Mental representations and cognitive processes related to the physical world in jackdaws (*Corvus monedula*)

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1. Introduction

Species from the corvid family have been reported to possess some outstanding cognitive abilities both from the physical and from the social domain. These abilities may even parallel those of great apes (Emery & Clayton 2004). Non-caching corvid species, such as the jackdaw (Corvus monedula) are relatively underrepresented in studies of corvid cognition. To fill in some of this gap, we investigated physical cognition of this species by utilizing comparative methods.

First we assessed the development of mental representations of the physical world, its objects and their interactions. Piagetian object permanence is the ability to form an inner mental representation of the physical world, and to follow object movements, localizing them even in the case when no direct perceptual input is available for the nervous system (Piaget 1954). Object search skills emerge in human infants by 18-20 months of age through a fixed series of steps (i.e. 6 stages), with characteristic transitional errors. Comparative research showed that many neurologically more sophisticated species, mainly primates, other social or carnivorous mammals, and some bird species, like parrots and corvids develop object permanence skills in the same or similar sequence as human infants, only at different speeds and varying final level (Doré & Goulet 1998). The development and final stage of this ability has been documented in case of some caching corvid species, such a magpies (Pollok et al. 2000), ravens (Bugnyar et al. 2007) and Eurasian jays (Zucca et al. 2007). We collected data on ontogeny of object permanence in jackdaws with the same method used in the above studies.

In the second part of our studies we assessed quantity related cognition of jackdaws. Various studies of comparative psychology showed that animals are capable of making choice decisions based on numerical information, while developmental psychologists have found evidence of numerical cognition in infants as early as a few months of age. From these results emerges the conclusion that numerical competence did not first appear in our own species, but is based on deep biological roots (Nieder 2005). Recently comparative research on quantity related abilities of animals was integrated with investigations of cognitive neuroscience (Feigenson et al. 2004) and research on child development (Brannon 2006) to form a new approach to the study of numerical cognition. There is a general agreement in the field that the question whether animals can count is not a very productive one. Instead we need to ask "what are the core components of numerical cognition and which of these are shared across species/can be demonstrated in a gives species (Shettleworth 2009)?"

Since the beginnings, many species have been reported to show some level of 'quantity related' processing, from fish through apes. However results from corvids were few and far between (Köhler 1941; Smirnova et al. 2000; Zorina & Smirnova 1996), and while the field of number related research in non-verbal subjects has grown immensely, data on corvid species did not seem to proliferate. The goal of our experiment was to investigate whether jackdaws are spontaneously (without any quantity related or communicational training) capable of making quantity judgements based on mental representations and to find out how the control of presentation rate and duration affects performance. Performance in the various relative quantity judgment tasks may be informative about the potential underlying mechanisms. A set size limitation at 3 or 4 may indicate that a precise small number representation system (i.e., "object file" system) is present, while if success should decline as the ratio of the smaller set to the larger set increases, that could be interpreted as a characteristics behavioural signature of an analogue magnitude system (i.e., "accumulator" system).

2. First experiment – Ontogeny of object permanence

We aimed to gather some basic data on the development and final stage of object permanence (OP) in jackdaws. Apart from gathering data on yet another corvid species, which has its merit in its own right, I was also interested in the fact that jackdaws store little or no food in the wild. This species lives a very 'object centred' life, as well as has a sophisticated social system (de Kort et al. 2003), so any deviations from OP development of storing species could be interpreted in the caching/non-caching context.

2.1 Question

At what age do jackdaws reach certain stages of Piagetian object permanence, what is the final stage reached and how does this relate to data on other corvid species?

2.2 Method

The ontogeny and final stage of Piagetian object permanence was documented by use of a paradigm ("Scale 1", (Uzgiris & Hunt 1975) that has been utilized with a wide variety of species, including three caching species from the corvid family, magpies, ravens and Eurasian jays. To further assess stage 6 competence we have used the Shell Game suggested by Pepperberg (2002).

