

The impact of peanut mechanical processing time on eastern gray squirrel foraging preferences

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The optimal foraging theory posits that foraging behaviors are governed by unseen efficiency assessments – animals forage in a way that maximizes their nutritional yield per unit time. The eastern gray squirrel (*Sciurus carolinensis*) is a small mammal that can be used to study mammalian foraging strategies. We evaluated optimal foraging theory principles in eastern gray squirrels on the University of Maryland, College Park campus. Previous experimentation has revealed that squirrels and other small foraging mammals preferentially select food sources on the basis of chemical digestibility. Our experiment sought to evaluate the impact of mechanical processing time spent prior to digestion on squirrel foraging preferences for peanuts with or without intact shells. After we presented squirrels with shelled and unshelled peanuts, we tabulated selection preference frequency and measured their time spent de-shelling and masticating selected nuts. We hypothesized according to optimal foraging theory tenets that peanuts with intact shells would pose significantly higher temporal and energetic input thresholds, and thus be selected less frequently compared to unprotected peanut kernels. Our results were inconclusive with regard to both selection preference and processing time divergence. Future research can more precisely quantify energetic inputs and outputs as functions of time to better assess the optimal foraging theory efficiency model.

Key words: *Sciurus, carolinensis*, eastern gray squirrel, peanut, urban, optimal foraging theory

Researchers have often attempted to describe mammalian foraging behavior using quantitative models (Pyke 1984). The optimal foraging theory is one such model that has historically been used to describe animal ecological foraging behaviors on the basis of nutritional efficiency (Pyke et al. 1977; MacArthur and Pianka 1966). This model describes foraging behavior as driven by the maximization of energetic yields, in which organisms seek the maximum caloric payoff per foraging bout or unit time (Pyke 1984; MacArthur and Pianka 1966).

In order to evaluate this efficiency model in mammals, we studied the eastern gray squirrel (*Sciurus carolinensis*) and their foraging preferences for peanuts. Eastern gray squirrels are commonly found in the University of Maryland, College Park campus, where our experiment was conducted, and can serve as an effective model for small mammalian foragers (Koprowski 1994). Peanuts are a natural part of the eastern gray squirrel diet, and were thus used in our experiment to examine squirrel preferences for nuts with shells intact or removed (Hartney et al. 2003).

The optimal foraging theory has been applied to eastern gray squirrel experiments in describing dietary preferences on the basis of food nutritional content and rate of digestibility (Smith and Follmer 1972). While these studies have quantitatively modeled digestibility as a factor of efficiency, they do not take into account the mechanical processing time of nuts prior to chemical digestion (Smith and Follmer 1972). By controlling for the nutritional content of presented nuts, we assessed the impact of mechanical processing time alone on food selection frequency.

Our experiment tested the principles of the optimal foraging theory and foraging efficiency by evaluating the impact of mechanical processing time prior to digestion (mastication

and handling of the food) and relating it to foraging preferences for peanuts with or without shells. The results of this study may be used to better understand animal and mammalian foraging behaviors in the light of foraging efficiency and optimal foraging theory principles. In highlighting factors driving foraging preferences, our results may elucidate principal mechanisms that determine dietary preferences in other foraging animals.

By presenting peanuts to eastern gray squirrels on the University of Maryland, College Park campus, we sought to determine if there was a significant difference in the mechanical processing time of peanuts with and without their shells. We also worked to experimentally determine if this temporal variation impacted eastern gray squirrel foraging preferences for peanuts with intact shells (high processing time), or with removed shells (low processing time). We hypothesized that there would be a significant difference between the mechanical processing times of peanuts with intact shells and peanuts with the shell removed. We thus posited, under the tenants of the optimal foraging theory, that eastern gray squirrels would exhibit a preference for peanuts without their shells on account of temporal differences in mechanical processing preceding digestion and chemical breakdown (MacArthur and Pianka 1966; Pyke et al. 1977; Pyke 1984; Smith and Follmer 1972; Rosen et al. 2007).

