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Preschool children’s taxonomic knowledge of animal species

Abstract: Previous research has established that learners can misclassify animals by not following the tenets of accepted taxonomic rubrics. Compounding the problem, they unwittingly apply these misconceptions to areas of biology where secure knowledge about living organisms is a pre-requisite such as evolution, ecosystems, and others. The current study represents an attempt to explore the biological classification concepts of children aged 3-5 years, and to compare that knowledge with data previously determined using older learners. Importantly, patterns in the way in which preschoolers’ taxonomic knowledge might progress with age were sought to illuminate any potential origins of naive conceptions. A quantitative approach was employed with a sample of 75 children utilising a structured interview method to determine their ideas about the taxonomic labels *animal, fish*, *amphibian*, *reptile*, *bird*, *mammal* and *insect*. Findings reveal that preschool children held many of the same naive conceptions as those previously reported in older learners. Some of these conceptions started to dissipate with age; however, others began to emerge in the older children within the sample. The five year-olds were generally better at classifying archetypal species although in most cases did not perform as well as their younger counterparts when they classified non-archetypal species, representing a decline in performance with age. This decline is concerning though can be accounted for by contemporary categorisation theory, giving support to the view that science misconceptions can emerge in the early years due to natural cognitive maturation, as well as exposure to formal and informal learning experiences. To supplement established conceptual change strategies, which deal with already-formed misconceptions, it is proposed that there be a fresh research emphasis towards *conceptual creation* where acceptable scientific ideas are seeded at the earliest years of schooling. Accordingly, the role of early years educators would become fundamental to effective science education.

**Key words**: Biology education; early years science; animal taxonomy; human categorisation abilities.

Introduction

In contemporary society importance is increasingly placed upon an understanding of ecology and biodiversity, so it is desirable that the populace be able to recognise and name certain plant and animal species (Randler, 2008) and also to locate species within taxonomic groups (Kattmann, 2001). However, taxonomic misconceptions are rife. Particularly, despite the concept of ‘animal’ being central to biology, students often classify animal species poorly (Braund, 1991; Tema, 1989). Learners unknowingly apply these misconceptions to areas of biology where secure knowledge about living organisms is a pre-requisite, such as evolution, genetics, photosynthesis, and ecosystems (Banet & Ayuso, 2003; Lin & Hu, 2003; Yen, Yao & Mintzes, 2007). For instance, understanding ecological crises that threaten to endanger species may be hampered by incorrect ideas about how animals, plants or micro-organisms are biologically classified (Yen, Yao & Chiu, 2004), and misconceptions about exactly which species are bacteria, fungi and aquatic plants interfere with a scientific understanding of food chains (Adeniyi, 1985).

Since science curricula require teachers of young children to deliver material relating to living things and their habitats, it is valuable to know children’s baseline knowledge of animals at the point of admission to primary school. That said, there is a dearth of empirical evidence that sheds light upon what preschool children[[1]](#endnote-1) understand by the taxonomic label *animal*, as well as the related vertebrate class taxa *fish, amphibian, reptile, bird* and *mammal*, and the arthropod taxon *insect*. The current study was devised to address this gap in knowledge which is timely in the light of the planned introduction of a new primary National Curriculum in England in 2014 (DfE, 2013), within which concepts about animal classification, including the vertebrate classes, have been newly introduced into the year 1 Programme of Study (ages 5-6 years). The study’s overarching aim was to sample the taxonomic ideas of children aged 3-5 years primarily in order to locate any progression in knowledge with age, using existing categorisation theory in order to explain patterns that may arise. As part of this process we wanted to compare the children’s ideas with those that have previously been reported by workers who have sampled older participants. Although other research has studied misclassifications both quantitatively and qualitatively in older children and adults there is little previous work that has accrued a sample of preschool children. In fact, this age group has been neglected generally in the field of substantive scientific conceptual research. In addition, the current research represents the first study to examine all of the target concepts using a statistical approach where any inferences are required to be borne out by statistically significant relationships.

Previous research

The current study was planned with reference to work situated largely in the developmental psychology genre which has focused on how young children categorise the world around them. This section will briefly summarise that work, and then specifically apply its underlying theories to other research from the field of science education that has surveyed how learners categorise animals.

*The development of categorisation abilities*

Evolution has provided humans with the capacity to construct a mental representation that is symbolic of any individual entity that exists in the environment. For reasons of cognitive efficiency people are also capable of mentally organising these representations into groups, called concepts. The capability to construct ever more sophisticated concepts and hierarchies increases throughout childhood and classic theorists proposed that these abilities are developmentally cued to appear at specific ages. They emphasised markedly different modes of thought at different stages, with a child’s thinking changing qualitatively in a stepwise manner, often over a short period of time. Perhaps the best known example is Jean Piaget’s model of the stages of cognitive development (Piaget, 1972). More recently, evidence has emerged that offer considerable challenges to these assumptions (e.g. Hughes, 1975; McGarrigle & Donaldson, 1974). Once-firm age boundaries that delineated stages have become blurred as experiments came to show that when given an appropriately-framed task, young children are quite capable of mental operations that were previously thought impossible given their current state of development.

