Failure to find altruistic food sharing in rats

Haoran Wan1, Cyrus Kirkman1, Greg Jensen2,3, & Timothy D. Hackenberg1

1. Reed College, Dept. of Psychology, Portland, OR, USA
2. Columbia University, Dept. of Neuroscience, New York, NY, USA
3. Zuckerman Institute, New York, NY, USA

**Abstract**

Prior research has found that one rat will release a second rat from restraint in the presence of food, thereby allowing that second rat access to food. Such behavior, clearly beneficial to the second rat and costly to the first, has been interpreted as altruistic. Because clear demonstrations of altruism in rats are rare, such findings deserve a careful look. The present study aimed to replicate this finding, but with more systematic methods to examine whether, and under what conditions, a rat might share food with its cagemate partner. Rats were given repeated choices between high-valued food (sucrose pellets) and 30-s social access to a familiar rat, with the (a) food size (number of food pellets per response), and (b) food motivation (extra-session access to food) varied across conditions. Rats responded consistently for both food and social interaction, but at different levels and with different sensitivity to the food-access manipulations. Food production and consumption was high when food motivation was also high (food restriction) but substantially lower when food motivation was low (unlimited food access). Social release occurred at moderate levels, unaffected by the food-based manipulations. When food was abundant and food motivation low, the rats chose food and social options about equally often, but “sharing” (food left unconsumed prior to social release) occurred at low levels across sessions and conditions, and did not appear to rely on the presence of a second rat. The results are therefore inconsistent with claims in the literature that rats are altruistically motivated to share food with other rats.

Pro-social behavior can be defined as behavior that produces benefits for another, sometimes even at a cost to the individual (Fehr et al. 2002; West et al., 2007). One type of pro-social behavior gaining currency in recent years is *social release*, in which one animal releases another from a trap or restraint. In an experiment by Ben-Ami Bartal, Decety, and Mason (2011), for example, one rat was restrained in a plastic restraint tube that could be opened by a second rat. Such release permitted the restrained animal to leave the tube and spend the remainder of the 60-min session in the presence of the other rat. Most of the rats learned to open the restraint, and generally did so only when (a) the restraint contained another rat and (b) the tube’s door permitted social release. Subsequent studies have verified that rats will, under a variety of conditions, respond in ways that release a rat from a restraint (Ben-Ami-Bartal et al., 2014; Blystead et al., 2019; Hachiga et al., 2018; Hiura, Tan, & Hackenberg, 2018; Sato et al., 2015; Schwartz et al., 2017; Silberberg et al., 2014). The basic effect is reliable, having been replicated across different procedures and laboratories, but its core mechanisms remain a matter of debate.

According to some authors (e.g., Ben-Ami Bartal et al., 2011, 2014; Sato et al., 2015), social release arises from altruistic motives: the free rat senses distress on the part of the trapped rat, and acts altruistically out of empathic concern for its social partner. An alternative explanation is based on social contact: social release is motivated by opportunities for social interaction (Hachiga et al., 2018; Hiura et al., 2014; Schwartz et al., 2017; Vanderhooft et al., in press). In other words, social release is a type *operant* (or *instrumental*) behavior, established and maintained by contingent social contact as a form of reinforcement. The competing theoretical accounts have been difficult to disentangle experimentally, owing to the fact that under many conditions in the standard procedure, releasing the other rat from a restraint can be viewed in terms consistent with either a social reinforcement view (opportunities for social interaction) or an altruistic view (releasing a distressed rat for its benefit, rather than that of the releaser). Therefore, unless special conditions are arranged to disentangle the two interpretations (cf. Hachiga et al., 2018; Sato et al., 2015; Schwartz et al. 2017), the mere fact of social release is not sufficient to favor one view over the other.

