypothesis, children who are more vulnerable to diseases were expected to react faster to disease carriers than healthier children. Ultimately, higher vulnerability to diseases increases the risk of being contaminated, thus specific psychological mechanisms (the behavioural immune system, see Schaller, 2006, 2011) should be activated to prevent a potential threat (Miller & Maner, 2011; Prokop & Fančovičová, 2013a; Prokop et al. 2010a,b,c; Schaller et al. 2015). It was found that children who were more susceptible to infectious diseases reacted faster, but only when they were asked to identify disease carriers against controls. Taken together, people not only avoid other people who are potential disease carriers (Faulkner et al., 2004; Park et al., 2003, 2007), but also respond faster to stimuli associated with visual contamination (this study).

Interestingly, two of the three disease carriers we presented to children were invertebrates (cockroach and mosquito). These animals always receive low preferences from people (Almeida et al., 2014; Arrindell, 2000; Bennett-Levy & Marteau, 1984; Bjerke & Østdahl, 2003; Driscoll, 1995; Schlegel & Rupf, 2010). These preferences can be seen amongst kindergarten children (Borgi & Cirulli, 2015) suggesting that the predisposition to have a negative attitude to invertebrates emerges early in childhood. Cockroaches were, interestingly, frequently misidentified as disease carriers with the European cockchafer (**Table 1**) suggesting that at least some invertebrates are perceived very superficially. Indeed, learners tend to categorize something as being an insect if it is small with jointed legs and has a "bug shaped" oval body (Allen, 2015; Braund, 1991; Shepardson, 2002). Suitable educational strategies and interventions, perhaps using arthropod – plant interactions, should therefore be applied in early childhood in order to increase ecological awareness about invertebrates which are inevitable parts of ecosystems (Prokop & Tunnicliffe, 2010).

The low number of correct responses in treatment with aposematically coloured animals can be attributed to the familiarity and aesthetic value of certain insects. The European peacock, for example, was almost never identified as an animal with warning colouration, albeit experiments on non-human animals supported the function of their wing colouration (e.g., Vallin et al., 2005). This species is in all probability preferred by people due to its beautiful colouration (Breuer et al., 2015), similarly as other coloured butterflies (Schlegel & Rupf, 2010) and, perhaps children with their direct experiences are aware that it is harmless. In contrast, children mistakenly perceived the Knot grass as the Common clothes moth which is the reason why the Knot grass was perceived as more dangerous.

Finally, females were hypothesized to react to harmful animals faster than males due to their lower physical condition and higher vulnerability to diseases. Although lower preferences for harmful animals in females are well documented (e.g., Almeida et al., 2014; Bjerke & Østdahl, 2003; Borgi & Cirulli, 2015; Prokop & Fančovičová, 2010b, 2013a; Prokop et al., 2010a,b), no differences were found in reaction times or in identification skills between genders. At first glance, it would seem that the null difference appeared because there were no significant differences in vulnerability to diseases among these young children. Borgi and Ciruli (2015), however, have demonstrated that gender differences in attitudes toward animals emerge already amongst kindergarten children which makes this argument invalid. It is possible that the negative perceptions of certain animals are translated to the reaction times later in life. Unfortunately, however, reports on gender differences in this field and age groups are scarce. For instance, LoBue and DeLoache (2008, 2011) studying the reaction time of 3 to 5-year-old children searching for a snake on a touch-screen monitor did find any gender differences in detection time.

### Limitations

This study has several limitations. First, the reaction time could be investigated with a touch-screen monitor rather than with a stopwatch. Although this approach would yield in a more precise examination of the reaction time, relative differences in reaction time between treatments in this study are still valuable. Second, a more objective assessment of children's health is required to test whether infectious and parasitic diseases, but not chronic somatic diseases are associated with children's reactions on disease carriers. Third, further research involving more diverse samples of participants is necessary to test whether children's reaction times are associated with the behavioural immune system.

## CONCLUSIONS

In conclusion, it was found that children at a young age are skilled in identifying potential threat. This can be caused by rapid learning about possible dangers and/or can be a reaction to certain harmful shapes, such as teeth, claws or spikes which elicit attention. Importantly, children's faster reaction times are not limited to snakes, which represented a danger to our ancestors as far back as 150 million years ago, but has been extended to more recent threats caused by large terrestrial carnivores and sharks. Potential disease carriers such as insects seem to activate the behavioural immune system particularly amongst those children who are more vulnerable to diseases. In this view, evolved psychological predispositions at least partly influence human perception of certain animals.