To illustrate, it was previously assumed that young children can only form concepts that are symbols of concrete objects or events in the environment which are able to be directly perceived (Bruner, Goodnow & Austin, 1967; Piaget & Inhelder, 1973). Because of this reason, between 2-5 years children tend to focus on perceptual attributes when forming categories, only grouping objects together if they have the same colour, shape, texture, taste, etc (Tversky, 1985; Wellman & Gelman, 1988). From 5 years upwards perceptual similarities are still important, but less obvious, more imperceptible characteristics such as the monetary value of a toy can become criteria that define categories (Whitney & Kunen, 1983). However, several studies have confirmed that young children can disregard similarity in appearance and instead focus upon imperceptible attributes when categorising cases. For instance Gelman and Markman (1986) were able to show that if children from 3½ years were given information about whether animals of similar appearance were cold or warm-blooded, they could correctly make a simple inductive prediction, ignoring visible similarity. There is evidence to indicate even infants are capable of constructing categories using non-visible, more abstract criteria; for example Téglás, Vul, Girotto, Gonzalez, Tenenbaum *et al*. (2011) found that 12 month-olds are able to draw upon abstract knowledge during simple reasoning tasks.

Children’s ability to reflect upon the more imperceptible attributes of a given case is not age-mediated, but instead is experience-mediated - as children learn more criteria over time and become more practiced in applying them they can build ever-more sophisticated categories and hierarchies. Such constructivist views of human development refute the hypothesis that different cognitive processes are required in order to account for the categorisation behaviours displayed by learners of different ages. They instead acknowledge that during categorisation tasks both infants and adults alike access precisely the same processes with differences in performance being solely attributed to the amount of source information that is currently available to each individual (Eimas, 1994; Madole & Oakes, 1999). Because of this, linguistic and cultural factors such as the assimilation of language, exposure to teaching, and cultural norms and practices are paramount to development. Studies underpinned by classic theories may give the impression that child development is preset with capabilities appearing according to a predetermined timetable. As discussed, more recent studies have refuted these models, and constructivist theories of development hold the view that concepts are built up piecemeal over time and do not suddenly appear at phase boundaries delineated by chronological age. These assumptions are compatible with those of constructivist science educators (e.g. Posner, Strike, Hewson & Hertzog, 1982) who posit that learning is highly dependent upon the quantity and quality of the knowledge that has been previously constructed by the learner.

Insert tables 1 & 2.

*Previous studies of animal classification*

The second part of this section is a résumé of previous research reported in the science education literature that has surveyed how learners classify animals. The findings of this research will be examined with reference to contemporary theories of categorisation in order to look for common explanations that may provide some synthesis. Tables 1 and 2 summarise this work, and include the kingdom taxon *animal*, the vertebrate class taxa *fish, amphibian, reptile, bird* and *mammal*, and the arthropod class taxon *insect.* With all of these taxa studies report a steady increase in classification performance with age (although with the animal and insect taxa the more archetypal organisms are correctly identified at a young age and performance does not improve beyond that). Reasons for these age-related improvements in performance have not been previously elaborated upon by the authors of the studies beyond the fact that as children gain more biological knowledge about species they become better at classifying animals. Hitherto, writers have not focused on children’s development of categorisation abilities as a possible factor for differences in performance. When children are asked to sort animals into sets they first approach the task as they would any other classification assignment – they look at the visible attributes of each case and then start to collate similar-looking cases into the same set. Although biological taxonomy relies heavily on visual characteristics, other, less obvious attributes are equally important such as the ability to respond rapidly to stimuli through movement, and whether a case is warm or cold blooded. Under normal circumstances most children under 7 years find it very difficult to even comprehend these less perceptual, more abstract criteria, much less apply them when making classification decisions. Older children are more capable of understanding these criteria and so become more adept at animal classification tasks. When they have given reasons for their choices, with most taxa there is some evidence of younger children preferentially relying on visual characteristics more than their older peers. Shepardson (1999) notes that young children’s ideas about insects were governed by perceptual similarity when they thought mealworms (beetle larvae) were not insects because they resembled earthworms. On the other hand, older students employ more sophisticated rubrics and use fewer perceptual characteristics; for instance Trowbridge & Mintzes (1985) found that college students (incorrectly) used their knowledge of the processes of life (nutrition, reproduction, etc) when deciding whether a species was an animal. To date, authors have not further developed these justifications beyond the descriptive.