2.3 Results

The subjects were generally able to master all the tasks of Scale 1 administered to them. We found that our birds were capable of following single visible displacements (task 4, stage 4b) by the mean age of 41.45 ± 6.09 (SD) days, successive visible displacements (task 8, stage 5b) by the mean age of 57.64 ± 7.44 (SD) days, single invisible displacements (task 10, stage 6a) by the mean age of 61.21 ± 6.84 (SD) days and successive invisible displacements (task 14 stage 6b) by the mean age of 74.3 ± 7.72 (SD) days. We found that the performance of the birds in the Shell game was significantly better than chance. These data suggest that jackdaws are capable of following complex invisible displacements, as well as being able to track and remember (at least for a short duration) spatial information about hidden objects, so this result may be considered as further evidence of stage 6 competence.

2.4 Conclusions

Contrary to the prediction that object permanence capacities of a non-caching species may be inferior to those reported in caching species (Pollok et al., 2000), we found that jackdaws develop object permanence abilities even quicker than magpies, where physical development of the two species follow approximately the same rate. We report that jackdaws reach stage six object permanence, i.e. are capable of following multiple invisible displacements, which finding has been corroborated by results of an additional test of stage six proposed by Pepperberg (2002), the Shell game.

3. Second experiment – Relative quantity judgements based on mental representations

The second experiment assessed mental representations of object quantity and quantity discrimination based on this representation.

3.1 Questions

Are jackdaws capable to form/upgrade mental representations of sets placed one-by-one into an opaque container and base quantity discriminations on this representation? Is their choice behaviour governed by temporal/referential factors? What underlying mechanism is suggested by success-failure patterns?

3.2 Method

Two opaque containers were used to one-by-one place sets of identical food items. The birds were given choices in between all the possible 10 combinations of item numbers between 1 and 5, namely 1-5, 2-5, 3-5, 4-5, 1-4, 2-4, 3-4, 1-3, 2-3 and 1-2. Following the initial quantity discriminations, to control for temporal/referential cues certain sets were balanced in placement time and movement by the placing of small stones, similar in size and shape, but different in colour to the food pieces.

3.3 Results

The birds performed significantly better than chance in the choice combinations 1-5, 2-5, 1-4, 2-4, 1-3, 2-3, and 1-2, but failed to do so in the case of the combinations 3-5, 4-5, and 3-4. Our control experiment showed that performance was not impaired in the case of the choices where the animals were previously successful by the introduction of the stones to control for temporal/referential factors.

3.4 Conclusions

The capacity to spontaneously make relative quantity judgements founded on mental representations of items in the sets is present in the non-caching Corvid species, the Jackdaw. Temporal/referential cues are not used as basis of discrimination, however we may not rule out the coding of total volume. Subjects were successful in making choices for the larger set regardless of the fact that the items were presented one-by-one in each set, so birds never had the opportunity to view the sets as a whole. This suggests that jackdaws are able to update their representation with each new item added. Results are in accordance with Weber's/Fechner's Law, meaning that successful discrimination depends on the ratio of the sets. The success and failure patterns presented indicate that the possible mechanism underlying the birds' performance may best be accounted for by the analogue magnitude representation or "accumulator" model.

References:

Brannon, E. M. (2006). The representation of numerical magnitude. Current Opinion in Neurobiology, 16(2), 222–9. doi:10.1016/j.conb.2006.03.002

Bugnyar, T., Stöwe, M., & Heinrich, B. (2007). The ontogeny of caching in ravens, Corvus corax. Animal Behaviour, 74(4), 757–767. doi:10.1016/j.anbehav.2006.08.019

De Kort, S. R., Emery, N. J., & Clayton, N. S. (2003). Food offering in jackdaws (Corvus monedula). Die Naturwissenschaften, 90(5), 238–40. doi:10.1007/s00114-003-0419-2

Doré, F. Y., & Goulet, S. (1998). The comparative analysis of object knowledge. In J. L. & M. Killen (Ed.), Piaget, evolution and development (pp. 55–72). Mahwah, NJ. Erlbaum.

