Counting With Colours? Effect of Colors on the Numerical Abilities of Crows (*Corvus splendens*) and Common Mynah (*Acridotheres tristis*)

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Abstract: We conducted several aviary experiments to investigate the influence of colors 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 red colored mealworms, for experiment 1, and using artificially green colored mealworms, for experiment 2. Both red and green colored 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 color 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 colored mealworms (ANOVA: $F_{6,30} = 1.183$, $p = 0.342$). In the next experiment, we hypothesized that both house crow and common myna will prefer red color food items over green color food items, when factors such as the amount of food is equal. We chose to test red and green color because both colors play an important role in most avian food selections. Results showed that there were no significant differences in the selection of red or green colored 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 Mynah, Colours

INTRODUCTION

Bright and colored objects are more conspicuous from a distance and plays an important role in animal behavior. Apart from visual contrast and memory, color is also important for scene segmentation (Gegenfurtner 2003). Colors can be used as warning signals for insects (Schmidt and Schaefer, 2004), courtship display in mating behavior (Zuk 1992) and signal fruit maturity to attract avian seed dispersers (Willson and Whelan 1990; Murray et al. 1993; Schmidt and Schaefer 2004). Color 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 and Whelan 1990). For humans, color 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 color which played a role in community ecology, species interaction, seed dispersal and plant pollination (Avery et al. 1999). Fruit colors 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 color 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 and Whelan 1990; Willson and Comet 1993; Willson 1994; Puckey et al. 1996; Kelly and 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 color inclinations (Puckey et al. 1996; Duan and 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 and Clayton 2004). Past studies have shown the exceptional skill of diverse species of crows in both numerical ability and memory (Emery and Clayton 2004; Bogale et al. 2011). Another bird species that had shown remarkable numerical capability is the common myna (*Acridotheres tristis*). Despite of having small body size, common myna can be considered as very smart bird species. Common myna showed some tendency for consumers 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*) is both capable of selecting food items that is higher in quantity. Common myna is shown to be capable of discriminating up to ten food items, whereas crows success rate are limited to four item 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 color in food selections in animals when other factors such as taste, nutrition and accessibility are the same (Willson and Whelan 1990; Rowe and Skelhorn 2003; Schaefer et al. 2008; Skelhorn 2011). However, to the best of our knowledge, there is almost no evidence linking colors to numerical competency for house crows and common myna. We chose to test red and green color because both colors play an important role in most avian food selections. Red color shows ripeness and palatability (Schmidt and Schaefer 2004) especially in fruits while the green color indicates unpalatability (Ham et al. 2006). The objectives of this study are (1) to detect whether the numerical competency of house crows (*Corvus splendens)* and common myna (*Acridotheres tristis*) can be influenced by red or green colors, and (2) between the two colors, red color mealworms are more preferred than green color mealworms.

METHODS

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 by using mist nets around Universiti Sains Malaysia (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 maximize 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 minimize stress on the birds. The experiments started at 1500h and ended approximately at 1700h. Although birds are typically active during early morning and late evenings, the experiments could not be conducted during that time period 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, 50cm 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 colored using non-toxic food color dye (Star Brand). We took spectrographic reading of the normal and colored mealworms using OceanOptics Jazz portable spectrometer with Xenon Pulse lamp as light source. An 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 colored mealworms. The spectrographic analysis is important to verify the colors used. Colors based on human vision are subjective, whereas a spectrometer can accurately display the specific wavelength of the colors.

There were three sets of experiment. We used red colored mealworms for the first set of experiment and green colored mealworms for the second set. Experiment one and two began with the researcher showing the colored food items (in succession) to the birds for five seconds. After the researcher had established that the bird had seen the colored 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 (one versus three, one versus four, two versus five, three versus seven, five versus eight, six versus nine, and eight versus ten) were presented to all 12 individuals and the test for each food combination was replicated six 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 colored food item would be more likely to be chosen compared to green color food items, we offered both red and green mealworms. Both colored 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 randomized, as well as the combinations pair (for experiment one and two).