To become proficient in biological taxonomy learners must know and understand all of the criteria needed for group membership, and appreciate that to be a member of that group it is necessary that a case possesses all of these attributes - it is not sufficient for a case to only possess some of them. During sorting tasks although they are able to name several characteristics possessed by a single case, children aged below 7 years tend to categorise cases by focusing on a single characteristic only such as the colour of an object, or the number of sides a shape has, instead of considering several characteristics in parallel (Wellman & Gelman, 1988). In addition, under normal circumstances the level of logical reasoning required to process necessary/sufficient decisions may not appear until 11 years (Smith & Medin, 1981). Biological taxonomic structures are hierarchical in nature with smaller sets being subsumed within larger sets, but understanding hierarchies is very difficult for children under 5 years who cannot focus on subclasses (e.g. cat) and superordinate classes (e.g. animal) simultaneously (Branco & Lourenco, 2004). This appeared to be evident in the animal classification studies (tables 1 & 2), for instance there was a clear over-generalisation by some students with respect to classifying amphibians, with the label being allocated to organisms that inhabit both aquatic and terrestrial habitats without the application of other necessary criteria (Yen *et al*., 2004, 2007). The taxonomic criteria for *amphibian* are more precise and exclusive however, and include the ability of a vertebrate to respire both underwater and in air.

Although learners become more proficient at biological classification with age, their cumulative experiences can also act in a converse way and be a contributory factor for misclassifications. For instance one reason given by students to why they believe penguins are mammals is because they provide milk for their young (Yen *et al*., 2007), which may be a result of watching natural history programmes where chicks are seen to take refuge underneath the mother’s body, engulfed in a thick layer of feathers (Braund, 1991). Trowbridge and Mintzes (1985) offer the interpretation that a penguin is squat, cannot fly, and so may be associated with the Antarctic seal. Bell (1981) explains the views of her New Zealand students aged 10-15 years who stated that mammals are mostly things that live in water, and suggests this was a consequence of TV conservation programmes about endangered whales and dolphins. The adverse effects of children’s experiences on their taxonomic decision-making are paramount to explaining the data from the current study and will be elaborated upon in later sections.

The studies cited above sampled a variety of learners from diverse countries of origin. Despite this, the same misclassifications appear in different samples that are geographically widespread which indicates a commonality of thought that is independent of learners’ cultures. However, there were some distinct language-based and cultural influences that appeared to mediate learners’ classification decisions. Those that were linguistically-mediated include the jellyfish and starfish having ‘fish’ in their names and so were incorrectly categorised as fish (Trowbridge & Mintzes, 1985, 1988). With the amphibian taxon students also displayed confusion with the meaning of *amphibious*, e.g. an amphibious vehicle can operate on both land and in water, and tended to categorise all species that had a mixed aquatic/terrestrial habitat as an amphibian (e.g. Braund, 1991). Another contributory factor is the existence of an alternative, everyday meaning for a taxon label (Ryman, 1974), with taxa such as animal, bird, fish and insect having restricted colloquial definitions that only include archetypal species; for example in everyday parlance a thrush could be commonly called ‘a bird’ but a penguin would not be. Other misclassifications were due to cultural or religious beliefs and practices. Tema (1989) found that 10-16 year-olds from Botswana correctly identified nearly all cases as animals (except humans), both archetypal and non-archetypal, and argued that the students had used anthropocentric reasoning based on Christian instruction and traditional African thinking that sets humans apart from all other animals.

To sum, factors that mediate learners’ categorisation decisions during animal classification tasks are experience-related and depend on a child’s present level of cognitive development. They can be accounted for by contemporary theories of categorisation, and include the amount of personal knowledge gained through formal and informal education, the ability to reason logically, the understanding that biological taxonomy involves hierarchies, being able to utilise less visual, more abstract concepts, and linguistic/cultural reasons that are less generalisable. The literature reports universal, steady improvements in animal classification performance with age, and these factors help explain why particularly children under 7 years have problems correctly classifying animals. The present study was devised to extend this previous work and explore the taxonomic knowledge of preschool children in order to compare their ideas and developmental trajectories with those reported by older learners, and to account for them with reference to categorisation theory and by considering potential linguistic and/or cultural influences. The research questions were:

1. How do children aged 3-5 years conceptualise *animal* and the related taxonomic entities of *fish*, *amphibian*, *reptile*, *bird*, *mammal* and *insect*?
2. Are there differences between these entities and those conceptualised by participants older than 5 years, as reported in the literature?
3. Are there any identifiable patterns in the way children’s ideas progress from ages 3-5 years, and can these patterns be explained with reference to existing theories of child development?

Methodology

*Participants and setting*

The research was carried out using an opportunity sample of 75 participants aged 3, 4 and 5 years accrued from eight different primary schools, nurseries and playgroups in the south east of England; 25 children from each of the three year groups took part.

*Validity*

In order to assess the content validity of the interview tasks the cases used with all taxa were forwarded to a university senior lecturer in biology for assessment. He was able to confirm that the schedule accurately represented biologically acceptable taxa.