Although most of the work to date on social-release procedures has focused on the main procedure, another result reported by Ben-Ami Bartal et al. (2011) has received far less empirical attention. In some conditions, rats were given a choice between two restrainers, one of which contained high-value food rewards (5 chocolate chips), the other of which was contained a restrained rat. These conditions permitted social release, as in the standard procedure, but here, was pitted against a known and powerful food reward as a means of assessing the relative value of social release. On average, the rats learned to approach and open the tube containing food more quickly (earlier in testing) than the tube containing another rat, though the latencies to access both tubes became low and roughly comparable (< 10 s) by the end of the 12-session experiment. And on slightly more than half of the trials, the trapped rat was released before the food was completely consumed, enabling the trapped rat access to the food rewards. This resulted in lower levels of food intake (70% of maximum, on average) than in a control condition in which the alternative restraint was empty (in which the free rats ate 96% of the food).

These two patterns of findings led the authors to the following conclusions: (a) the reward value of releasing a restrained rat is comparable to that of high-valued food (similar latencies to food and social release doors), and (b) social release in some cases comes at the expense of food intake (lower levels of food intake in a social context). In other words, rats not only value social contact equally with food, but engage in altruistic food sharing, sacrificing some high-value food to make it available to a distressed social partner. On its face, these findings appear to lend strong support to accounts appealing to some type of altruism, and simultaneously pose serious theoretical challenges to strict cost-benefit models. If not for altruistic motives, why would a rat sacrifice its own food? While there is ample evidence of food sharing in rats, it is usually of the reciprocal exchange (tit-for-tat) variety, in which animals alternate roles as donors and receivers (Taborsky et al. 2016). Far less common is the type of unreciprocated food sharing reported by Ben-Ami Bartal et al. (2011), in which a rat leaves highly-valued food for another to consume with no tangible short-term gain. Given both the novelty and theoretical significance of the findings, these food-sharing conditions warrant closer examination.

The main objective of the present study was to replicate and extend the food-sharing conditions from Ben-Ami Bartal et al. (2011), using more robust methods for assessing reward value and food sharing. The methods were patterned after Hiura et al. (2018), in which rats were given repeated choices between high-valued food rewards (sucrose pellets) and social release (10-s social contact). Unlike the findings reported by Ben-Ami Bartal et al. (2011), however, Hiura et al. found that rats showed a consistently strong preference for food over social release, even in the face of large increases in food cost (number of responses to produce food), while the costs of social release remained low. Costs were manipulated via a progressive ratio (PR) schedule, in which the number of responses per reward was low at the beginning of the session, but increased with each reward earned. Social release typically only occurred in the latter parts of the session, when food costs were high and after many food rewards had been earned and consumed. The overall session-wide preference for food generally exceeded 90%.

This strong preference for the food over the social release option is at odds with the equal value of social release and food reported by Ben-Ami Bartal et al. (2011). There are several procedural differences between the experiments, however, that may account for the different findings. First, and perhaps importantly, there were differences in motivation. In the Ben-Ami Bartal et al. experiment, there were no restrictions placed on social or food access outside the session: rats had free access to food and social contact in their homecages. In the Hiura et al. (2018) experiment, on the other hand, food or social access (or both) were generally restricted outside the session. When food was freely available outside the session, the rats still preferred food over social contact, but substantially less so than when it was restricted, suggesting some sensitivity to the motivational context. In the present experiment, we included conditions that both restricted and did not restrict access to food and social contact outside the sessions to assess the impact of motivational variables on the relative value of food and social rewards. If the higher levels of food versus social responding reported by Hiura are due primarily to motivational variables (restricted post-session access to rewards), then providing free access to those rewards would be expected, through satiation, to reduce the reward value of food, bringing food preferences more in line with social preference, akin to findings of Ben-Ami Bartal et al. (2011).

We also sought a more detailed characterization of altrusitic food sharing, the second important claim put forth by Ben-Ami Bartal et al. (2011). In their study, sharing was defined in terms of differences in food consumed when a rat was available for release and when no rat was available (empty tube), differences thought to reflect the amount of food that is consumed (hence, shared) with the other rat. While this provides a tangible measure of some important *outcomes* of sharing, it has little to say about the functional characteristics of the sharing behavior itself, or the conditions under which it occurs. In the present experiment, we adopted a functional definition of *altruistic food sharing*, focusing on a coordinated sequence of behavior: (a) food production, followed by (b) social release, given that (c) food was still remaining, permitting (d) the formerly restrained rat access to food. Measuring such episodes of food sharing alongside preference for food and social release will provide important information on how these behavior patterns are related to each other as well as to the experimental conditions.