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 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 experiment 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 the experiment 3, as to verify the preference of red over green, the dependent variable is the difference between the amount of red color selection and green color selection (Red – Green). Statistical test was conducted using SPSS 20. 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

Experiment One And Two

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

Results from experiment two showed that the green color 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) . Figure 2c and 2d shows the success and failure results for house crow and common myna, respectively.

Experiment Three

For the hypothesis that red color is more preferred than green, results show that there is no significant difference for the selection of red or green colored 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). Figure 3a and 3b shows the failure and success rate for house crow and common myna respectively. There were differences in the performance of both species in experiment three 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 colored mealworms indiscriminately. One individual myna showed a specific preference to red.

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 colors could possibly affect the numerical abilities of both bird species. Results of experiment three showed that both species of birds showed no specific preference of either red or green color. We took great care to use an odourless and tasteless food dye for coloring the mealworm. However, since all the food color 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, 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 and Comet 1993; Willson 1994). Individual birds differed in initial color inclinations, transitivity, and temporal stability of color preferences (Willson et al. 1990). Previous studies had shown that, when the taste of the food is similar, color preferences are not exclusive to red colors (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 color differences (Caine et al. 2003; Dominy et al. 2003; Riba-Hernandez et al. 2004). It is possible that not all species utilize red–green color perception equally or garner the same benefits from trichromacy (Leonhardt et al. 2009). Since our food item mealsworms; 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 color preferences compared to frugivorous birds. Fruits chosen by frugivores is based on the specific traits; hardly changed, and consistent (Willson and Whelan 1990). Other than size, shape and nutrition level in fruits (Willson and Whelan 1990), color 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, often red or black (Willson and 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 includes insect, animals and seeds or grains. Since our food items were not a natural or artificial fruit, it might have some effect on their preferences.

Green color seemed to have negatively affected the numerical capabilities of both species of birds. Unlike red, green displays foliage coloration (Burns and Dalen 2002) and the unripe fruits (Wheelwright and Janson 1985) and mostly indicates less palatability. Marples et al. (1998) had reported that wild blackbirds and robins tend to avoid green colored baits. However, since we had established that there were no specific preference between colors (red or green), we can only assume that green color 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 color 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 color 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 colors; 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 simply single color at one time during experiment one and two. When presenting both colors simultaneously, it may lead to the novel experiments or even intervene with their memory with old experiment. Even human infants become habituated to number '2' after repeatedly display, 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 subitizing range is reduced to be similar to the estimation range (Burr et al. 2010).

Red color 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 colored mealworms, common mynas made excellent results in proportions of 1 vs 4; 2 vs 5; 3 vs 7; 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 color do affect the numerical abilities of common myna, but somehow reduce the maximum limit of item comparison.

Our result infers that color does helps common myna with their quantity judgment, but just up to a certain level. Their performance of this session had reached an asymptote, unlike humans and infants which 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 numbers of items and successfully add and subtract over numbers of items that exceed object-tracking limits (Starkey and Cooper Jr 1980; McCrink and Wynn 2004).

Liebe et al. (2009) suggest that color can lead to either enhanced or decreased recognition memory for natural scenes dependent on whether the color is diagnostic for the task at hand. Vision senses numerosity directly, presenting it to consciousness as a visual quality like shape or color, enabling rough estimates of number to be made without the intervention of counting or other cognitive mechanisms (Burr and 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 colors 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 colored stimuli, which are red and green. We found strong evidence that red color does influenced common myna in quantity judgment, but less consistent evidence that green color can affect their counting ability. Based on later experiments, we assumed that house crows do not have any inclinations towards these two colors. Common myna also showed no consistent selection in between these two color preferences. Differences in visual discriminations are 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 colors can be used in future experiments but larger samples will be required to draw such conclusions.