*Interview procedure*

Children were interviewed singly by two researchers in a quiet corner of the classroom. The aim of the interview was to ascertain each child’s understanding of the taxonomic labels *animal, fish, amphibian, reptile, bird, mammal* and *insect*, and was achieved by having the child carry out seven simple sorting tasks, one task per taxonomic label. The taxa were presented in the same order for children and were dependent upon the predicted familiarity of the taxa to prevent them becoming disheartened and giving up early in the exercise; the order of presentation was *animal*, *bird, fish, insect, reptile, amphibian* and *mammal.*

For each sorting task the researchers presented anatomically accurate plastic models and the child decided whether or not the taxonomic label in question was appropriate for each model by undertaking a straightforward binary choice. To illustrate, with the *animal* task 22 plastic models were placed on a table and the child was firstly asked to name each model. If the model was not named correctly the interviewer supplied the name. With all of the models on the table in full view the child was then asked to divide them into two sets, animals and non-animals. Children were given as much time as they needed when choosing and were permitted to change their minds and switch sets. When all the models had been allocated to a set children were asked to give reasons why selected models had been allocated to a set and this followed a system – one correct positive case (e.g. tiger in the animal set), one correct negative case (e.g. robot in the non-animal set), then all the cases that the child had allocated incorrectly (e.g. spider in the non-animal set). These reasons were recorded along with any other comments the child made that were thought to be relevant. An identical procedure was carried out for the remaining six taxa.

The models used for each taxon are given in the results tables. Except for *animal*, each taxon collection was composed of 13 models, consisting of five correct cases and eight incorrect cases. Of the incorrect cases one was an ‘obvious’ incorrect case (e.g. cat for the *bird* task) and one was an inanimate object (a piece of furniture, used to test whether the child had understood that basic rubric of the task). The remainder of the incorrect cases were used because of their status as known misconceptions that had been reported in the literature. The *animal* taxon collection in contrast had 22 models, 17 of which were correct cases and five incorrect cases. In total all the seven taxa together comprised 100 cases.

*Analysis*

Given the binary nature of the data,statistical operations were undertaken using simple and complex chi-square for goodness of fit. These were applied to the frequency data, the verbal reasons data, and when determining the possible influence of gender on performance. The confidence limits for statistical significance were set at 95%; p values are denoted in the tables as follows: \* p < 0.05; \*\* p < 0.01; \*\*\* p < 0.001; \*\*\*\* p < 0.0001.

Data are presented in three elements. *Frequency tables* show the number of times each year group of 25 children chose each case, correctly or incorrectly, as belonging to a taxon (tables 3, 6, 9, 12, 15, 18 & 21). *Prototype-relevant categorisation reasons* *tables* draw on the comments that children had given as warrants for their classification choices (tables 4, 7, 10, 13, 16, 19 & 22). The verbal reasons that children gave during interview were allocated to categories that reflected main themes, almost all of which were predetermined and refer to the types of reason that children from previous studies have offered for their classification decisions. These themes were*, appendages, locomotion, behaviour, habitat, nutrition, physiological, cites identity, anthropocentric* and *miscellaneous*. The themes were not exactly the same for each taxon as class-specific themes are evident that usually relate to correct taxonomic attributes of that taxon, e.g. *beak* (bird), *claws* (reptile). Note that only those themes that were relevant to a common prototype specific to each taxon are presented in the tables and these were usually attributes that were age dependent to a statistically significant degree. Two researchers independently coded the verbal reasons data and the inter-relater reliability coefficient was within acceptable boundaries (93.9%). *Summary of prototypical features* *tables* (tables 5, 8, 11, 14, 17, 20, & 23) recap any common prototypes that were applicable for each age group, drawing upon age dependent attributes from the other two tables in the taxon that had a statistically significant differential. These particular tables form the essence of the results.

For brevity when each year group is discussed as a whole it is referred to thus: three year-olds, 3s; four year-olds, 4s; and five year-olds, 5s. For the frequency tables n=25 for each of the three year groups, and when the entire sample is represented, n=75. For the prototype-relevant categorisationtables each value given is the number of children per year group who had stated that category of reason, per taxon. All claims made in the main text are statistically significant unless otherwise indicated and can be cross-referenced to the tables where probability values are denoted. When a claim is made that is not recorded in the tables then the probability and chi square values are given alongside the claim in the main text. Because the sample was accrued on an opportunity basis gender balance was not purposely stratified; however, gender distribution was subsequently found to be statistically equivalent with the entire sample (35 girls, 40 boys; *X*2 = 0.02, p > 0.8) and within each of the three year groups. When all the analyses were considered there were no gender differences throughout, with boys and girls performing equally well in all tasks.

Results

Insert tables 3-23.

Discussion

This section compares data from the current research with those acquired by previous workers (tables 1 & 2) by presenting common prototypes and misclassifications that were prevalent with each of the taxa under study. Within each taxon, prototypes and misclassifications differed according to age and general patterns emerged that indicated trajectories of development that were common across taxa. As was the case with the literature review, these trajectories will be accounted for with reference to existing theories of categorisation.

