

Mirror Effects on Feeding Black-Capped Chickadees (*Poecile atricapillus*)

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Black-capped chickadees (*Poecile atricapillus*) are a social species that travel in flocks and have a strict dominance hierarchy. Feeding sites enable researchers to explore their intraspecific behaviors as they engage in contests over food. This study investigated whether the presence of a mirror at a feeder would alter the length of time and frequency of feeding by Black-capped chickadees. With the mirror image as a proxy for another bird, the study also tested whether the chickadees will interact with their mirror images with aggressive or exploratory behaviors. Chickadees were additionally presented with foil and glass to assess which property of the mirror was accountable for the behavioral changes: the mirror image, the light-reflecting properties of the mirror, or the mere presence of an object by the feeder. Since chickadees generally arrive at a feeder one at a time, I predicted that the mirror image presented at the perch would make them take flight, resulting in reduced feeding, visitation, and time at the feeder. The results showed that while feeding was indeed suppressed, chickadees stayed significantly longer at the feeder, had a longer time lag before feeding, and displayed aggressive behaviors such as wing-beating, pecking, or agonistic gargle vocalizations. In addition, a higher visitation frequency in the presence of foil compared to the mirror and glass suggested that the shimmering property attracted chickadees to the feeder, rather than deter them. In conclusion, chickadees are much less likely to abandon a feeding site than previously understood. Furthermore, the high energy and time investment in aggressive displays to its mirror reflection suggest that there is a strong incentive for chickadees to secure a safe feeding environment or to assert dominance when the opposing individual is equally matched.

INTRODUCTION

It has been well established that Black-capped chickadees (*Poecile atricapillus*) are a social species that travel in flocks and defend their respective territories. Within each flock, a strict dominance hierarchy is established through various social behaviors, most commonly vocalizations, postures, and physical fights (Baker et al., 1991; Clemmons & Lambrechts, 1992). These interactions are often observed at feeding sites. Previous studies employing an artificial feeder found that the presence of one chickadee deters another from approaching the feeder. If the incoming bird is of a higher dominance rank, it displaces the existing bird before feeding (Baker et al., 1991; Seok An et al., 2011).

Mirror studies have been useful in the past to model such social interactions. While humans, chimpanzees, and orangutans recognize themselves in a mirror (Rajala et al., 2010), very few bird species have demonstrated this ability (Pepperberg et al., 1995; Prior et al., 2008). Instead of using a mirror to inspect their own body as humans would, Black-capped chickadees respond to a mirror image as if it were another individual. In studies by Censky and Ficken (1982) and Malpede and Baker (2000), chickadee behaviors demonstrated towards a mirror image were the same as behaviors they displayed in natural social interactions. Given this, researchers have utilized mirrors to trigger vocalizations that chickadees would usually express to members of their flock (Bloomfield et al., 2004; Gammon, 2004).

Mirror studies conducted on other birds have reported conflicting responses of birds to their mirror images. For example, parakeets and finches preferably spent time on perches with mirrors than perches without a mirror. Parakeets also interacted with and vocalized to their mirror images (Gallup, 1970). In pair-raised starlings, kea, and domestic fowl chicks, mirrors induced calming and preening behaviors and helped reduce their isolation stress in laboratories (Henry et al., 2008). On the other hand, mirrors placed inside a nest box have effectively kept starlings away from roosting and breeding inside the nest box (Seamans et al., 2001).

One of the few mirror studies on Black-capped chickadees was conducted by Censky and Ficken (1982), who found that when presented with a mirror, chickadees visit the feeders less often and take less seeds compared to when there was no mirror. A few instances of gargle calls and gapes that suggest aggression towards the mirror were recorded as well, but these behaviors were displayed by only a few dominant birds. Censky and Ficken (1982) suggest that the majority of chickadees were intimidated by their mirror images.

Few studies on chickadees have analyzed the nature and range of responses induced by mirrors, as researchers in the past have focused only on a specific vocalization of interest when using a mirror. However, a mirror is also a useful tool to study chickadee behavioral responses, as it creates an image of a conspecific with which an individual bird can interact.