Statement of Animal Welfare

All procedures performed in studies involving animals were in accordance with the ethical standards of Universiti Sains Malaysia.

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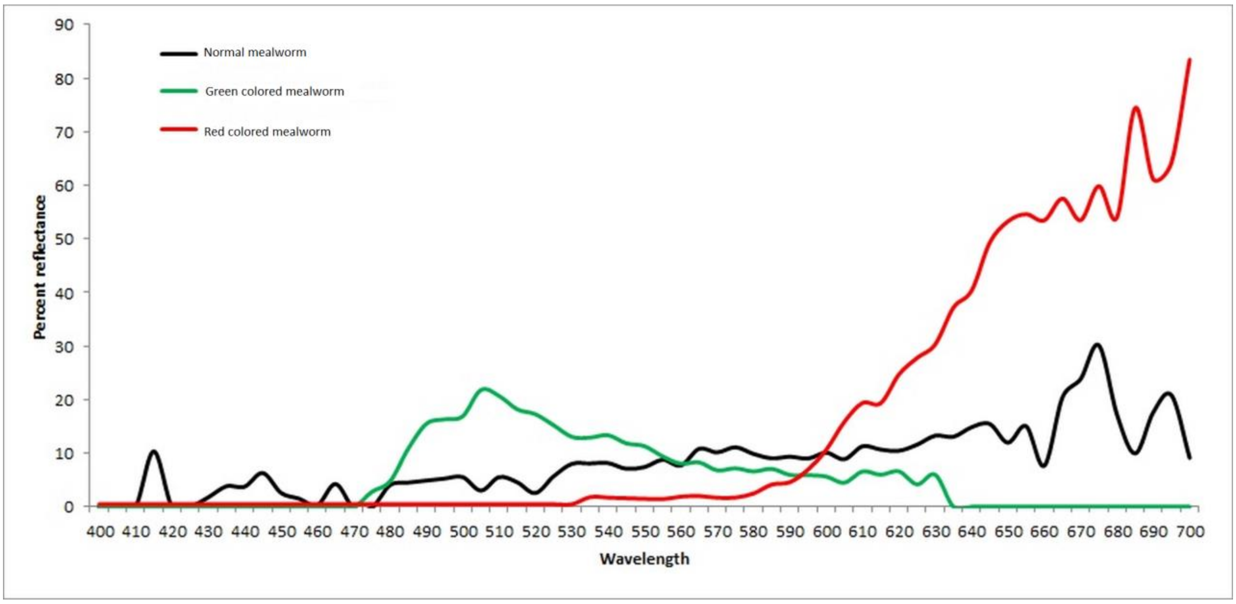

Figure 1: The percent reflectance wavelength of the normal and colored mealworms.