## ACKNOWLEDGEMENTS

I would like to thank Barbora Bučeková for help with data collection. David Livingsone improved the English. This research was supported by the university grant no. 5/TU/2017 and KEGA no. 001PU-4/2017.

## REFERENCES

Allen, M. (2015). Preschool children's taxonomic knowledge of animal species. *Journal of Research in Science Teaching, 52*(1), 107–134. https://doi.org/10.1002/tea.21191

Almeida, A., Vasconcelos, C., & Strecht-Ribeiro, O. (2014). Attitudes toward animals: a study of Portuguese children. *Anthrozoös, 27*(2), 173–190. https://doi.org/10.2752/175303714X13903827487403

Arrindell, W.A., Eisemann, M., Richter, J., Oei, T.P., Caballo, V.E., van der Ende, J., Sanavio, E., Bgés, N., Feldman, L., Torres, B., Sica, C., Iwawaki, S., Edelmann, R.J., Crozier, W.R., Furnham, A., & Hudson, B.L. (2003). Phobic anxiety in 11 nations: Part I: Dimensional constancy of the five-factor model. *Behaviour Research & Therapy*, *41*(4), 461–479. https://doi.org/10.1016/S0005-7967(02)00047-5

Barrett, H. C. (2005). Adaptations to predators and prey. In D. M. Buss (Ed.), *The handbook of evolutionary psychology* (pp. 200 – 223). New York: Wiley.

Barrett, H. C., & Broesch, J. (2012). Prepared social learning about dangerous animals in children. *Evolution and Human Behavior, 33*(5), 499–508. https://doi.org/10.1016/j.evolhumbehav.2012.01.003

Baumholtz, M. A., Parish, L. C., Witkowski, J. A., & Nutting, W. B. (1997). The medical importance of cockroaches. *Internationa Journal of Dermatology*, *36*(2), 90–96. https://doi.org/10.1046/j.1365-4362.1997.00077.x

Bennett-Levy, J., & Marteau, T. (1984). Fear of animals: What is prepared? *British Journal of Psychology, 75*(1), 37–42. https://doi.org/10.1111/j.2044-8295.1984.tb02787.x

Bjerke, T., Østdahl, T., & Kleiven, J. (2003). Attitudes and activities related to urban wildlife: pet owners and nonowners. *Anthrozoös, 16*(3), 252–262. https://doi.org/10.2752/089279303786992125

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

Bohlin, T., Gamberale-Stille, G., Merilaita, S., Exnerová, A., Štys, P., & Tullberg, B. (2012). The detectability of the colour pattern in the aposematic firebug, *Pyrrhocoris apterus*: an image-based experiment with human 'predators'. *Biological Journal of the Linnean Society, 105*(4), 806–816. https://doi.org/10.1111/j.1095-8312.2011.01834.x

Borgi, M., & Cirulli, F. (2015). Attitudes toward animals among kindergarten children: Species preferences. *Anthrozoös*, *28*(1), 45–59. https://doi.org/10.2752/089279315X14129350721939

Braund, M. (1991). Children's ideas in classifying animals. *Journal of Biological Education, 25*(2), 103–110. https://doi.org/10.1080/00219266.1991.9655186

Breuer, G. B., Schlegel, J., Kauf, P., & 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. https://doi.org/10.1080/09500693.2015.1099171

Cardoso, P., Erwin, T. L., Borges, P. A. V., & New, T. R. (2011). The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation, 144*(11), 2647–2655. https://doi.org/10.1016/j.biocon.2011.07.024

Case, A., & Paxson, C. (2005). Sex differences in morbidity and mortality. *Demography, 42*(2), 189–214. https://doi.org/10.1353/dem.2005.0011

Davey, G. C. L. (1994). The "disgusting" spider: the role of disease and illness in the perpetuation of fear of spiders. *Society & Animals, 2*(1), 17–25. https://doi.org/10.1163/156853094X00045

Driscoll, J. W. (1995). Attitudes toward animals: species ratings. *Society & Animals, 3*(2), 139–150. https://doi.org/10.1163/156853095X00125

