

Counting with Colours? Effect of Colours on the Numerical Abilities of House Crows (*Corvus splendens*) and Common Myna (*Acridotheres tristis*)

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Abstrak: Kami menjalankan beberapa eksperimen aviari untuk mengenal pasti kesan warna ke atas pemilihan kuantiti oleh dua jenis burung, burung gagak (*Corvus splendens*) dan burung tiung (*Acridotheres tristis*). Cacing dalam kuantiti berbeza (tujuh pembahagian berlainan) diberikan kepada burung dalam turutan rawak menggunakan cacing dicat dengan warna merah bagi eksperimen 1 dan menggunakan cacing dicat warna hijau bagi eksperimen 2. Kedua-dua warna cacing merah dan hijau tidak memberi kesan kepada pemilihan kuantiti gagak (merah: ANOVA: $F_{6,30} = 1.748$, $p = 0.144$; dan hijau: ANOVA: $F_{6,30} = 1.085$, $p = 0.394$). Namun demikian, burung tiung menunjukkan kesan pengaruh kuat bagi warna merah ke atas pemilihan kuantiti (ANOVA: $F_{6,30} = 2.922$, $p = 0.023$), dengan burung berjaya memilih jumlah makanan yang lebih besar antara dua cawan, tetapi tidak apabila cacing berwarna hijau ditawarkan (ANOVA: $F_{6,30} = 1.183$, $p = 0.342$). Dalam eksperimen seterusnya, hipotesis kami ialah kedua-dua burung gagak dan burung tiung akan memilih makanan berwarna merah berbanding warna hijau apabila faktor jumlah makanan adalah sama. Kami memilih untuk menguji warna merah dan warna hijau kerana kedua-dua warna memainkan peranan penting dalam pemilihan makanan burung. Keputusan menunjukkan tiada perbezaan signifikan bagi pemilihan cacing merah dan hijau bagi kedua-dua burung gagak (ANOVA: $F_{6,30} = 2.310$, $p = 0.06$) dan burung tiung (ANOVA: $F_{6,30} = 0.823$, $p = 0.561$).

Kata kunci: Kebolehan Mengira, Burung, Gagak, Tiung, Warna

Abstract: We conducted several aviary experiments to investigate the influence of colours in quantity judgments of two species of birds; house crow (*Corvus splendens*) and common myna (*Acridotheres tristis*). Different quantity (in seven different food proportions) of mealworms were presented nonsequentially to all birds using artificially coloured red mealworms, for experiment 1, and using artificially coloured green mealworms, for

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experiment 2. Both red and green coloured mealworms have no significant effect on house crow's quantity judgments (red: ANOVA: $F_{6,30} = 1.748$, $p = 0.144$; and green: ANOVA: $F_{6,30} = 1.085$, $p = 0.394$). Common myna, however, showed a strong influence of red colour in their quantity judgment (ANOVA: $F_{6,30} = 2.922$, $p = 0.023$) as they succeeded in choosing the largest amount of food between two cups, but not when offered food using green coloured mealworms (ANOVA: $F_{6,30} = 1.183$, $p = 0.342$). In the next experiment, we hypothesised that both house crow and common myna will prefer red coloured food items over green coloured food items, when factors such as the amount of food is equal. We chose to test red and green colours because both colours play an important role in most avian food selections. Results showed that there were no significant differences in the selection of red or green coloured mealworms for both house crows (ANOVA: $F_{6,30} = 2.310$, $p = 0.06$) and common myna (ANOVA: $F_{6,30} = 0.823$, $p = 0.561$).

Keywords: Numerical Abilities, Birds, Crows, Common Myna, Colours

INTRODUCTION

Bright and coloured objects are more conspicuous from a distance and plays an important role in animal behaviour. Apart from visual contrast and memory, colour is also important for scene segmentation (Gegenfurtner 2003). Colours can be used as warning signals for insects (Schmidt & Schaefer 2004), courtship display in mating behaviour (Zuk 1992) and signal fruit maturity to attract avian seed dispersers (Willson & Whelan 1990; Murray *et al.* 1993; Schmidt & Schaefer 2004). Colour appears as a more important feature in the category of food objects (Delorme *et al.* 2000) if other factors such as taste, nutrition, and accessibility were the same (Willson & Whelan 1990). For humans, colour is an important factor in helping the cognitive system and enhances the memory performances (Wichmann *et al.* 2002).