Therefore, the main aim of this study was to further explore the impact of mirrors on chickadee behaviors with populations in the Vancouver, British Columbia (Canada) area. In this study, a feeder was fitted with a mirror adjacent to the perch and installed in the field to study the behavior of chickadees when they encountered a mirror, compared to when there was no

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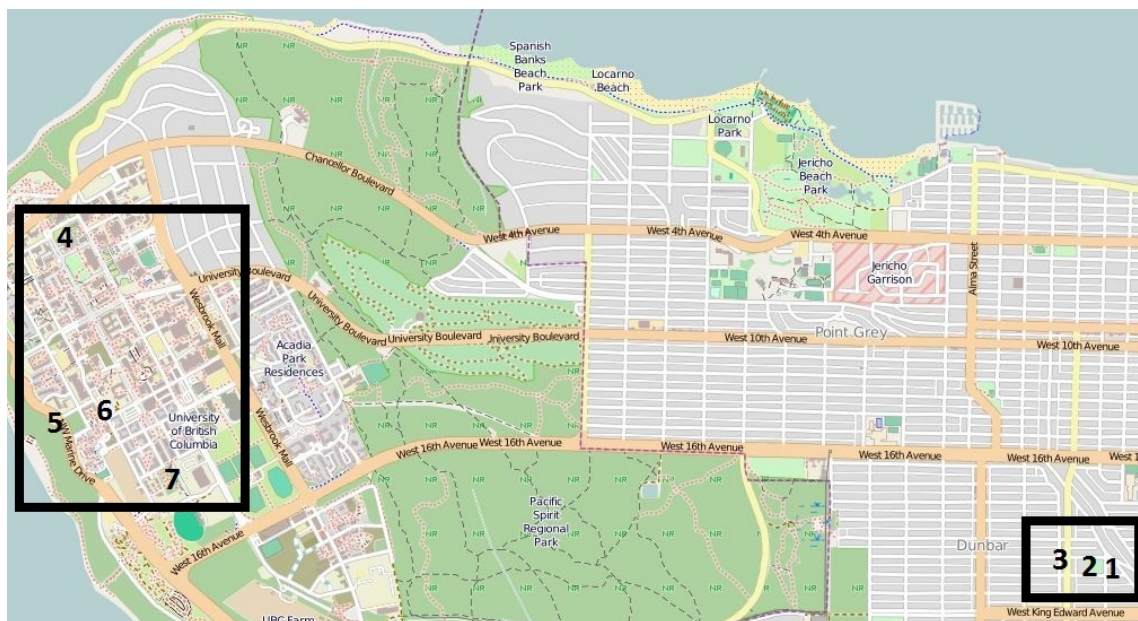


Figure 1. Field site locations indicated on a 1:54500 scale map of Vancouver, BC, Canada. The Dunbar sites include (1) East Road, (2) Valdez Park (3) Garage. UBC sites include (4) Buchanan (5) West Mall (6) Marine Drive, and (7) Rhodo Wood.

mirror. Since mirrors are able to reflect light and also create a self-image, the study also employed other reflective materials—foil and glass, to determine which of these properties were causing chickadees to interact with mirrors. Foil was used because although it has similar light-reflecting properties as a mirror, it does not create a clear reflection (Censky & Ficken, 1982). A sheet of glass was used to determine whether the chickadees were responding just to the novelty of an object by the feeder (Rensel & Wilder; 2011). Glass alone would create a reflection, but the glass was covered with crinkled cling wrap to minimize the reflection while retaining the transparency of the glass (Johnson, 2003). Thus, the foil and glass treatments offered two levels of control, with foil controlling for the light-reflecting properties of a mirror, and glass representing the barrier to feeding due to attaching an object by the perch.

Most food contests between chickadees are resolved by passive avoidance and threatening postures or vocalizations rather than physical interactions (Baker et al., 1991; Baker et al., 2012). Based on this information, the hypothesis of this study was that incoming chickadees would be startled by the presence of another individual at the feeder and would draw away from the mirror image as soon as they arrive at the perch. This would result in reduced feeding and reduced time at the feeder. The results of my study will further the understanding of feeding-related social behaviors in Black-capped chickadees and expand upon the role of mirrors, foil, and glass as alternative ways to study chickadee feeding behaviors.

MATERIALS AND METHODS

Subjects and study sites

Subjects consisted of unmarked Black-capped chickadees in the field. Resident populations were located on the University of British Columbia (UBC) campus and in the adjacent neighborhood of Dunbar in Vancouver. Three locations were selected in the Dunbar neighborhood (named East Road, Valdez Park, and Garage), and four sites were selected at UBC (named Buchanan, West Mall, Marine Drive, and Rhodo Wood) (Figure 1). Chickadees are often found at forest edges, so the field sites encompassed an open area adjacent to trees and shrubs that provided protective cover (Johnson, 2003). All sites were within 10 m from a driveway; however, the sites were selected for their minimal human traffic to reduce the source of disturbances during the study.