Duncan, L. A., Schaller, M., & Park, J. H. (2009). Perceived vulnerability to disease: Development and validation of a 15-item self-report instrument. *Personality and Individual Differences, 47*(6), 541–546. https://doi.org/10.1016/j.paid.2009.05.001

Faulkner, J., Schaller, M., Park, J. H., & Duncan, L. A. (2004). Evolved disease-avoidance mechanisms and contemporary xenophobic attitudes. *Group Processes & Intergroup Relations, 7*(4), 333–353. https://doi.org/10.1177/1368430204046142

Gerdes, A. B. M., Uhl, G., & Alpers, G. W. (2009). Spiders are special: fear and disgust evoked by pictures of arthropods. *Evolution and Human Behavior, 30*(1), 66–72. https://doi.org/10.1016/j.evolhumbehav.2008.08.005

Gunnthorsdottir, A. (2001). Physical attractiveness of an animal species as a decision factor for its preservation. *Anthrozoös*, *14*(4), 204–215. https://doi.org/10.2752/089279301786999355

Hart, B. L. (1988). Biological basis of the behavior of sick animals. *Neuroscience Biobehavioral Reviews*, *12*(2), 123–137. https://doi.org/10.1016/S0149-7634(88)80004-6

Hart, B. L. (2011). Behavioural defences in animals against pathogens and parasites: parallels with the pillars of medicine in humans. *Philosophical Transactions of the Royal Society B., 366*(1583), 3406–3417. https://doi.org/10.1098/rstb.2011.0092

Hart, D., & Sussman R. W. (2009). *Man the hunted: primates, predators, and human evolution*. Westview Press, Boulder, Colorado.

Jimenez, J. N., & Lindemann-Matthies, P. (2015). Public knowledge of, and attitudes to, frogs in Colombia. *Anthrozoös*, *28*(2), 319–332. https://doi.org/10.1080/08927936.2015.11435405

Johnson, D. D., Blumstein, D. T., Fowler, J. H., & Haselton, M. G. (2013). The evolution of error: Error management, cognitive constraints, and adaptive decision-making biases. *Trends in Ecology & Evolution, 28*(8), 474–481. https://doi.org/10.1016/j.tree.2013.05.014

Kellert, S. R. (1993). Values and perceptions of invertebrates. *Conservation Biology, 7*(4), 845–855. https://doi.org/10.1046/j.1523-1739.1993.740845.x

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*(1), 94–103. https://doi.org/10.1016/j.jenvp.2007.10.001

Kubiatko, M. (2012). Kindergarten childrens perception of animals focusing on the look and fear of animals. *Educational Sciences: Theory & Practice*, *12*(4), 3181–3186.

Lima, S. L., & Dill, L. M. (1990). Behavioral decisions made under the risk of predation: a review and prospectus. *Canadian Journal of Zoology, 68*(4), 619–640. https://doi.org/10.1139/z90-092

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. https://doi.org/10.1080/09500690500038116

LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass. Attention to fear-relevant stimuli by adults and young children. *Psychological Science, 19*(3), 284–289. https://doi.org/10.1111/j.1467-9280.2008.02081.x

LoBue, V., & Rakison, D. H. (2013). What we fear most: A developmental advantage for threat-relevant stimuli. *Dev. Rev.*, *33*(4), 285–303. https://doi.org/10.1016/j.dr.2013.07.005

LoBue, V., Rakison, D. H., & DeLoache, J. S. (2010). Threat perception across the life span: Evidence for multiple converging pathways. *Current Directions in Psychological Science, 19*(6), 375–379. https://doi.org/10.1177/0963721410388801

Lorenz, A. R., Libarkin, J. C., & Ording, G. J. (2014). Disgust in response to some arthropods aligns with disgust provoked by pathogens. *Global Ecology and Conservation, 2*, 248–254. https://doi.org/10.1016/j.gecco.2014.09.012

Masataka, N., Hayakawa, S., & Kawai, N. (2010). Human young children as well as adults demonstrate 'superior'rapid snake detection when typical striking posture is displayed by the snake. *PLoS One*, *5*, e15122. https://doi.org/10.1371/journal.pone.0015122