Visual cues are important for sensing and picking food for diurnal passerine birds. One of the significant aspects of the visual of birds is the sense of colour which played a role in community ecology, species interaction, seed dispersal, and plant pollination (Avery *et al.* 1999). Fruit colours are associated to the age of the fruits and often entice the birds to eat fruits and disperse the seed. There are multiple studies that had been conducted since the last three decades to test the function and effect of fruit colour preferences by various species of birds such as Anna hummingbirds, *Calypte anna*; waxwings, *Bombycilla cedrorum*; American robin, *Turdus migratorius*; common crows, *Corvus splendens*; and common myna, *Acridotheres tristis* (Stiles 1976; McPherson 1988; Willson & Whelan 1990; Willson & Comet 1993; Willson 1994; Puckey *et al.* 1996; Kelly & Marples 2004; Schaefer *et al.* 2008; Rahman *et al.* 2014).

Birds have demonstrated not only the ability to count (Pepperberg 2006; Hunt *et al.* 2008), but also excel in colour inclinations (Puckey *et al.* 1996; Duan & Quan 2013). Compared to other species of birds, crow's brains are remarkably developed and in some aspects such as causal reasoning, flexibility, and prospection are almost similar to humans (Emery & Clayton 2004). Past studies have shown the exceptional skill of diverse species of crows in both numerical ability and memory (Emery & Clayton 2004; Bogale *et al.* 2011). Another bird species that had shown remarkable numerical capability is the common myna

(*Acridotheres tristis*). Despite having a small body size, common myna can be considered as a very smart bird species. Common myna showed some tendency for consumer and motor innovations, with 55% and 22% (respectively) of individuals solving the respective tasks (Sol *et al.* 2012). Apparently, common myna can manage better under novel environmental conditions with increasing cognitive ability (Berthouly-Salazar *et al.* 2012). Common myna also functioned much better alone compared to working in pairs or group due to the risk and competition (Griffin *et al.* 2013). Rahman *et al.* (2014) had shown that both common myna and crows (*Corvus splendens*) are capable of selecting food items that is higher in quantity. Common myna is shown to be capable of discriminating up to 10 food items, whereas crows success rate are limited to 4 items in comparison. Crows might not rely much on numerical capabilities, but rather choose food items that are in close proximity to where they are perched.

Other researches were likely to emphasis on the purpose of colour in food selections in animals when other factors such as taste, nutrition, and accessibility are the same (Willson & Whelan 1990; Rowe & Skelhorn 2003; Schaefer *et al.* 2008; Skelhorn 2011). However, to the best of our knowledge, there is almost no evidence linking colours to numerical competency for house crows and common myna. We chose to test red and green colours because both colours play an important role in most avian food selections. Red colour shows ripeness and palatability (Schmidt & Schaefer 2004) especially in fruits while the green colour indicates unpalatability (Ham *et al.* 2006). The objectives of this study are (1) to detect whether the numerical competency of house crows (*C. splendens*) and common myna (*A. tristis*) can be influenced by red or green colours, and (2) between the two colours, red coloured mealworms are more preferred than green coloured mealworms.

MATERIALS AND METHODS

All procedures performed involving animals were in accordance with the ethical standards of Universiti Sains Malaysia (USM). Six house crows were taken from the traps set by the local municipal authority, around Gelugor, Pulau Pinang, Malaysia (5°22.605'N, 100°18.541'E) and six common myna were captured using mist nets around USM campus (5°21'N, 100°18'E). All the captured house crows and common myna were kept in a custom-made wire-mesh cage. The cage is divided into three compartments and the middle compartment is designated as the experiment area and the other two were used to keep the birds. The cage has a translucent panel roof to maximise sunlight penetration. The birds were fed (mealworms, bread, and fruits) twice a day.