A preliminary study was conducted to locate residential populations of chickadees and to observe natural chickadee feeding. From August to December 2011, chickadees in both Dunbar and UBC areas were exposed to Black-capped chickadee call recordings and feeding at an artificial feeder either on a wooden board or in a feeder. Calls used for attracting mates (whistled two-note *fee-bee* calls) and those used for flocking (*chicka-dee-dee-dee* calls) were obtained from the Cornell Lab of Ornithology and Lang Elliott. The calls were recorded and played on a Sony Ericsson w580i phone audio device.

The main data collection occurred in the winter between January and March 2012. It has been shown that in winter, the lack of insect prey facilitates an environment in which human-habituated chickadees are easily baited out to feeders (Johnson, 1997; Freas et al., 2013). Also, chickadee populations form

mating pairs and establish territories in the winter, thus this study exploited the stable social groups and territorial behavior of chickadees to limit social interactions within family groups (Odum, 1941; Baker et al., 1991). For any given sampling day, the chickadees arrived in pairs or as flocks of up to seven individuals.

Thirty-seven sampling periods took place over twenty days between January and mid-March 2012. A randomized combination of mirror, foil, glass, or no object was presented each day up to nine consecutive 10-minute sampling periods within a day. In a given day, exposing chickadees to one treatment could potentially alter their responses to a treatment following it. Therefore, each time the feeder attachment was changed, the presentation order among the four treatments was recorded for later statistical evaluation. Due to limited visitations, not all treatments were presented at each site (Table 1), however, roughly equal visitations to each treatment was achieved: mirror (70), foil (75), and glass (75).

Feeder set-up and treatments

This study employed a 7-cm diameter Wild Birds Unlimited Small Quick-Clean™ Seed Tube Bird Feeder (Part # 1032). The feeder had two perches on opposite sides, but one perch was removed and the adjacent opening was covered up so that birds could only feed from one side of the feeder. A further adjustment included an addition of a slit emerging beside the perch in which a sheet of mirror, foil, or glass could be inserted. Chickadee visitations with no object attached to the feeder were also sampled for three sampling periods (for a total of 19 visitations) to obtain a baseline response of chickadees to the feeder.

The mirror measured 10.5 cm x 8.2 cm. A white plastic frame covered the back and edges of the mirror, ensuring the mirror was only visible from the perch. For the foil treatment, the same mirror was covered with a smooth sheet of kitchen-grade aluminum foil. For the glass treatment, a sheet of glass was cut in the same dimensions as the mirror. The foil and glass were modified to prevent creating a reflection off the chickadee. Hence, the duller side of the foil faced the chickadees, and the glass was covered by a sheet of crinkled cling wrap.

Table 1. Attachments to a feeder (none, glass, foil, or mirror) presented to Black-capped chickadees at each of the seven field sites in UBC and Dunbar areas in Vancouver, BC, Canada. An "x" indicates that data was collected for that treatment.

Site	None	Glass	Foil	Mirror
Dunbar - East Road				x
Dunbar - Valdez Park		x		x
Dunbar - Garage		x	x	
UBC - Buchanan	x	x		x
UBC - West Mall	x	x	x	x
UBC - Marine Drive		x	x	x
UBC - Rhodo Wood	x	x	x	

Behavior type	Description
Aggression	1. Pecking or kicking 2. Batting the wings 3. Taking a threatening posture 4. Gargles: trilled <i>tseedleedeet</i> vocalization
Exploration	1. Perching in front of the object 2. Hopping on the perch 3. Chirps: short <i>tsit-tsit-tsit</i> vocalization
Other Vocalizations	1. Singing: whistled 2-noted <i>fee-bee</i> 2. Alarm calls: <i>chicka-dee-dee-dee</i>

Table 2. Description of object-directed behaviors scored as aggressive, exploratory, or other vocalizations. This was used to record Black-capped chickadee behaviors displayed towards the glass, foil, or mirror feeder attachments.

The feeder was filled with black sunflower seeds, a commonly preferred food for this species (Johnson, 1997; Henning & Allen, 2003). The feeder was suspended from a deciduous tree at approximately 1 m off the ground at the outermost edge of the forest or shrubbery. When the feeder was in an area surrounded by branches and in low visibility, seeds were placed on a wooden board along the flight path to the feeder to attract attention to the feeder. The same playbacks used for the preliminary study were played on a LG Wink GU297 phone sound recording device as another method to attract chickadees.

Data collection

Observations on the behavior of chickadees that came in contact with the feeder were taken approximately 5 m away from the feeder and without blinds. Data was collected in 10-minute samples, starting from when the first chickadee arrived at the feeder. For each visitation, all of the following qualitative and quantitative measures of data were recorded: the chickadee’s method of approach to the feeder, the time until it picked up the first seed, the number of seeds handled, the frequency and length of aggressive displays and exploratory behaviors, the total time spent at the feeder, and the method of departure from the feeder. All observations were recorded by the same observer for consistency.