*Animal*

Relatively large, terrestrial, quadrupedal mammalian archetypes dominate the top of the frequency ranking, with the tiger heading the list (table 3). The species least thought to be animals were invertebrates; this trend is in accordance with previous research (Chen & Ku, 1998; Trowbridge & Mintzes, 1985, 1988; Tunnicliffe, Gatt, Agius & Pizzuto, 2008; Yen *et al*., 2007). On the whole, with all ages considered, children classified animals with a fair degree of accuracy although there were many misclassifications, largely with non-archetypal animals, and importantly there was an age-related decline in performance with the 5s being surpassed by the 3s. When participants’ choices are examined more closely, with the five most archetypal animals (tiger, pig, cow, giraffe and dog) all ages performed equally well, but with the non-archetypal species (all the other cases) a decline in performance with age was again apparent. Earlier studies have similarly found no differences between the correct choices of differently aged participants with respect to archetypal species, although correct classification with non-archetypes tends instead to increase with age (e.g. Trowbridge & Mintzes, 1988).

*Fish*

The clownfish, blue angelfish and green angelfish were the most commonly chosen cases (*X*2 = 99.15, p < 0.0001), with the whole sample of 75 children correctly identifying these three cases as fish (table 6). This concurs with previous research with older students where archetypal fish having an elongated, streamlined body, fins and a tail are the more commonly recognised (Braund, 1991; Chen & Ku, 1998; Ryman, 1974; Trowbridge & Mintzes, 1985, 1988). The 3s were more likely than the 4s or 5s to think that exclusively the three archetypal cases and no others were fish (*X*2= 3.98, p < 0.05). The fact that the 3s rejected other aquatic species as being fish suggests that they were referencing a mental prototype based more on physical appearance; older children were more willing to include species that did not resemble archetypal fish. With the non-fish cases there was a decline in performance with age with the 3s outperforming the 5s which indicates that the 5s were more willing to erroneously accept aquatic non-fish species such as the dolphin and octopus into their fish set. This can be explained by the fact that although all ages were able to mention the easily observable physical features of models when giving reasons to why something was a fish, the 5s focused more than the other children on the more abstract idea of an ability to move through water which led them to over-generalise their fish concept and include non-fish (table 7). Linguistically-based misconceptions such as a starfish or a jellyfish being a fish because it has ‘fish’ in the name were mentioned by only four children, all five year-olds.

*Amphibian*

As a whole children did not perform as well when identifying members of the amphibian class as they had done with most of the other taxa, as shown by an even spread of the amphibian cases throughout the ranking (table 9). Nevertheless, the 5s outperformed the 3s with the amphibian species; conversely, there was a decline in performance with age as the 3s outperformed the 4s when the non-amphibian species were considered, with cases such as dolphins, crocodiles and seals being erroneously placed into the four year-old children’s amphibian sets. There were many such misclassifications, for example 40/75 children believed a giraffe was an amphibian. The misclassification of non-amphibians such as turtles and penguins has been reported by previous workers who note that learners often over generalise and include species that are *amphibious* into the amphibian class, neglecting other necessary taxonomic criteria (e.g. Yen *et al*., 2004, 2007). The 5s cited habitat as a reason as to why a case was an amphibian more than the other age groups, giving a wide variety including snow/ice and jungle (table 10), though the most frequent kind of habitat given was aquatic/semi-aquatic. However, only 4/75 gave a purely semi-aquatic explanation, the remainder being solely aquatic reasons. That the 5s were to some extent using a watery habitat criterion does not provide convincing evidence that they fully understood whether a species was an amphibian since for instance they were reluctant to choose the archetypal frog as part of their amphibian set.

*Reptile*

Overall the most frequently chosen cases were the five reptile species including the iguana and lizard; the least popular were invertebrates such as the centipede and cockroach (table 12). In line with earlier studies the turtle is the least popular reptile (Trowbridge & Mintzes, 1985; Yen *et al*., 2004, 2007). There were many misclassifications included in children’s reptile sets including invertebrates such the stick insect and snail; 44/75 children thought the horse was a reptile. The 5s outperformed the 3s and 4s when classifying the reptile species correctly and there was no decline with non-reptile species as all ages performed equally well. The reptile concept seemed poorly understood at ages 3 and 4 years with some children seemingly choosing species for their reptile set in a more-or-less random way. At age 5 however, many children appeared to have an emerging idea of what constitutes a reptile and were able to correctly identify species such as the lizard and iguana with fairly good accuracy.