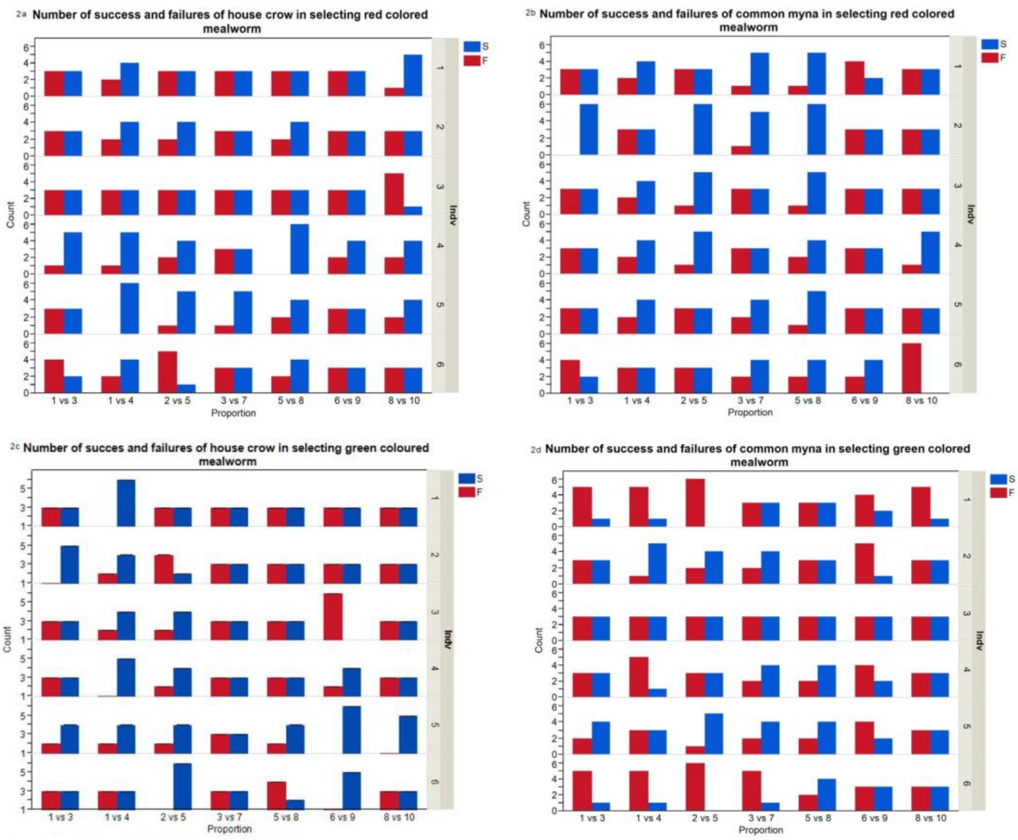

Figure 2: Number of success and failures of selection by both birds for experiment 1 and 2. Blue bars represents success (S) and blue as failures (F).

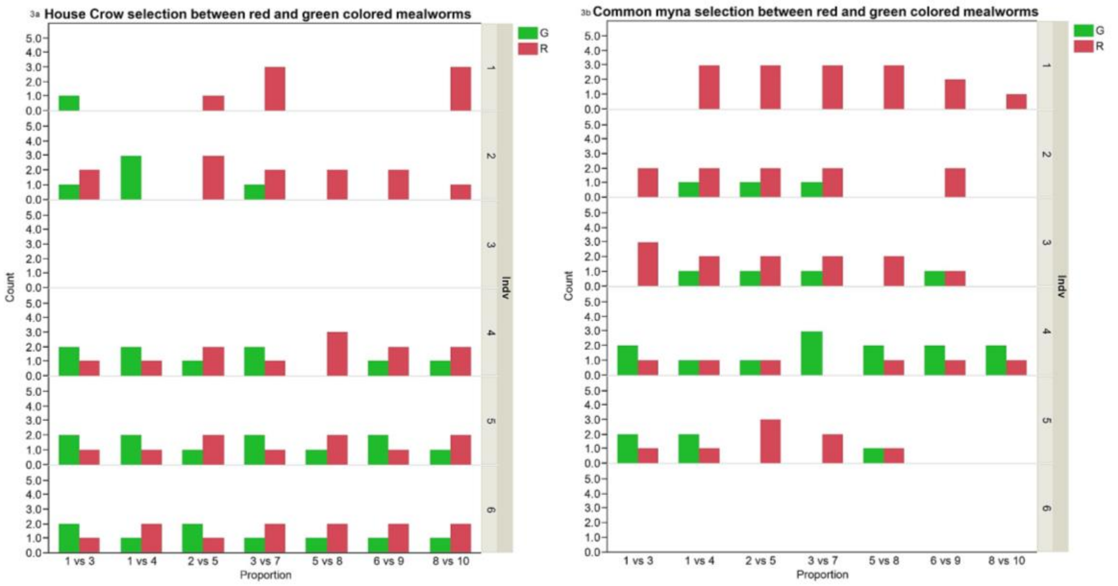

Figure 3: Number of selection made between green and red mealworms offered to the birds in different number of food proportions.