A chickadee’s approach and departure from the feeder were categorized as either *direct* or *gradual*, as indicators of the birds’ caution of the feeder. A chickadee usually flies in swiftly to the perch, takes a seed, and flies away (direct approach and departure). On the contrary, a more slow approach—such as hopping between nearby branches before landing on a feeder—would indicate caution (gradual approach) (Censky & Ficken, 1982; Huang, 2010). For departure style, hopping around in the vicinity of the feeder was an indicator of a safe enough environment to explore the area or feed nearby (gradual departure) (Lima et al., 1985; Huang, 2010). From the preliminary study, chickadees normally flew in and out beyond

the observer’s visible area, so a 5 m mark was chosen to distinguish direct and gradual approach and departure styles.

The baseline for seed handling was considered 1 seed per visit and 1-2 seconds at the feeder based on the preliminary study and previous studies (Censky & Ficken, 1982; Seok An et al., 2011). Any deviation in the number of seeds taken per visit or time at the feeder was an indicator of disturbance at the feeder.

The study recorded behaviors indicative of aggression (Kershner & Bollinger, 1999; Baker et al., 2012), exploration (Huang, 2010; Seok An et al., 2011), and other vocalizations (Gammon, 2004), as documented by previous research on chickadee intraspecific behaviors (Table 2). Exploratory behaviors are known to be indicators of curiosity and comfort (Huang, 2010; Seok An et al., 2011). These behaviors in the presence of the mirror, foil, and glass were recorded as “object-directed behavior” (*sensu* Rajala et al., 2010). The observer tallied the number of occurrences of each behavior type and recorded the length of time of such behaviors.

With concern for learning (Ficken, 1981; Feeney et al., 2011) and seasonal changes such as breeding and winter lack of food that may influence data across the data collection period (Lemmon et al., 1997; Lewden et al., 2011), the presence of other bird species or animals and environmental factors in the study area were also noted, including weather, temperature, wind, humidity, and time of day.

Statistical tests

For time at the feeder, latency time to feeding, time for object-directed behaviors, proportion of birds that showed object-directed behaviors, and visitation rate, the mean values for each attachment to the feeder (mirror, foil, glass, or no object) were compared in a Kruskal-Wallis test. Since a different number of individuals were sampled each day, quantitative data were first converted to per-individual averages and then averaged across days. The Spearman’s Rank-Correlation test and Kruskal-Wallis test evaluated the presence of any potentially confounding environmental factors of (a) photoperiod (measured by date), (b) order of presenting treatment objects (1, 2, or ≥ 3), and (c) field site. For (b), the treatment objects (mirror, foil, glass, or none) were assigned a number of 1-4 in the order they were presented each day. Since chickadee visitation to the feeder did not often continue enough to present three or four treatments in one day, the Kruskal-Wallis test compared orders 1, 2, and ≥ 3, grouping the treatments presented third and fourth. A test with a significant difference was followed up with a post-hoc multiple comparison test ($\alpha=0.05$) to further assess the impact of the factor on the main results. Approach-style, departure style, and object-directed behaviors were converted to frequencies (number of occurrences per treatment), and a contingency association analysis combined with a Pearson’s chi-squared test checked for any biased occurrence of behaviors for a certain treatment. The threshold of significance was $\alpha = 0.05$ for all statistical tests.

Aggressive and exploratory behaviors were scored based on object-directed behaviors and required either a mirror, foil, or glass with which the chickadees would interact. Therefore, a feeder with no object was not included in the analysis for object-directed behaviors.

RESULTS

Eleven out of twenty sampling days succeeded in attracting chickadees to a feeder, and analyses were based on a total of 239 Black-capped chickadee visitations. The chickadees arrived at the field site individually or in flocks, often with a flock following the first individual. Some birds were travelling in mating pairs. Chickadees readily approached the feeders further into the winter months, with more visits on cool, sunny days, as they tended to hide under cover during precipitation.

No noticeable disturbance by other species was observed. A few other species of birds were sighted but none landed on the feeder. Chickadees on a few occasions made alarm calls and flew away in response to humans and vehicles passing by the feeder, but they promptly returned to the same site in response to a playback of chickadee calls.