*Bird*

The three cases most frequently recognised as birds were the goose, owl and duck (table 15). Having noticeable wings, feathers, a beak and being capable of flight, previous research confirms that cases resembling this archetype are more commonly cited by older children (Braund, 1991; Chen & Ku, 1998; Prokop, Kubiatko & Fančovičová, 2007; Trowbridge & Mintzes, 1985, 1988; Ryman, 1974; Yen *et al*., 2007). The two flightless birds (ostrich and penguin) occupy positions lower down the frequency table, and more 5s than 3s identified the ostrich as a bird. However, the ability to reject flight-capable non-birds such as insects, the pterosaur and bat from the bird taxon did not similarly improve with age. The most common reasons given by children to explain why a case is a bird involved themes around appendages (generally wings) and locomotion - expressly the ability to fly was offered by more 5s than 3s (table 16), which would help explain why more flight-capable non-birds were favoured by the 5s. Although the possession of wings was the most commonly noted feature of belongingness to the bird taxon (by 47/75 children) there were no age differences.

*Mammal*

The overall ranking is mixed, with mammalian species sprinkled evenly throughout the table (table 18). To the contrary, previous research with older children has found that mammals such as dolphins, dogs, mice, humans and seals head the frequency lists (Braund, 1991; Ryman, 1974; Trowbridge & Mintzes, 1985, 1988; Yen *et al*., 2007). This mixed performance demonstrated by all ages in this study indicates children had only a tentative grasp of the mammal concept; in fact they scored the least correct responses of all the taxa surveyed – on average each child scored only 48.08% correct cases with the mammal taxon. Nevertheless, the 5s outperformed the 3s with the mammal species, although conversely there was a decline in performance with age as the 3s performed better than the 5s with non-mammal species. There were numerous misconceptions particularly with the 5s misclassifying birds such as the owl, kiwi and penguin as mammals.

*Insect*

Overall, the most popular choices were the five insect species (table 21) and the ranking approximates with those from previous studies which have found that learners tend to categorise something as being an insect if it is small with jointed legs and has a ‘bug shaped’ oval body (Braund, 1991; Shepardson, 2002). Most children were able to categorise all the insect cases correctly and performance improved with age, with the 3s less adept at correctly identifying archetypal insects. There was an age-related decline however, for the non-insect cases with the 3s outperforming the 5s. More 5s than 3s mistakenly believed that the centipede and the earthworm were insects, the centipede mainly because it had lots of legs, and the earthworm because of its ground-dwelling habitat (table 22). As age increased more reference was made to insects having lots of legs or a specified number of legs, whether that be six legs, eight legs, (etc). More 5s and 4s gave the reasons of being able to slither/slide/wriggle, and/or being ground-dwelling, which broadly concur with those given by older children in previous studies (Shepardson, 2002; Strommen, 1995).

*Summary*

When overall achievements are considered the sample as a whole performed comparably well with the animal (mean 84.36% correct cases per child), fish (72.08%) and bird (68.00%) taxa making many taxonomically correct choices. They performed less well with the insect (60.62%) and reptile (57.77%) taxa, and comparatively poorly with the amphibian (53.92%) and mammal taxa (48.08%). With nearly all the taxa there were age-related declines in performance at least in part caused by the older children focusing more on abstract criteria, which served as distracters. The younger children gave reasons for their choices based more on concrete, observable features of the species and since making correct taxonomic decisions depends largely on grouping species by physical appearance, performed better than their older counterparts. Referring to the insect taxon as an exemplar, at 3 years children focused on a case’s physical features such as wings or legs when deciding whether it was/was not an insect. At 5 years these physical features were still important, but other, less discernible factors emerge involving habitat, method of locomotion, and comparative body size. Five year-olds tended to believe an insect has many legs, is ground-dwelling, has a slithering, sliding or wriggling gait and is comparatively small. For these reasons the older children were more adept at correctly classifying archetypal insects such as the ant and ladybird. However, for those very same reasons they were more ready to include spurious cases into their insect taxon because they had mistakenly applied criteria that the younger children did not seem to be aware of such as having many legs (e.g. centipede) and being ground dwelling (e.g. earthworm) which impaired their overall performance.

Conclusions

Previous workers have determined that learners of all ages can misclassify animals and that performance nearly always improves with age. The current study provides data to show that 3-5 year-olds can also be susceptible to these same misconceptions and that some of them similarly begin to dissipate with age. However, with most of the taxa (*animal, fish, amphibian, mammal* and *insect*) there were also declines in performance in one or more aspects of classification as age increased. If these declines from ages 3-5 years are compared with the steady increases from 5 years onwards reported previously then this represents an overall U shaped performance. Older children in the current study were more adept at classifying taxon species, for instance they knew that a seahorse is a fish, but at the same time were willing to include more non-taxon species such as the crab into the fish set and so made more errors. These non-taxon classification errors were responsible for the declines in performance by the older children and were almost always related to them considering more abstract criteria that were taxonomically inappropriate, usually habitat and/or means of locomotion. The younger participants tended to focus solely on anatomical criteria and as such made fewer misclassifications.