Emery, N. J., & Clayton, N. S. (2004). The mentality of crows: convergent evolution of intelligence in corvids and apes. Science (New York, N.Y.), 306(5703), 1903–7. doi:10.1126/science.1098410

Feigenson, L., Dehaene, S., & Spelke, E. S. (2004). Core systems of number. Trends in Cognitive Sciences, 8(7), 307–14. doi:10.1016/j.tics.2004.05.002

Köhler, O. (1941). Von Erlernen unbennanter Anzahlen bei Vögeln (On the learning of unnamed numerosities by birds). Die Naturwissenschaften, 29, 201–218.

Nieder, A. (2005). Counting on neurons: the neurobiology of numerical competence. Nature Reviews. Neuroscience, 6(3), 177–90. doi:10.1038/nrn1626

Pepperberg, I. M. (2002). The value of the Piagetian framework for comparative cognitive studies. Animal Cognition, 5(3), 177–82. doi:10.1007/s10071-002-0148-5

Piaget, J. (1954). *The child's construction of reality* (p. xiii, 386 p.). Routledge & Kegan Paul (London).

Pollok, B., Prior, H., & Güntürkün, O. (2000). Development of object permanence in food-storing magpies (Pica pica). Journal of Comparative Psychology, 114(2), 148–157. doi:10.1037//0735-7036.114.2.148

Shettleworth, S. J. (2009). The evolution of comparative cognition: is the snark still a boojum? Behavioural Processes, 80(3), 210–7. doi:10.1016/j.beproc.2008.09.001

Smirnova, A. A., Lazareva, O. F., & Zorina, Z. A. (2000). Use of number by crows: investigation by matching and oddity learning. Journal of the Experimental Analysis of Behavior, 73(2), 163–76. doi:10.1901/jeab.2000.73-163

Uzgiris, I. C., & Hunt, J. M. (1975). Assessment in infancy: Ordinal scales of psychological development. (p. xi 263 pp). Champaign, IL, US: University of Illinois Press.

Zorina, Z. A., & Smirnova, A. A. (1996). Quantitative evaluations in gray crows: generalization of the relative attribute "larger set". Neuroscience and Behavioral Physiology, 26(4), 357–364. doi:10.1007/BF02359040

Zucca, P., Milos, N., & Vallortigara, G. (2007). Piagetian object permanence and its development in Eurasian jays (Garrulus glandarius). Animal Cognition, 10(2), 243–58. doi:10.1007/s10071-006-0063-2

List of publications

Publications that form the basis of the Thesis

- **Ujfalussy, D. J., Miklósi, A., & Bugnyar, T. (2012).** Ontogeny of object permanence in a non-storing corvid species, the jackdaw (Corvus monedula). Animal cognition. doi:10.1007/s10071-012-0581-z

- **Ujfalussy, D. J., Miklósi, Á., Bugnyar, T. and Kotrschal, K. (2014**) Role of mental representations in quantity judgements by Jackdaws (Corvus monedula) Journal of comparative psychology (Washington, D.C.□*: 1983)*, **128**, 11–20.

Other related publications

- **Ujfalussy, D. J., Bugnyar, T., és Miklósi, Á.** Csóka – Matek, avagy képes- e a madárelme számosság spontán reprezentációjára? (2006) (***előadás***) MAKOG, 2006. Tihany

- **Ujfalussy, D. J., Bugnyar, T., és Miklósi, Á.** Csóka – Matek, avagy képes- e a madárelme számosság spontán reprezentációjára? (2006) In Tudat és Elme. Szerkesztette: Mund Katalin és Kampis György. Typotex 2007.

- **Ujfalussy, D. J., Bugnyar, T., Miklósi, Á.** Counting in Jackdaws – is the mind of a bird capable of spontaneous representation of numerosities? (2006) **poszter**, ISBE, 2006. Tours