Overall, there were visible differences between mirror, foil, and glass treatments in the frequency and types of behaviors elicited by chickadees. The mirror had the longest average time at the feeder. Results of a Kruskal-Wallis test confirmed that there was a significant difference between the mirror, foil, and glass in time spent at the feeder ($\chi^2=18.992$, $df=3$, $p<0.001$; Figure 2). While the chickadees spent a longer time at the feeder, the time was not spent on feeding: an increasing proportion of chickadees left the feeder without taking a seed in the order (least to greatest) of no object, glass, foil, and then mirror. Based on a Pearson’s Chi-squared test the type of

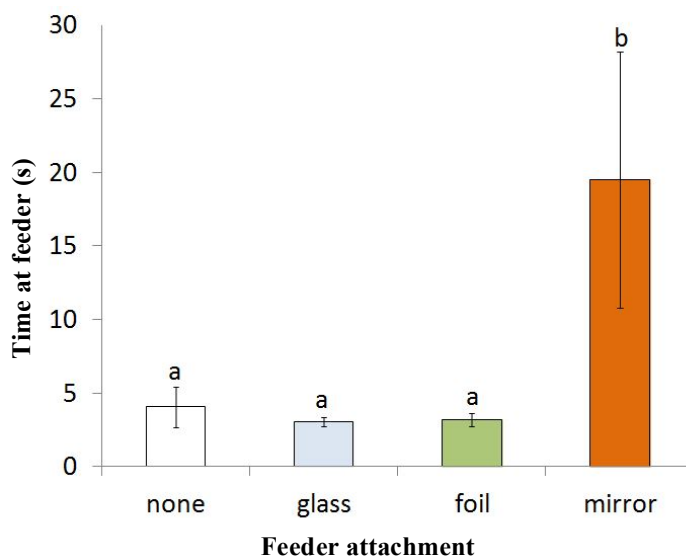


Figure 2. Effect of treatment (none, glass, foil, or mirror mounted on a feeder) on mean visit time (seconds ± s.e.) by Black-capped chickadees. Bars with the same letters are not statistically significant from each other.

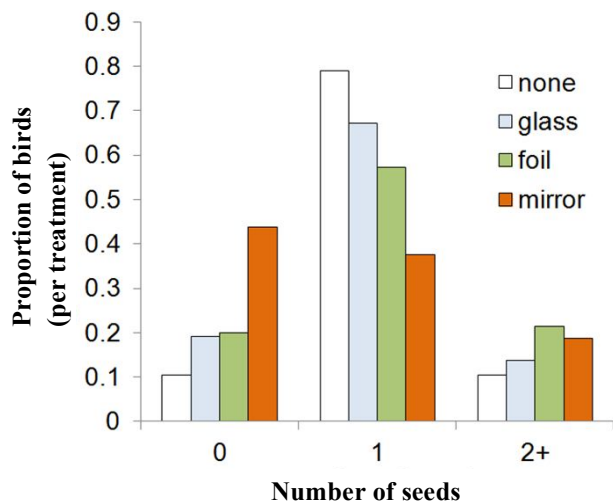


Figure 3. Effect of feeder attachment (none, glass, foil, or mirror mounted on a feeder) on mean number of seeds handled by Black-capped chickadees. The feeders were set up with no object, glass, foil, or mirror. Each bar shows the proportion of chickadees that took the given number of seeds. The proportions were calculated individually on data within each treatment.

attachment on the feeder (none, glass, foil, or mirror) was a strong predictor of whether a chickadee would handle 0 or 1 seed ($\chi^2=18.597$, $df=3$, $p<0.001$; Figure 3). Only 10% of chickadees left without a seed when there was no object mounted on the feeder, but 44% left without a seed for the mirror treatment. For the chickadees that took a seed, the time until it took its first seed in the mirror treatment was delayed on average to 5 seconds

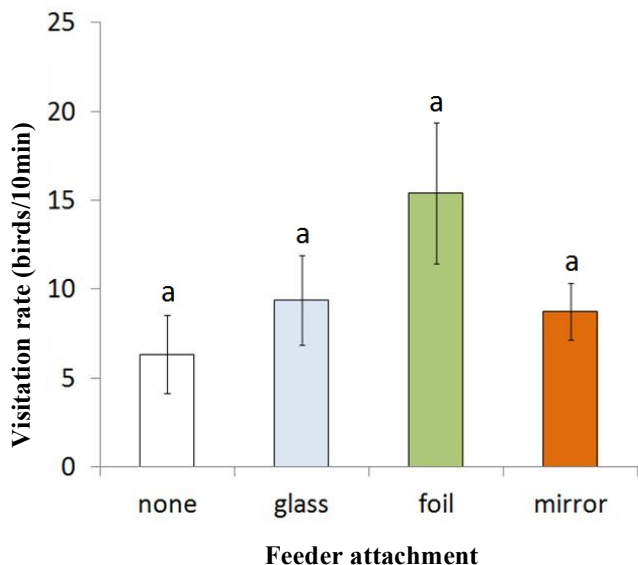


Figure 4. Effect of feeder attachment (none, glass, foil, or mirror mounted on a feeder) on mean feeder visitation rate (number of birds/10 min. ± s.e.) by Black-capped chickadees. The 10-minute sample was measured from when the first chickadee landed on the feeder. Bars with the same letters are not statistically significant from one another.

compared to the 1 second in the none, glass, and foil treatments. This difference was significant based on a Kruskal-Wallis test ($\chi^2=11.058$, $df=3$, $p=0.011$).