Children of all ages typically offered anatomical reasons for their choices at frequencies that did not statistically alter with age, although the five year-olds focused more on taxonomically valid anatomy such as the number of legs, having a beak, or fins, so had demonstrated more scientifically acceptable ideas in this regard. For most taxa the three year-olds barely mentioned the more abstract criteria such as habitat and locomotion. These differences in performance can be explained with reference to categorisation theory, particularly constructivist theories of child development which assume that age disparities in children’s thinking are not due to any discontinuous, qualitative cognitive advancement. Instead they are solely experience-mediated and depend crucially on linguistic and cultural factors (Madole & Oakes, 1999), a view not compatible with classic stepwise theories of stage development previously presented by Piaget, Bruner and others. In the current context this can be clarified by attributing the age-related performance declines to two reasons, which are in effect two aspects of the same process and is fundamental to constructivist theory: that capabilities increase with age because of cumulative exposure to enriched experiences over time. Firstly, there were quantitative differences between the knowledge of the younger and older participants that influenced their respective performances. It seems likely that because the three year-olds had less life experience and probably knew fewer facts about animals this meant they had less to draw upon concerning where an animal lived, how it behaved, etc (Gelman & Meyer, 2011). It is counterintuitive to think that that the enrichment of a child’s general understanding of the world that occurs with cumulative experiences may have perversely caused a regression in scientific performance, but this could well have been the case.

Secondly, and in parallel to the first reason there may have also been age-related differences in children’s thinking that are developmentally-linked. When very young children are set classification tasks they rely on superficial perceptual attributes and group cases together simply because they look alike (e.g. Flavell, 1963; Rakison & Lupyan, 2008; Smith, Jones & Landau, 1996). Thus, to the 3s the crab and jellyfish simply did not look like the angelfish and so were (correctly) not placed in the fish set. Under normal circumstances the typical three year-old child is not capable of categorising beyond this perceptual level and so has considerable difficulty considering more abstract criteria such as habitat or locomotion, which would account for the younger children outperforming their older peers with non-taxon species which did not resemble a prototype. For instance the 3s did not consider a crab’s aquatic habitat and so the fact it was visually dissimilar to an archetypal fish led to its correct rejection from the fish taxon. For the same reason the 3s and 4s erroneously rejected fish species such as the seahorse and stingray due to decisions based on their non-archetypal physical attributes, which would explain the superior performance of the older children with many of the taxon species. All this considered, contemporary theories of categorisation have shown that these limitations in young children’s thinking can sometimes be overcome if a task is presented to them in certain way (e.g. Gelman, 2003), which bodes well for early years education and is discussed further in the final section of the paper.

In order to successfully categorise cases people must have first constructed some mental representation of a typical case (prototype) that represents the category, which can be matched up against each novel case when they undertake classification decisions. In addition, they need to know all the attributes required for inclusion into that category and be aware that all of those attributes are necessary - it is not sufficient that a case possesses less than all of them. In the current study there was very little evidence of necessary/sufficient forms of reasoning which are fundamental to biological classification with children of all ages invariably happy to apply a single attribute when allocating to a set without thought of other defining features - a butterfly has wings so then it must be a bird, despite having no feathers, beak, etc. Smith and Medin (1981) found that this level of logical reasoning only emerges at around 11 years under normal circumstances. Children under 5 years find it very difficult to understand hierarchies because they are not able to focus on subordinate and superordinate classes simultaneously (Branco & Lourenco, 2004) and this was evident in the current study as the inappropriate citing of identity was a common response at all ages, e.g. *it’s not an animal because it’s a fish.*  Although children readily offered reasons for their choices hardly any were aligned with acceptable taxonomic criteria which is unsurprising considering that statutory nursery and reception curricula in England do not include this advanced biological knowledge. This drawback has been noted frequently by other researchers using samples of much older students (e.g. Ryman, 1974).

The animal taxon deserves special mention. As with the other taxa, the performance decline demonstrated by the 5s appeared to be due to their younger counterparts focusing less on abstract criteria such as locomotion and habitat and so making more taxonomically correct decisions. However, the spurious four-legged, terrestrial, mammalian archetype described by the 5s suggests that a major influence could have been linguistic or cultural, since alongside the biological definition for *animal* there is an everyday definition that reflects precisely this archetype. The 5s could have assimilated this via formal and/or informal learning situations to a greater degree than the younger children, and this phenomenon has been noted in studies with older students (e.g. Bell, 1981). The fact that the younger children in the current sample were less susceptible to the everyday archetype and so made fewer errors is notable. Similar linguistic or cultural factors may have led to the misclassification of non-archetypes in other taxa where there are also colloquially restricted definitions such as bird, fish and insect. For instance in an everyday sense the label ‘bird’ could be readily applied to a goose, but not a penguin,