MATERIALS AND METHODS

Study location—We performed this study at the University of Maryland, College Park campus, on the McKeldin mall during the month of May. Testing locations included various sites on the mall, in areas with high tree density lining concrete walkways.

Experimental subject—Eastern grey squirrels are diurnal, with their peak foraging activity taking place at dawn and at dusk (Koprowski 1994). Grey squirrels at the University of

Maryland, College Park are habituated to close contact with humans, which make them ideal test subjects.

Equipment/ supplies used— Our experimental supplies included unsalted, unsweetened raw peanuts (*Arachis hypogaea*) with shells intact and with shells removed by hand, measuring tape, and digital Android™ phone stopwatch software.

Design of Study— Our experimental schedule was conducted based on squirrel foraging activity. We conducted our experiments for approximately one hour at 5 pm to 6 pm (Koprowski 1994). Experimental testing locations on the McKeldin mall were chosen at locations of high tree density, lower grass blade length (to increase subject and sample visibility) and relative remoteness from concrete and asphalt surfaces. At testing sites, we conducted our experiments where other food sources were not present to prevent interference. Two treatment levels were tested: peanuts with shells intact and peanuts with shells removed. Our sample presentation for one observational trial consisted of 2 peanut kernels without a shell placed edge on edge, and 2 peanut kernels naturally within one shell. This presentation controlled for nutritional and caloric value. Peanuts were also selected to be similar in length, making both treatment levels visibly similar. All presented peanuts were at least 1-inch minimum in length.

We presented peanut kernels without their shell one in front of the other, edge to edge. We placed the 2 peanut types 1 foot from one another, at least 5 feet from concrete/asphalt surfaces, and within 5 feet of tree trunk edges. One observational trial collectively consisted of one preference observation and one processing time tabulation event. Mechanical processing timing and peanut preference tabulation began the instant a test subject picked up a peanut. We stopped timing if the test subject moved with the peanut without processing it, dropped the peanut, or left the visible vicinity of the test site. The processing time only accumulated when a

squirrel was masticating and de-shelling the peanut. Care was taken to not sample a single squirrel individual more than once. The observation site was moved each trial to minimize this risk.

Data Analysis—The mean processing times for peanuts with and without shells were calculated using processing times of those squirrels that selected the respective nut type. A t-test of the means with a .05 P-value was used to determine if there existed a statistically significant variation in mean processing time values. To determine if there was a statistically significant preference for peanuts with or without shells, a 2-tailed binomial test of peanut type selection frequency was used with a .05 P-value of significance.

RESULTS & ANALYSIS

We conducted a total of 25 trials over two days of observation. Of those trials, 14 squirrels showed a preference for peanuts with shells intact while 11 showed preference for peanuts with the shell removed (Figure 1). The squirrels we observed showed no significant preference for nut type (binomial, $p > .05$). A handling time was associated with all except 3 with shell trials and 1 no shell trial. 21 total handling time observations were made, as 4 handling time assessments were rendered incomplete due to the subject vacating the visible test area. The mean handling times for squirrels that chose peanuts with shells versus those who chose peanuts without shells was 77.56 ± 7.27 seconds and 65.42 ± 10.24 seconds, respectively (Figure 2). There was no statistical divergence between the mean processing times of the two peanut types ($t = .96$, $df = 20$, $p = .347$).