With the introduction of an object (mirror, foil, or glass), chickadees displayed aggressive behaviors previously not observed when no object was attached. Aggression was highest in the mirror treatment. The proportion of birds that showed aggressive behaviors was 12% with glass, 15% with foil, and 39% with the mirror. The difference between these proportions was significant based on a Kruskal-Wallis test ($\chi^2=18.255$, $df=2$, $p<0.001$). The mirror treatment also had higher frequencies of exploratory behaviors than the foil and glass, with 19% for glass, 21% for foil, and 29% for the mirror, but in a Kruskal-Wallis test, the groups were not significantly different ($\chi^2=2.403$, $df=2$, $p=0.301$). Time for object-directed behaviors including both aggressive and exploratory behaviors were significantly different between treatments, and increased in order of glass, foil, then mirror ($\chi^2=10.684$, $df=2$, $p=0.005$).

Results were unaffected by differences in date (photoperiod) and predominantly unaffected by order of treatment presentation (Table 3). However, Kruskal-Wallis tests indicated that order significantly influenced treatment effects on latency time to feed ($\chi^2=12.631$, $df=2$, $p=0.002$). A post-hoc multiple comparison identified that the difference between the orders 1 and ≥ 3 (CD: 22.130, $p<0.05$) as well as 2 and ≥ 3 (CD: 25.881, $p<0.05$) accounted for this significance. When a treatment was the first or second feeder attachment presented in a given day, the treatment effect on latency time to feed was significantly different compared to when the treatment followed other feeder attachments and thus was the third or later to be presented on the day. For field site, Kruskal-Wallis tests found a significant interaction of field site with treatment on time at the feeder and time for object-directed behaviors. Follow-up multiple comparison analyses indicated that the Buchanan and West Mall sites differed significantly in latency time to feed (CD: 38.56019, $p<0.05$), whereas Rhodo Wood and Valdez Park accounted for the significant difference in the time spent on object-directed behaviors (CD: 33.617, $p<0.05$).

There was a significant treatment effect on mean visitation rates (number of birds/10 minute sampling period) in a Kruskal-Wallis test ($\chi^2=18.499$, $df=3$, $p<0.001$) (Figure 4). This is likely due to the higher visitation rate for the foil compared to the glass and mirror treatments.

DISCUSSION

The objective of this study was to explore the impact of a mirror on chickadee feeding and social behaviors, with a hypothesis that a mirror would cause chickadees to fly away from the feeder and deter them from feeding. The winter data collection succeeded in attracting Black-capped chickadees to artificial feeding, likely because soft-bodied insects are lacking in colder weather and chickadees are obliged to feed on cacheable seeds (Freas *et al.*, 2013). The results supported the hypothesis in that the chickadees fed less in the presence of a mirror. However,

Table 3. Statistical outputs for Kruskal-Wallis (χ^2), Pearson's Chi-squared (χ^2), and Spearman's rank correlation (r) tests for shown variables and response behaviors by Black-capped chickadees (*=significant at $p < 0.05$). The treatments consisted of either no feeder attachment (none), glass, foil, or mirror mounted on the feeder.

	χ^2	df	p -value	Test
Treatment effect (glass, foil, mirror) on time at the feeder	18.992	3	< 0.001*	Kruskal-Wallis
Treatment effect (none, glass, foil, mirror) on latency time to feeding	11.058	3	0.011*	
Treatment effect (glass, foil, mirror) on aggressive behaviors	18.255	2	< 0.001*	
Treatment effect (glass, foil, mirror) on exploratory behaviors	2.403	2	0.301	
Treatment effect (glass, foil, mirror) on time for object-directed behaviors	10.684	2	0.005*	
Treatment effect (none, glass, foil, mirror) on number of seeds handled	18.597	3	< 0.001*	Pearson's Chi-squared
Order interaction with treatment on number of seeds handled	5.586	2	0.061	Kruskal-Wallis
Order interaction with treatment on latency time to feed	12.631	2	0.002*	
Order interaction with treatment on time at feeder	3.476	2	0.176	
Order interaction with treatment on time for object-directed behaviors	4.114	2	0.128	
Order interaction with treatment on aggression	2.1064	3	0.551	
Order interaction with treatment on visitation rates	0.039	2	0.981	
Field site interaction with treatment on number of seeds handled	7.378	6	0.287	Kruskal-Wallis
Field site interaction with treatment on latency time to feed	12.458	6	0.052	
Field site interaction with treatment on time at feeder	18.790	6	0.005*	
Field site interaction with treatment on time for object-directed behaviors	20.339	6	0.002*	
Field site interaction with treatment on aggression	1.408	2	0.495	
Field site interaction with treatment visitation rates	0.365	2	0.833	
Treatment effect (none, glass, foil, mirror) on visitation rates	18.499	3	<0.001*	Kruskal-Wallis
	r	df	p-value	Test
Date effect on aggression (glass)	0.24	8	0.507	Spearman's rank correlation
Date effect on aggression (foil)	0.59	8	0.070	
Date effect on aggression (mirror)	0.14	8	0.690	