Experiments were conducted three days per week, which is on Monday, Wednesday and Friday. The one-day gap between experiments is to minimise stress on the birds. The experiments started at 1500 h and ended approximately at 1700 h. Although birds are typically active during early morning and late evening, the experiments could not be conducted during those time periods due to logistical problems. The cage was built near a parking area and the main road. We found that traffic noise and movement interfered with our video recording

session. Throughout the study, we found that the birds cooperated well with the study, regardless during active or non-active periods. The subject was presented with two white paper cups that were placed on a black plastic board, 50 cm apart. All three experiments were recorded using Sony Legria video recorder and followed the protocols described by Hunt *et al.* (2008). All the mealworms were coloured using non-toxic food colour dye (Star Brand, PBG Sdn. Bhd., Kuala Lumpur). We took spectrographic reading of the normal and coloured mealworms using OceanOptics Jazz portable spectrometer (Douglas Avenue, Dunedin, USA) with Xenon Pulse (Douglas Avenue, Dunedin, USA) lamp as the light source. Object reflectance properties were measured as the proportion of a diffuse reflectance standard (Teflon coated white standard OceanOptics). Spectra were calculated at 5 nm intervals from 400 to 700 nm (visible wavelength for human perception) with SpectraSuite OceanOptics software. Figure 1 shows the percent reflectance wavelength of the normal and coloured mealworms. The spectrographic analysis is important to verify the colours used. Colours based on human vision are subjective, whereas a spectrometer can accurately display the specific wavelength of the colours.

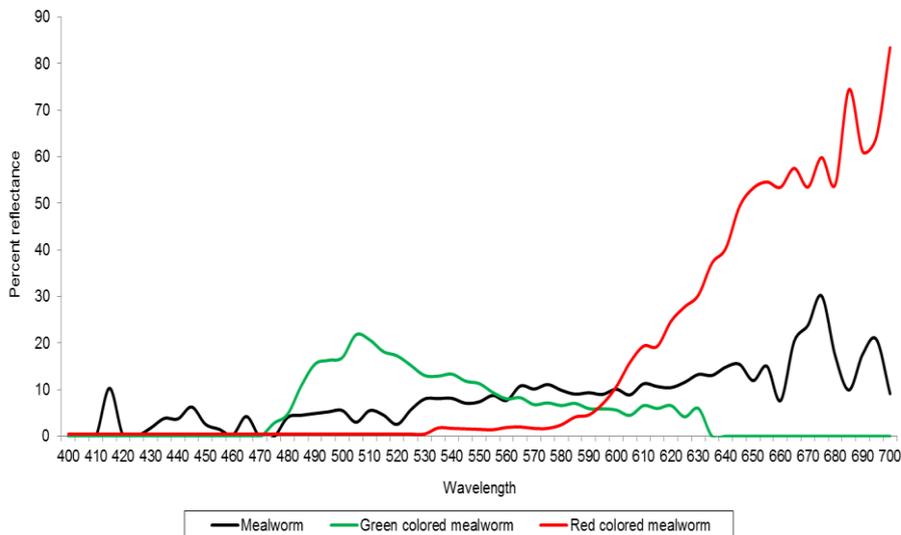


Figure 1: The percent reflectance wavelength of the normal and coloured mealworms.

There were three sets of experiment. We used red coloured mealworms for the first set of experiment and green coloured mealworms for the second set. Experiments 1 and 2 began with the researcher showing the coloured food items (in succession) to the birds for five seconds. After the researcher had established that the bird had seen the coloured food item, the researcher placed the food item inside the paper cups. We placed a different quantity of food items in each cup, where one cup would have more food items than the other. Seven food combinations (1 versus 3, 1 versus 4, 2 versus 5, 3 versus 7, 5 versus 8, 6

versus 9, and 8 versus 10) were presented to all 12 individuals and the test for each food combination was replicated 6 times. We consider the experiment a success if the bird selects the cup with the higher number of food items. For the third experiment, to test whether a red coloured food item would be more likely to be chosen compared to green coloured food item, we offered both red and green mealworms. Both coloured mealworms were offered simultaneously at the same quantity (one, three, four, five, seven, eight, and nine). To prevent observational learning and preference bias for all the three sets of experiments, the left and right combinations were randomised, as well as the combinations pair (for experiments 1 and 2).

Data Analysis

We considered several statistical analysis choices for the study. Although the choice selection is a binomial design, it does not allow the interaction analysis between success, food proportions, and bird species. A non-parametric approach such as the Mann Whitney U lacks the statistical power. Furthermore, since our number of animal subject is quite limited, each trial experiment is not independent (since we are re-using the same individual). After testing for sphericity with Mauchly test of sphericity, we ran repeated measure ANOVA with the number of successful attempts for each proportion as the dependent variable for experiments 1 and 2. Repeated measure ANOVA allows a closer look at the individual level of how each bird would react to the experiment. However, for experiment 3, as to verify the preference of red over green, the dependent variable is the difference between the amount of red colour selection and green colour selection (Red – Green). Statistical test was conducted using SPSS 20 (IBM Computing, Chicago, Illinois, USA). We also ran bootstrapping (1000 times) on the data. Bootstrapping the data is required due to the small number of sample size and to achieve normal distribution for ANOVA.