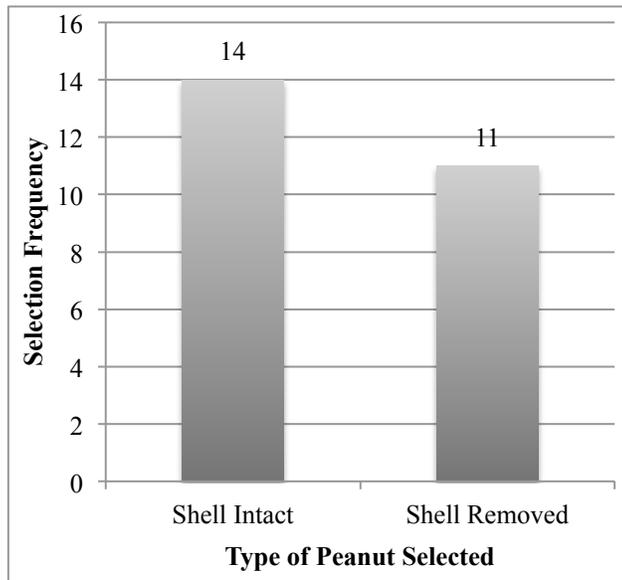


Figure 1 – Selection frequency of peanuts with shell intact versus peanuts with shell removed. Each of the 25 trials represented is independent of the others.

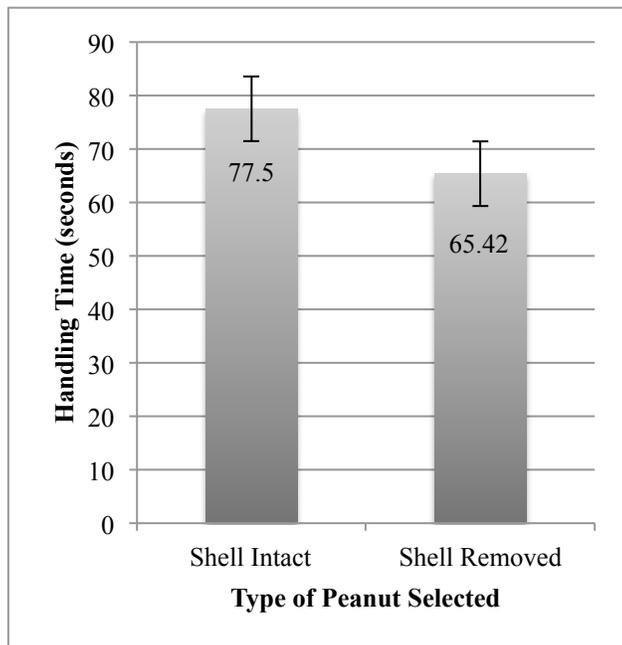


Figure 2 – Mean handling time for squirrels that consumed peanuts with shell intact versus those that consumed peanuts with shell removed. Standard error, designated by error bars is 7.27 seconds and 10.24 seconds for shell intact and shell removed, respectively.

DISCUSSION

The results we obtained in our experiment were insignificant with regard to squirrel peanut foraging preferences and the related effects of processing time. While the optimal foraging theory suggests that a preference should be exhibited for those nutritional payloads with a lower threshold for energetic payoff, our results do not agree (Pyke 1984). There was no statistically significant variation in either selection preference or mechanical processing time in sampled squirrels. Previous experimentation has spoken on the positive correlation between chemical digestibility of food after mastication and food preference, however our experimental effort to link pre-digestion energy expenses to foraging preferences did not highlight such a relationship (Smith and Follmer 1972).

Of course, any behavioral study is limited by the scope of the data pool. Our sample sizes of $N=25$ for preference data points and $N=21$ for processing time data points is of course relatively limited. The restriction of test subject location to the University of Maryland, College Park campus also necessitated that we observe selected subjects during times of inert weather conditions, as foraging activity is significantly reduced during times of rain (Koprowski 1994).

Preference results may have been impacted by the nature of our sample presentation, and by subject behavioral habituation. Eastern gray squirrels consume nuts as they are found in nature – they are found with their shells intact (Koprowski 1994; Spritzer 2002). Thus, the presented peanuts with intact shells may have been more desirable on the basis of them being visually similar to naturally foraged nuts. However, the examined squirrels inhabit a relatively urban college campus, and may be relatively habituated to anthropocentric foodstuffs and human traffic, so the impact of this factor on our results is unclear (Koprowski 1994). While our experimental design mostly accounted for physical and visual features of the presented peanuts,

there may be subtle visual or olfactory cues that may have influenced selection preference (Koprowski 1994). While peanuts with and without intact shells are roughly similar in size and visual appearance, other minute physical differences may have influenced final selection (Smith and Follmer 1972; Koprowski 1994).