contrary to expectations, chickadees faced with a mirror tended to stay longer and show more aggressive behaviors.

The increased time at the feeder was predominated by aggressive behaviors towards the mirror instead of feeding. This suggested that the mirror reflection was perceived by the chickadees as a direct competitor for food. Chickadees responded to this threat with interference competition: they engaged in aggressive interactions in such a way to prevent the other from feeding. It can also be inferred from the latency to feeding that chickadees were much less likely to feed until they establish, or at least assert their dominance. It is documented that chickadees may compete over who feeds first (Baker *et al.*, 1991; Seok An *et al.*, 2011), but the results of this study demonstrated that competitions can continue for a significant length of time and will interrupt normal feeding patterns.

The nature of the mirror image helped explain the observed prolonged aggression from chickadees at the feeder. Since the mirror image will persist as long as the individual is in front of the mirror, the mirror image will present an equally matched bird that “returns” any aggressive displays. Due to this, the conflict perceived by the chickadee subjects in the study could not be resolved and had led to an extended interaction (Mennill & Otter, 2007; Hof & Hazlett, 2012). The presence of the mirror image posed a threat to the chickadee as expected, but the chickadees tended to respond with aggression rather than passive avoidance, likely due to the unestablished dominance hierarchy with its mirror image.

The vocalizations from a playback also posed a new environmental factor that deviated from the method in Censky & Ficken’s past example (1982) who found chickadees visiting feeders less when a mirror was present. A more recent study showed that overlapping vocalizations are agonistic behaviors in Black-capped chickadees (Mennill & Otter, 2007). The playback, meant to attract chickadees to the feeder, possibly simulated aggressive overlaying of calls, and could account for the reason chickadees displayed threat behaviors at the feeder. Indeed, at the Marine Drive field site, one chickadee demonstrated intense aggression (data for this individual was removed as an outlier): it engaged in a physical attack on the playback device instead of the mirror, suggesting that the auditory feedback from the playback may have added to the displays of aggression posed by the visual mirror reflection, and stimulated retaliation from the chickadee subjects. Overall, the aggressive displays observed in this study suggest an alternate hypothesis to how chickadees feed when faced with a mirror.

Similar to how the chickadees were not scared away by the mirror, traditional beliefs dictated that foil acts as a deterrent to birds (Bishop *et al.*, 2003; Ober & Kane, 2012) but the results suggested the contrary, as the highest visitation was found in the foil treatment rather than the mirror or glass treatments. Chickadees may have been attracted to objects with reflective properties. However, the mirror, which had the highest reflective properties of the three feeder attachments used, did not have as high of a visitation rate; in fact, the visitation rate for the mirror

was not significantly different from when the feeder had no mirror.

The visibility of foil from a distance and its consistent light-reflectance (as opposed to mirrors that would also reflect an image of the surrounding environment unless directly reflecting sunlight) may have made the dark green feeder in the green environment more conspicuous and resulted in foil having the highest visitation rate. Potentially, the UV reflectivity of foil (Yalpani, 2004) may have also attracted chickadees. Many studies support the notion that chickadees rely on UV vision for their choice of mates, and thus the visual stimulation may account for the high visitation rate of the chickadees at the foil (Mennill, 2003; Doucet *et al.*, 2004; Klems & Saenger, 2013).

Impact of order and field site

When glass or foil was presented after other treatments, the mean latency time to feed was shorter than when they were presented first or second. In contrast, when the mirror followed other treatments, the latency time was higher than when the mirror was presented first. After exposure to a “disturbing” mirror treatment, chickadees likely had less hesitation to feed in the presence of glass and foil, resulting in a reduced latency time. It is possible that due to consecutive trials, the study underestimated the latency time in the glass and foil treatments, thus making a type I error: judging an incorrect significance in the treatment effects. On the other hand, the repeated trials may have accustomed the chickadees to a novel object attached to the feeder, and enabled later trials of the day to more aptly represent the chickadees’ responses to the specific properties of each treatment object (mirror, foil, and glass), rather than the novelty of the object attached to the feeder.