In addition, to ensure that the choices were well informed by their outcomes, we gave rats repeated choices each session, rather than the single choice per session used by Ben-Ami Bartal and colleagues (2011). In single-choice procedures, the duration of social contact depends on when in the session the door opening occurs. If the duration of social contact contributes to reward value, as some research suggests (Vanderhooft et al., in press), then the value of social release in these single-choice procedures may fluctuate across sessions; and this may, in turn, affect sharing opportunities. We sought to hold constant the value of social contact, both within and across sessions, and therefore used a consistent (30 s) duration of social contact throughout the present experiment. Against this background of constant value of social reward, we manipulated food quantity (pellets per response) and motivational context (restricted versus unrestricted food access) on a within-subject basis, including some conditions closely resembling the original Ben-Ami Bartal et al. procedure. Collectively, the methods permit a rigorous evaluation of Ben-Ami Bartal’s two main conclusions bearing on their claim of altruistic food sharing, namely, that (1) reward value of food and social release are equal, and (2) a rat will share food with another rat, even at the expense of food for itself.

**Method**

*Subjects*

Six female Sprague-Dawley rats (*Rattus norvegicus*) were used in this experiment. The rats were experimentally naïve, and were pair-housed in a temperature-controlled colony room, with a 12-hr light/dark cycle. One rat from each pair designated the unrestrained (focal) rat and the other the restrained rat. In some conditions, the rats had continuous homecage access to water, food (Purina rat chow) and social contact; in other conditions, homecage access to was limited to 60 min access shortly after experimental sessions.

*Apparatus*

The apparatus consisted of three adjacent chambers, each measuring 31 cm × 25 cm × 22 cm with a wire grid floor. The central chamber contained two levers (5 cm × 1.5 cm × 1.5 cm) set on either side of a pellet tray, which could receive individual pellets from a gravity-fed dispenser outside the chamber. Additionally, a small light (2 cm diameter) was mounted above each lever. Both the left and right chambers contained a Plexiglas rodent restrainer (25 by 8.75 by 7.5 cm, Harvard Apparatus, Holliston, MA), each of which was connected to the central chamber by a metal door that was mechanically controlled. Experimenters were able to access each chamber separately via a hatch that, when closed, acted as a ceiling to the chamber, Experimental schedules were controlled and data recorded via a PC computer programmed in MedState Notation language and MED-PC software.

*Training*

**Food reinforcement training.** Focal rats were trained to press the right lever by reinforcing successive approximations with food, delivered into the pellet tray (see Figure 1). Only the right lever was active in these sessions, denoted by the illumination of the right cue light.

**Restraint training.** To minimize the delay between lever pressing and social interaction, restrained rats were trained to leave the restraint soon after the door was opened. During these sessions, the restraint door was lifted independently of a subject’s behavior. Leaving the restraint was defined as the entire body of the rat (except the tail) outside the restrainer. Once the rat left the restraint and entered the middle chamber, it was allowed to explore for 30 s before being returned to the restrainer by hand for the next trial. These sessions lasted for 30 min, and continued for 3-5 sessions, until the rats were leaving consistently within a few seconds of when the door was raised.

**Social reinforcement training.** After food and restraint training was complete, all rats received social reinforcement training. In these sessions, the restrained rat began each trial in the restraint in the left chamber, with the focal rat in the center chamber. Only the left lever was active in these sessions, denoted by the left cue light. A left lever press opened the door to the restraint, and produced a xxx tone. When the restrained rat moved from the restraint into the center chamber, the door was closed, beginning the 30-s social interaction period. This also extinguished the light and deactivated the lever. After 30 s, the restrained rat was returned to the restraint for the next trial. Because Rat 8 did not readily press the left lever for social access, it received a few sessions of supplemental training in which left lever presses produced food. Once pressing occurred consistently, the food was withdrawn and social access was the sole consequence of left lever presses. Rats 4 and 6 did not require additional training; left lever presses only produced social access throughout the experiment.