Implications

At a basic level the current research informs interested early years teachers and carers of children’s taxonomic concepts including specific misclassifications that they may be susceptible to between the ages of 3-5 years. This is particularly important when children first experience formal teaching of simple taxonomy at school, as baseline knowledge of what learners believe to be an animal, a fish, etc will be of concern to practitioners prior to teaching the topic. This has immediate relevance in England, since from 2014 primary teachers in state schools will be obliged for the first time in the history of the National Curriculum to teach animal classification to children aged 5-6 years (DfE, 2013). Taxa will include *animal, fish, amphibian, reptile, bird,* and *mammal*, with children being required to learn the names of the taxa, identify examples and describe and compare animals’ structures. There is evidence to suggest that some elementary teachers have their own latent misconceptions about animal classification (Burgoon & Duran, 2012; Chen, Huang & Wang, 1994; Trowbridge & Mintzes, 1988), therefore if biological taxonomy is to be taught effectively early years practitioners both in England and elsewhere would ideally undergo some form of training or self-study to confirm their own knowledge.

In understanding how to classify biological species in a scientifically appropriate way learners must first construct a mental prototype that reflects a typical instance of each taxon. This prototype can be then compared with novel cases and the relevant choice is made whether to accept or reject that case from the set. Experience is crucial to the development of mental faculties, and so exposure to a wider variety of set exemplars (both archetypal and non-archetypal) will strengthen the prototype and sharpen the boundaries of the set, helping to differentiate it more clearly from other, competing sets (Posner & Keele, 1968). More recently, Oakes, Coppage and Dingel (1997) found that 10 month-old infants could categorise plastic models of animals more effectively when they were exposed to both archetypal cases as well as non-archetypal cases that were exclusive of the set, suggesting that the ability to enhance a prototype using varied exemplars is fundamental to categorisation. Young children are capable of learning by rote (simple song lyrics, nursery rhymes, numbers, etc) therefore teachers can provide a variety of cases that with practice, children would be able to recall, helping them to overcome a seemingly-programmed tendency to classify using only physical features. When called upon most preschool children would be capable of recalling by rote a few exemplars of biological taxa, which seems to be one of the statutory tasks within the new English Science National Curriculum for Year 1 (ages 5-6 years). However, the application of many exemplars to further define the set may be more problematic - the danger here being that the unintentional assimilation of incorrect exemplars will only culminate in the construction of spurious sets.

One approach has been found to be particularly powerful in helping young children to see beyond the merely perceptual attributes of a case during categorisation. If a two or three year-old child hears a case being given an explicit label by knowledgeable others such as parents or teachers this has a dominant effect on their subsequent categorisation decisions. They will categorise with respect to the label and override physical cues (e.g. Fulkerson & Waxman, 2007; Gelman & Meyer, 2011; Jaswal & Markman, 2007); for instance, they would be more likely to correctly categorise less archetypal species such as ostriches or penguins as birds. If teachers give explicit taxonomic labels to cases such as these by reciting aloud for example *an ostrich is a bird*, preferably in conjunction with a rhyming, musical delivery, children may rote learn them and subsequently recall them correctly. If exemplars with category labels are reinforced at frequent intervals this would help challenge misconceptions that may be constructed after the initial teaching due to subsequently learning about an animal’s habitat or means of locomotion, for instance.

Finally, further research could investigate whether other science misconceptions might emerge as a result of children’s’ natural cognitive development by similarly surveying preschool children to see how their scientific knowledge progresses with age. Many writers have suggested that science misconceptions are constructed in the early years prior to compulsory schooling but there is a surprisingly few number of studies that have demonstrated this. Uncovering the early origins of misconceptions would represent a way forward in assisting primary school children to understand science, so helping to foster a firm interest in the discipline later on in their school careers. The conceptual change movement pioneered by researchers such as Posner *et al*. (1982) has become a dominant paradigm in contemporary science education. Numerous pedagogies (summarised by author, 2010) have arisen from this research and apply to science misconceptions that students may have formerly constructed earlier in their childhood, aiming to change these conceptions to scientifically acceptable variants. A fresh emphasis on research into *conceptual creation*, that is to say, when, how and why misconceptions first originate, with the aim of formulating pedagogies that help ensure that children are prevented from constructing these ideas in the first place would be a better approach. Examining such data through the lens of constructivist theories of child development would seem to be favourable, not merely because these theories are compatible with the assumptions of Posner *et al*.’s constructivism that is currently so pervasive within science education. The child development literature is all too infrequently cited within our genre, although further research that accrues preschool samples would likely reference established theories that are well known to developmental psychologists. If studies into conceptual creation were to gain popularity, eventually becoming the norm, then findings would shift a considerable responsibility for the initial science education of the populace onto the shoulders of early years practitioners, and would require thoughtful reformation of present educational structures and curricula.

1. ‘Preschool’ in the context of the current study refers to the period of time before a child is exposed to the English National Curriculum in Year 1 (ages 5-6 years).

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