The analyses on field site effects suggested that chickadee responses to the object presented (mirror, glass, foil, or none) differed by which field site the feeder was located. Data from West Mall, compared to data from Buchanan, showed a more drastic increase in time at the feeder from glass to mirror treatments. Rhodo Wood had a longer time for object-directed behaviors in the glass treatment compared to Valdez Park. Field sites were chosen for their similar physical features to reduce bias, yet some of the field sites may have been a merging point of multiple chickadee territories where chickadees sensed more competition or displayed heightened territorial behaviors.

For the time data mentioned above, the order and field site effects add uncertainties to the conclusion that chickadees took longer to feed, stayed longer at the feeder, and interacted more with the object due to the presence of a mirror. However, the number of seeds handled, the frequency of aggressive behaviors, and visitation rates were not significantly affected by field site or order, and thus support isolated treatment effects based on differences between the mirror, foil, and glass.

Limitations

Censky and Ficken (1982), who used marked individuals, found that high dominance rank and mid-rank birds showed agonistic behaviors towards its mirror image, whereas lower ranked birds did not. The present study had no system to control whether

dominant or subordinate chickadees approached the feeder. Thus, it is possible that a group more representative of higher-ranking birds than others were captured. However, if a long term (> 1 year) study of this residential flock or a study that accounts for the dominance rank of arriving birds produces results consistent with this study, it would further support the conclusion that chickadees in general, regardless of dominance rank, respond aggressively to a competitor for food.

This study distinguished between a swift, direct approach and a gradual, step-by-step approach to the feeder as a measure of the chickadees' comfort in the area. However, there was more variation in the approach style than what was expected. There were chickadees that flew back and forth past the feeder before closing their distance to the feeder. The initial sweeps may have been a form of exploratory behavior that the study did not capture, leading to an underestimate of the change in approach-styles across treatments (Huang, 2010). Time at the feeder and time until start of feeding offered alternative measures to evaluate caution in the present study. Nevertheless, having a revised measure of approach style could provide information about how much the information received prior to landing on a perch affected chickadee visitation or behavior at the feeder.

In some cases, aggressive and exploratory behaviors could not easily be distinguished. For example, if the bird paused "facing" the mirror, it could be displaying a threatening posture, or may simply have the mirror and its surroundings in its range of vision (Baker *et al.*, 2012; Henry *et al.*, 2008). Thus, some aggressive or exploratory behaviors could have been overestimated. These behaviors were categorized by the observer as aggressive or exploratory based on whether they were displayed with other known aggressive or exploratory behaviors. In a future study, high-speed video could possibly record and detect subtle posture changes, tension, and eye movements to identify truncated versions of a fully threatening behavior and to better distinguish aggressive from exploratory behaviors (Clemmons & Lambrechts, 1992; Huang, 2010). Visual cues are the key stimuli in mirror studies, and increased understanding of a range of aggressive and exploratory behaviors could help to further specify the reasons for chickadee behaviors at the feeder.

Conclusion

In summary, the results of this study supported the prediction that Black-capped chickadees would feed less or not at all when a mirror is present at a feeder, but rejected the hypothesis that chickadees are deterred at the sight of their reflections. Chickadees were not "scared away" by any of the novel objects presented at the feeder. Instead, they remained longer at the feeder and engaged in extended bouts of dominance displays and aggression with their mirror images. These aggressive displays always preceded feeding (if they fed at all) and resulted in chickadees taking significantly longer to feed. This behavior implied the tendency of chickadees to respond to competition with interference competition rather than exploitation competition. In other words, the chickadees did not consider consuming the seeds as a priority, and rather abandoned feeding for direct competition. The unique property of mirrors that reflect

an apparently equally dominant individual and the use of aggression-mimicking playbacks could account for the novel results. Since these behaviors were demonstrated despite in a time of limited food resources, the study provided preliminary evidence that in natural encounters with an equally matched or persistent competitor for food, chickadees are likely to engage in aggressive encounters at the expense of feeding. The effectiveness of mirrors in inducing such social interactions, and the insight it offers combined with a better control of playbacks and chickadee visitations are useful to consider in future designs utilizing mirrors in controlled behavioral studies on Black-capped chickadees. The four treatments in this study yielded useful comparisons to attribute chickadees' extended presence and aggression to the image-creating property of a mirror. Therefore, I suggest inclusion of foil and glass controls in future mirror studies to interpret mirrors as a proxy for another individual and allow further inferences about intraspecific behaviors.

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