*Experimental procedure*

During all experimental sessions, the rat in the central chamber made repeated concurrent choices between social release and food. Choice trials began with both left and right cue lights illuminated. In all conditions (with the exception of Condition 5; see below), a restrained rat was placed in the left restraint, and a press on the left (social release) lever turned off the left cue light and opened the left door. At the end of the social interaction period, the apparatus was reset, with the restrained rat returned to the left restraint while the focal rat remained in the central chamber. Unless otherwise indicated, all social interaction periods had a fixed duration of 30-s. a total of Subjects in Conditions 1-3 were fed on a restricted schedule in their home cages, whereas subjects in Condition 4-7 had free access to food in their home cages.

and summarized their manipulations“”

During Phase 1, a press on the right (food) lever resulted in food delivery to the pellet tray, and briefly extinguished the cue light. In Conditions 1, a right lever press resulted in the delivery of 1 pellet; in Condition 2, each right lever press yielded 2 pellets; in Conditions 3 and 4, each right lever press yielded 4 pellets. During Phase 1, the initiation of a social interaction period via a left lever press deactivated both levers for its 30-s duration, having their cue lights extinguished and yielding no consequences when pressed.

During Phase 2, a press to the right pellet no longer resulted in the delivery of food to the pellet tray. Instead, the right door opened to reveal 5 pellets in the right restraint tube, which could then be collected by the focal rat during a food collection period. In Condition 5, no rat was placed in the left restraint, and the left cue light was left dark, and left lever presses had no mechanical effects. Instead, presses to the right lever opened the right door for a 30-s food collection period, after which the door closed whether or not all pellets had been consumed. In Condition 6, both the left and right levers were active, and made available both social interaction (via the left restraint) and pellets (via the right restraint). In this condition, social interaction periods lasted 30-s, but the right door remained open for as long as it took for all five pellets to be consumed. Finally, in Condition 7, both the social interaction periods and the food collection periods each lasted for 30-s following when their respective doors opened.

*Analysis*

Subject performance was modeled using multi-level generalized linear regression, implemented using the Stan programming language (Carpenter et al. 2017). This Bayesian approach yielded a full estimate of the posterior probability density across all relevant parameters, as well as the behaviors those parameters predict. As such, our analysis does not compare behavior to a null hypothesis; instead, we report the patterns of future behavior that are predicted on the basis of the collected evidence, as well as the uncertainty of those predictions given our statistical models. The analytic scripts used to perform these analyses are included in the electronic supplement.

**Results**

In order to model the proportion of choices made between food and social reinforcement, a multi-level logistic regression was performed, modeling each subject in each condition with an intercept term. The resulting estimated proportion of responses made by each rat to the food lever in each session of Phase 1 is plotted in Figure 2, as is the estimated mean of the three subjects. When access to food in the home cage was restricted (Conditions 1-3), subjects consistently favored the food lever over the social lever, doing so most when each lever press yielded only 1 pellet (92.4% mean preference, ± 0.4%), somewhat less when yielding 2 pellets (86.9% mean preference, ± 0.7%), and less still when yielding 4 pellets (67.7% mean preference, ± 1.5%). In Condition 4, with 4 pellets per press and free chow available in the home cage, subjects displayed an equivocal preference between the two levers (49.3% mean preference, ± 2.3%).

However, choosing the food lever less often did not necessarily result in fewer pellets being delivered or consumed. In order to model the estimated number of pellets either consumed or left uneaten, a multi-level negative binomial regression was implemented (Gelman et al. 2014). This distribution was chosen because we wanted to allow for the possibility that the distributions of pellets consumed was overdispersed. Figure 3 plots the estimated average frequency with which pellets were either consumed (black circles) or left behind (white diamonds) in a given session. Subjects generally consumed over 100 pellets when access to chow in their home cage was restricted (Conditions 1-3), but consumed around 50 pellets even when they had unrestricted home cage chow (Condition 4). Despite this, subjects effectively never left behind a food pellet in Condition 1 and left behind only one or two pellets in a typical session of Conditions 2-4. Subjects almost never left behind pellets for the restrained rat to collect, even under circumstances in which pellets could be generated easily and during which the focal rat was not experiencing caloric restriction.