Michalski, R. L., & Shackelford, T. K. (2010). Evolutionary personality psychology: Reconciling human nature and individual differences. *Personality and Individual Differences, 48*(5), 509–516. https://doi.org/10.1016/j.paid.2009.10.027

Miller, S. L., & Maner, J. K. (2011). Sick body, vigilant mind: The biological immune system activates the behavioral immune system. *Psychological Science, 22*(12), 1467–1471. https://doi.org/10.1177/0956797611420166

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology-General, 130*(3), 466–478. https://doi.org/10.1037/0096-3445.130.3.466

Park, J. H., Faulkner, J., & Schaller, M. (2003). Evolved disease-avoidance processes and contemporary anti-social behavior: Prejudicial attitudes and avoidance of people with disabilities. *Journal of Nonverbal Behavior, 27*(2), 65–87. https://doi.org/10.1023/A:1023910408854

Park, J. H., Schaller, M., & Crandall, C. S. (2007). Pathogen-avoidance mechanisms and the stigmatization of obese people. *Evolution and Human Behavior, 28*(6), 410–414. https://doi.org/10.1016/j.evolhumbehav.2007.05.008

Penkunas, M. J., & Coss, R. G. (2013). Rapid detection of visually provocative animals by preschool children and adults. *Journal of Experimental Children Psychology, 114*(4), 522–536. https://doi.org/10.1016/j.jecp.2012.10.001

Prokop, P., & Fančovičová, J. (2010a). Perceived body condition is associated with fear of a large carnivore predator in humans. *Annales Zoologici Fennici, 47*(6), 417–425. https://doi.org/10.5735/086.047.0606

Prokop, P., & Fančovičová, J. (2010b). The association between disgust, danger and fear of macroparasites and human behaviour. *Acta Ethologica, 13*(1), 57–62. https://doi.org/10.1007/s10211-010-0075-4

Prokop, P., & 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*(1), 15–23. https://doi.org/10.1027/1614-0001/a000092

Prokop, P., & Fančovičová, J. (2013b). Does colour matter? The influence of animal warning colouration in human emotions and willingness to protect them. *Animal Conservation,16*(4), 458–466. https://doi.org/10.1111/acv.12014

Prokop, P., & Fančovičová, J. (2017). Animals in dangerous postures enhance learning, but decrease willingness to protect animals. *Eurasia Journal of Mathematics, Science Technology Education, 13*(9), 6069–6077. https://doi.org/10.12973/eurasia.2017.01000a

Prokop, P., & Fedor, P. (2013). The effects of parasites on human behaviour: An evolutionary perspective. *Problems of Psychology in the 21st Century*, *5*(5), 46–64.

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

Prokop, P., & Kubiatko, M. (2014). Perceived vulnerability to disease predicts environmental attitudes. *Eurasia Journal of Mathematics, Science and Technological Education, 10*(1), 3–11. https://doi.org/10.12973/eurasia.2014.1017a

Prokop, P., & Tunnicliffe, S.D. (2010). Effects of keeping pets at home on children's attitudes toward popular and unpopular animals. *Anthrozoös*, *23*(1), 21–35. https://doi.org/10.2752/175303710X12627079939107

Prokop, P., Fančovičová, J., & Fedor, P. (2010c). Health is associated with antiparasite behavior and fear of disease-relevant animals in humans. *Ecological Psychology, 22*(3), 222–237. https://doi.org/10.1080/10407413.2010.496676

Prokop, P., Fančovičová, J., & Krajčovičová, A. (2016). Alternative conceptions about micro-organisms are influenced by experiences with disease in children. *Journal of Biological Education, 50*(1), 61–72. https://doi.org/10.1080/00219266.2014.1002521

Prokop, P., Fančovičová, J., & Kubiatko, M. (2009a). Vampires are still alive: Slovakian students' attitudes toward bats. *Anthrozoös*, *22*(1), 19–30. https://doi.org/10.2752/175303708X390446

Prokop, P., Özel, M., & Usak, M. (2009b). Cross-cultural comparison of student attitudes toward snakes. *Society & Animals, 17*(3), 224–240. https://doi.org/10.1163/156853009X445398

Prokop, P., Tolarovičová, A., Camerik, A., & Peterková, V. (2010d). High school students' attitudes towards spiders: A cross-cultural comparison. *International Journal of Science Education, 32*(12), 1665–1688. https://doi.org/10.1080/09500690903253908