The similarity in mechanical processing time in peanuts with and without shells may be due to a habitual time limit imposed on nut processing (Smith and Follmer 1972). Previous experimentation has indicated that eastern gray squirrels often cease to process nuts based on the nut's energetic threshold to nutritional payoff, which is variable based on shell hardness or complexity (Smith and Follmer 1972). Oftentimes this means that squirrels open the nutshell and only partially consume the nut kernel. In the case of our experiment, this may have meant that the subjects selected the perceived "natural" nut with the intact shell, and only partially consumed the kernels.

Other subjects may have spent a similar amount of time completely eating the kernels of peanuts with removed shells, which led to the temporal similarity in mean processing times (Smith and Follmer 1972). This may indicate that those squirrels that selected the peanuts lacking shells received a denser caloric or nutritional payoff in the same timespan compared to those squirrels that removed the nut and only partially consumed all the nut kernel material. Unfortunately, our experimental design does not quantify or account for nutritional intake per unit time.

Our experiment sought to link the optimal foraging theory and energetic expense of foraging behaviors to preference. Our results were not significant, and do not allow us to conclude that mechanical processing time as defined by our experiment impacts peanut selection preference in an urban squirrel population. Future experimentation may be able to account for

nut foraging and consumption paradigms and more precisely quantify nutritional intake and energetic expense as functions of time.

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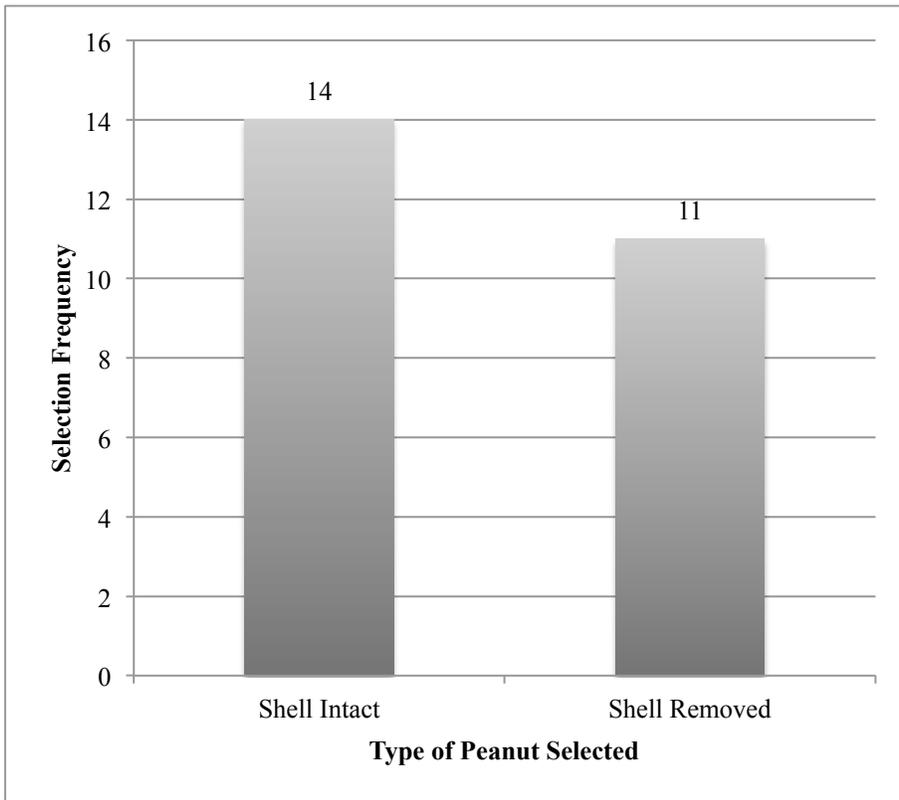


Figure 2 – Selection frequency of peanuts with shell intact versus peanuts with shell removed. Each of the 25 trials represented is independent of the others.