This systematic consumption of food may have been stimulus-driven, insofar as subjects pressing the food lever in Conditions 1-4 had the resulting pellets immediately delivered to the pellet tray mere centimeters away from the lever. In Conditions 5-7, however, pellets had to be collected from the right restraint tube, making the pellet both more laborious to collect and less salient as direct consequences of the lever press. Additionally, Conditions 5-7 featured unrestricted home cage chow, so subjects were less motivated by immediate caloric deficit.

Figure 4 shows subjects’ preference for food responses relative social responses in Phase 2 (Condition 5 is not present because it lacked a concurrent social schedule), as estimated using multi-level logistic regression. In general, preference was equivocal, close to 50% in both Conditions 6 and 7. On average, subjects were slightly, but probably not meaningfully, more likely to choose food in Condition 7 than in Condition 6 (mean difference of 5.0% ± 3.5%).

Figure 5 shows the average number of pellets consumed in each condition of Phase 2, as estimated by multi-level negative binomial regression. As in Phase 1, subjects tended to consume more far more pellets than were left behind, but unlike Phase 1, they also tended to leave more pellets behind. In general, the largest number of pellets was left behind in Condition 5 (5.0 mean pellets, ± 0.8), followed by Condition 7 (3.4 mean pellets, ± 0.3), with Condition 6 yielding the smallest average number of pellets left behind (1.5 mean pellets, ± 0.6). The relatively low rate of pellets left behind in Condition 6 is not surprising given that the right restraint tube was not reset until all pellets were consumed. Meanwhile, Conditions 5 & 7 did not appreciably differ from one another, suggesting that the presence of the restrained rat did not encourage increased “sharing” (i.e. pellets left unconsumed prior to a social response). If anything, the current data suggest that subjects may have tended to leave more pellets behind in Condition 5, in which no restrained rat was present, than in Condition 7, when the social response was available.

**Discussion**

The present experiment was designed to replicate and extend some key conditions from the Ben-Ami Bartal et al. (2011) study, in which rats chose between social release and food. The present research focused on two main findings and related conclusions from that study: (1) rats chose food and social release with similar latencies, and therefore, food and social release are equally valued; and (2) rats willingly share food with their social partner, even if it comes at a cost to the individual. Taken together, these findings provide key support for the authors’ claims of altruistic food sharing. Because occurrences of such unreciprocated food sharing are rare in the published literature, they warrant further scrutiny.

With respect to the first claim of equal reward value of social release and food, we found that relative value of food and social release varied systematically across conditions. More specifically, when food and social motivation were low (unrestricted homecage access outside the session) and food quantity was high (4-5 pellets per trial), food and social release were chosen about equally often (Conditions 4-6), consistent with the Ben-Ami Bartal (2011) findings. When food motivation was high (restricted acccess to food outside the session), however, rats strongly preferred food over social release (Conditions 1-3). This finding is consistent with the Hiura et al. (2018) findings, showing strong and reliable preference for food over social release when food is restricted outside the session (see also Blystad et al., 2019). Taken as a whole, then, the presents results show that relative preference between social and food is not invariant, but rather, is subject to reward and motivational variables (food quantity and overall food access). The relative value of social release and food are always subject to these (and other) variables, and it would therefore be premature to draw broad conclusions about their relative value from sampling only a limited range of conditions.

The changes in preference across manipulation of food quantity in the first three conditions were driven mainly by changes in the number of food choices per session. This is partly due to economic factors (i.e., because the number of pellets per choice was increasing across these conditions, fewer food choices were needed to maintain comparable levels of food consumption), and partly due to satiation. Given the low price (1 response) and the dozens of choice opportunities each session, rats were producing and consuming large numbers of sucrose pellets each session (xx-xx, across rats). And when coupled with unlimited food access outside the session in Condition 4, the procedures combined to produce conditions of low food need. Indeed, our rats had such an abundance of food, there was often food left at the end of the session (xx). That rats did not consume rewards as highly valued as sucrose pellets suggests a high degree of satiation.