Prokop, P., Usak, M., & Fančovičová, J. (2010a). Health and the avoidance of macroparasites: A preliminary cross-cultural study. *Journal of Ethology, 28*(2), 345–351. https://doi.org/10.1007/s10164-009-0195-3

Prokop, P., Usak, M., & Fančovičová, J. (2010b). Risk of parasite transmission influences perceived vulnerability to disease and perceived danger of disease-relevant animals. *Behavioural Processes, 85*(1), 52–57. https://doi.org/10.1016/j.beproc.2010.06.006

Réale, D., Dingemanse, N. J., Kazem, A. J. N., & Wright, J. (2010). Evolutionary and ecological approaches to the study of personality. *Philosophical Transactions of the Royal Society B. 365*(1560), 3937–3946. https://doi.org/10.1098/rstb.2010.0222

Røskaft, E., Bjerke, T., Kaltenborn, B. P., Linnell, J. D. C., & Andersen, R. (2003). Patterns of self-reported fear towards large carnivores among the Norwegian public. *Evolution and Human Behavior, 24*(3), 184–198. https://doi.org/10.1016/S1090-5138(03)00011-4

Shepardson, D. P. (2002). Bugs, butterflies, and spiders: Children's understandings about insects. *International Journal of Science Education*, *24*(6), 627–643. https://doi.org/10.1080/09500690110074765

Schaller, M. (2006). Parasites, behavioral defenses, and the social psychological mechanisms through which cultures are evoked. *Psychological Inquiry, 17*(2), 96–101.

Schaller, M., Murray, D. R., & Bangerter, A. (2015). Implications of the behavioural immune system for social behaviour and human health in the modern world. *Philosophical Transactions of the Royal Society B*., *370*(1669), 20140105. https://doi.org/10.1098/rstb.2014.0105

Schlegel, J., & 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. https://doi.org/10.1016/j.jnc.2009.12.002

Sih, A., Cote, J., Evans, M., Fogarty, S., & Pruitt, J. N. (2012). Ecological implications of behavioural syndromes. *Ecology Letters*, *15*(3), 278–289. https://doi.org/10.1111/j.1461-0248.2011.01731.x

Smith, B. R., & Blumstein, D. T. (2008). Fitness consequences of personality: a meta-analysis. *Behavioral Ecology, 19*(2), 448–455. https://doi.org/10.1093/beheco/arm144

Souchet, J., & Aubret, F. (2016). Revisiting the fear of snakes in children: the role of aposematic signalling. *Scientific Reports, 6,* 37619. https://doi.org/10.1038/srep37619

Štefaniková, S., & Prokop, P. (2015). Do we believe pictures more or spoken words? How specific information affects how students learn about animals. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(4), 725–733. https://doi.org/10.12973/eurasia.2015.1380a

Tabachnick, W. J. (1991). Evolutionary genetics and arthropod-borne disease: the yellow fever mosquito. *American Entomologist, 37*(1), 14–26. https://doi.org/10.1093/ae/37.1.14

Tollenaere, C., Rahalison, L., Ranjalahy, M., Duplantier, J.M., Rahelinirina, S., Telfer, S., & Brouat, C. (2010). Susceptibility to *Yersinia pestis* experimental infection in wild *Rattus rattus*, reservoir of plague in Madagascar. *EcoHealth*, *7*(2), 242–247. https://doi.org/10.1007/s10393-010-0312-3

Treves, A., & Naughton-Treves, L. (1999). Risk and opportunity for humans coexisting with large carnivores. *Journal of Human Evolution, 36*(3), 275–282. https://doi.org/10.1006/jhev.1998.0268

Vallin, A., Jakobsson, S., Lind, J., & Wiklund, C. (2005). Prey survival by predator intimidation: an experimental study of peacock butterfly defence against blue tits. *Proceedings of the Royal Society of London B. 272*(1569), 1203–1207. https://doi.org/10.1098/rspb.2004.3034

Yorzinski, J. L., Penkunas, M. J., Platt, M. L., & Coss, R. G. (2014). Dangerous animals capture and maintain attention in humans. *Evolutionary Psychology*, *12*(3), 534–548. https://doi.org/10.1177/147470491401200304