RESULTS

Experiments 1 and 2

For experiment 1, involving red mealworms, the results show that there was no significant effect on the numerical abilities of house crows (ANOVA: $F_{6,30} = 1.748$, $p = 0.144$) (Fig. 2[a]). On the contrary, common myna performed very well with red coloured mealworms, choosing cup containing more food items at frequencies above-chances (ANOVA: $F_{6,30} = 2.922$, $p = 0.023$) (Fig. 2[b]).

Results from experiment 2 showed that green colour did not have any effect on the successful attempt for all food proportions for both house crow (ANOVA: $F_{6,30} = 1.085$, $p = 0.394$) and common myna (ANOVA: $F_{6,30} = 1.183$, $p = 0.342$). Figures 2(c) and 2(d) show the success and failure results for house crow and common myna, respectively.

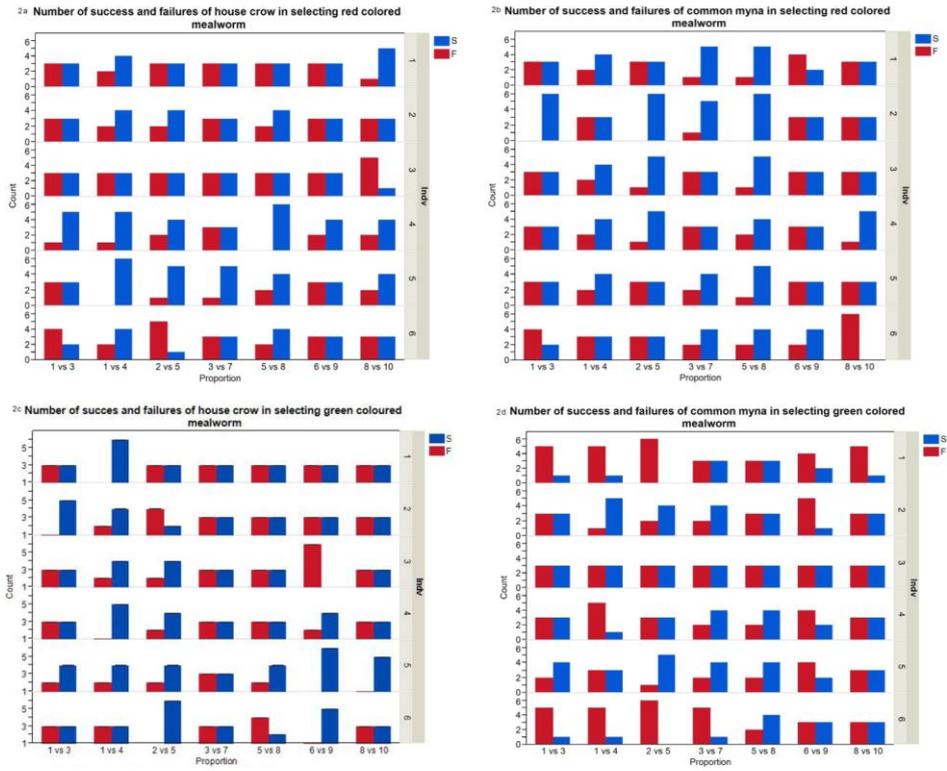


Figure 2: Number of success and failures of selection by both birds for experiments 1 and 2. Blue bars represents success (S) and red failures (F).

Experiment 3

For the hypothesis that red colour is more preferred than green, results show that there is no significant difference for the selection of red or green coloured mealworms for both house crows (ANOVA: $F_{6,30} = 2.310$, $p = 0.06$) and common myna (ANOVA: $F_{6,30} = 0.823$, $p = 0.561$). Figures 3(a) and 3(b) show the failure and success rates for house crow and common myna, respectively. There were differences in the performance of both species in experiment 3 compared to the first and second experiment. Two individuals (one from each species) did not show any reaction during the experiment. The other birds that did make the selection, alternated between the red and green coloured mealworms indiscriminately. One individual myna showed a specific preference to red.

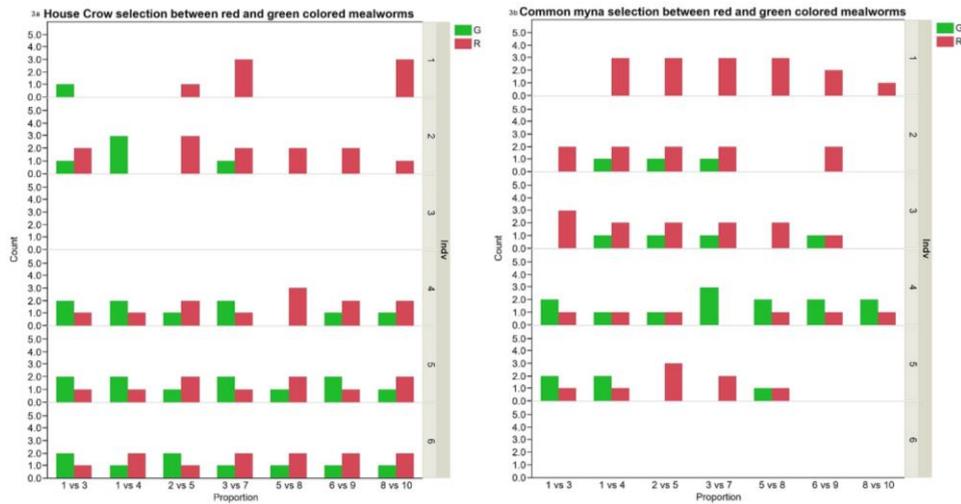


Figure 3: Number of selection made between green and red mealworms offered to the birds in different number of food proportions.

DISCUSSION

Rahman *et al.* (2014) had already demonstrated that both house crow and common myna are capable of quantity judgement and counting. Scarf *et al.* (2011) had shown that pigeons are on par with primates in terms of numerical capability, although it was suggested that both animals use abstract numerical rule rather than actual counting. In this study, we further tested the idea of how colours could possibly affect the numerical abilities of both bird species. Results of experiment 3 showed that both species of birds showed no specific preference to either red or green colour. We took great care to use an odourless and tasteless food dye for colouring the mealworm. However, since all the food colour dyes are designed for human consumption, we can only speculate it would have the same bland taste to the birds. We also experimented with several types of food items (bread, banana, and apple), but both species only reacted positively towards mealworms. All the birds used in the experiment are naïve, untrained birds. The individuals used are also different test subjects compared to Rahman *et al.* (2014) previous experiments. The strength of preferences is considered weak when the changes in accessibility can alter the preferences (Willson & Comet 1993; Willson 1994). Individual birds differed in initial colour inclinations, transitivity, and temporal stability of colour preferences (Willson *et al.* 1990). Previous studies had shown that, when the taste of the food is similar, colour preferences are not exclusive to red colour (Willson 1994). Wild robins (*Turdus migratorius*) commonly feed on red fruits in the field, but apparently tend to prefer blue fruits in captive conditions (Murray *et al.* 1993). Another comparison that can be made is from the trichromatic New World primates that have reduced spectral shifts between opsins and also show reduced ability to visually distinguish

red–green colour differences (Caine *et al.* 2003; Dominy *et al.* 2003; Riba-Hernandez *et al.* 2004). It is possible that not all species utilise red–green colour perception equally or garner the same benefits from trichromacy (Leonhardt *et al.* 2009). Since our food item, mealworms, are not typically accessible to both species of birds, it might have some effect on their preferences. The introduction of a novel food might have caused neophobia (Marples *et al.* 1998) or dietary conservatism (Thomas *et al.* 2003).

Both house crows and common myna can be considered omnivorous, therefore both species might not have specific colour preferences compared to frugivorous birds. Fruits chosen by frugivores are based on specific traits; hardly changed, and is consistent (Willson & Whelan 1990). Other than size, shape, and nutrition level in fruits (Willson & Whelan 1990), colour is one of the source of preferences by frugivores over brightness (Puckey *et al.* 1996). Most fleshy fruits that are attractive and consumed by vertebrates, especially birds, are often red or black (Willson & Whelan 1990; Willson *et al.* 1990; Puckey *et al.* 1996) but rarely green or yellow (Willson *et al.* 1989). Known as opportunistic feeders, both house crows and common myna eat not only fruits, but almost anything including insects, animals, and seeds or grains. Since our food item was not a natural or artificial fruit, it might have some effect on their preferences.

Green colour seemed to have negatively affected the numerical capabilities of both species of birds. Unlike red, green displays foliage colouration (Burns & Dalen 2002) and unripe fruits (Wheelwright & Janson 1985) and mostly indicates less palatability. Marples *et al.* (1998) had reported that wild blackbirds and robins tend to avoid green coloured baits. However, since we had established that there were no specific preference between colours (red or green), we can only assume that green colour somehow disrupts the numerical capabilities in both species of birds. Since the birds are naïve and did not undergo any preconditioning procedure, the detrimental effect of green colour could have originated from prior experiences in the wild. Studies by Dhandukia and Patel (2012) showed that common myna often uses green leaves and twigs (*Azadirachta indica*) as the preferred nest materials. For common myna, we postulate that the birds might have associated the colour green as non-edible cues, but still useful for nest building materials.

Referring back to our results about the no significant effect between red and green, there is a possibility that the use of both red and green colours simultaneously could have caused learning confusion for both species of birds. Both house crow and common myna were habituated with different amount of food items, but were given a single consistent amount of food item for experiments 1 and 2. When presented with both colours simultaneously, it may lead to novel experiments or even intervene with their memory with old experiments. Even human infants become habituated to number “2” after repeatedly displayed, but prompt a novelty response when they are shown with number “3” (Feigenson *et al.* 2002).

Rather than the change in numbers, the change in dimensions of continuous extent may have caused the novelty of the test outcome (Feigenson *et al.* 2002). When attention is diverted on a demanding task, estimation mechanisms still operate, but with lower precision (Burr *et al.* 2010). According to

Lemaire and Mereille (2007), estimation performance was influenced by the physical features of stimuli only for very large numerosities, presumably because these are poorly represented in long-term memory. Furthermore, under conditions of high attentional load, the precision in the subitising range is reduced to be similar to the estimation range (Burr *et al.* 2010).

Red colour had no positive effect on the numerical capability of house crows, but had a significant effect on common myna. However, after comparing the original results from Rahman *et al.* (2014), the results were quite interesting. In choosing normal mealworms (results from Rahman *et al.* 2014), common mynas made successful attempts on 4 different proportions: 1 vs 4; 2 vs 5; 6 vs 9; 8 vs 10. However, using red coloured mealworms, common mynas made excellent results in proportions of 1 vs 4, 2 vs 5, 3 vs 7, and 5 vs 8. Although common myna showed numerical capabilities when offered with red mealworms, the maximum number of items compared was only limited up to 8. Therefore, we suggest that red colour do affect the numerical abilities of common myna, but somehow reduce the maximum limit of item.

Our result infers that colour does helps common myna with their quantity judgment, but just up to a certain level. Their performance for this session had reached an asymptote, unlike humans and infants who have much more complex and higher level of numerical ability. Wynn (1992) suggests that infants possess true numerical concepts, and humans are innately endowed with arithmetical abilities where they are capable of discriminating, representing, and remembering particular small number of items, and successfully add and subtract over number of items that exceed object-tracking limits (Starkey & Cooper Jr 1980; McCrink & Wynn 2004).

Liebe *et al.* (2009) suggest that colour can lead to either enhanced or decreased recognition memory for natural scenes dependent on whether the colour is diagnostic for the task at hand. Vision senses numerosity directly, presenting it to consciousness as a visual quality like shape or colour, enabling rough estimates of number to be made without the intervention of counting or other cognitive mechanisms (Burr & Ross 2008). Even if animals are able to discriminate stimuli very well, they often judge them as similar to each other (Gumbert 2000). Common crows reaction suggests that colours do not seem to affect the birds' numerical ability. Although considered one of the most intelligent birds amongst the avian species, numerical capabilities might not be a forte for this species.

CONCLUSION

Our results had shown that the counting abilities of house crow is not affected by the presented coloured stimuli, which are red and green. We found strong evidence that red colour does influence common myna in quantity judgment, but less consistent evidence that green colour can affect their counting ability. Based on later experiments, we assumed that house crows do not have any inclinations towards these two colours. Common myna also showed no consistent selection in between these two colour preferences. Differences in visual discriminations

detected likely also depends on the nature of foraging task. Since we offered subjects with food objects at close range in a non competitive environment, it is more likely they were more unperturbed towards the selection. To understand more about house crows and common myna counting abilities and preferences, additional stimuli such as other type of food items with different size or shape, or different colours can be used in future experiments but larger samples will be required to draw such conclusions.

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