Despite such low levels of food need, there was very little evidence of food sharing – the second and most controversial claim set forth by Ben-Ami Bartal et al. Behavior that met our operational definition of sharing (i.e., producing food and then releasing the rat while food remained available) was exceedingly rare across all conditions in the experiment (xx%, across all subjects and conditions), even late in the sessions when much of the social release occurred (Figure 3?). It did not matter whether social and food access outside the session were restricted (Conditions 1-3) or not (Conditions 4-7); nor did it matter how many pellets were produced per response (Condition 1-3): rats rarely shared with the other rat any of the hundreds of food pellets they produced each session. Even in the final three conditions, with procedures that most closely matched the original study (i.e., symmetrically arranged social and food locations, 5 sucrose pellets, and unrestricted access to food and social contact outside the session), sharing was seldom observed. Thus, on the whole, we found no evidence to support Ben-Ami Bartal et al. claim that a rat willingly shares food with another rat.

It is difficult to reconcile the food sharing reported by Ben-Ami Bartal et al. (2011) with the near complete absence of sharing in the present study. Low levels of food sharing cannot be explained in terms of reduced opportunities for sharing, as the number of social releases (hence, sharing opportunities) remained fairly constant across conditions for individual rats (see Table 2). This was accomplished by providing repeated exposure to a consistent duration of social contact (30 s) across the experiment. With long sessions and repeated trials, rats had ample opportunities to share the food they had produced; they simply did not do so.

The discrepant results also cannot be explained in terms of differing definitions of sharing between experiments. Ben-Ami Bartal et al. (2011) used a less stringent indirect measure of sharing (difference between food consumed with and without a rat available to release) than our behavioral definition of sharing (produce food, then social release with food remaining). This alone cannot be responsible for the different results, however, for even if we adopt the less stringent criterion, our rats showed no differences in food consumption with or without a rat available to release (Conditions 5 vs 6). This is important, as evidence of sharing-related costs are crucial to an altruistic food sharing explanation. Thus, by neither definition did our rats engage in sharing.

There are other differences between the procedures, and the only way to know for certain which factors are responsible for the discrepant results would be to begin with a *direct replication*, an exact reproduction of the orginal procedures, and thereafter change one variable at a time. We chose instead to conduct a *systematic replication* (Sidman, 1960), in which some, but not all, of the orginal procedures are reproduced. Systematic replications are useful in assessing the generality of a finding, and this fit with our broader objectives of providing a more thorough characterization of preference and sharing. We sought not only to *replicate* but to *extend*, to assess the generality of the findings by exploring behavior across a range of conditions, including but not limited to, those of the original study. Indeed, sampling independent variables at multiple points on a function puts replication efforts into a broader context, changing the focus from *binary* questions with yes-no answers (e.g., Do rats value social release over food? Do rats share food with another rat?) toward *conditional* questions (e.g., Under what conditions is social release favored over food, and vice versa? Under what conditions does sharing occur?). Viewed in this way, the Ben-Ami Bartal et al. findings are not so much incorrect as they are incomplete; they are part of more general relationships between preference and sharing and the variables of which they are a function.

Exploring such functional relationships across a parametric range can also shed light on theoretical disputes. For example, when examined at only a single point on a function, social release can be interpreted either in terms of social reward (response-contingent access to social interaction) *or* in terms of empathy (acting out of concern for the other rat): both accounts make the same prediction, namely, that door opening will occur. The accounts begin to differ, however, as behavior is examined across a parametric range of conditions. For example, in procedures similar to those used here, Vanderhooft et al. (In press) established social release in rats. The price of social release (number of responses to produce it) was then systematically increased across sessions, generating demand functions. Overall, the functions (27 in all) were well described by the Hursh and Silberberg (2008, 2017) essential value model (96% VAF), a model that has proven useful in quantifying the value of numerous other rewards, including food, water, drugs (refs). In other words, these functions were predictable, with a high degree of quantitative precision, on the basis of social reward functions. It is less clear, however, what, if anything, an empathy account would have to say about these data: it makes no obvious predictions about how empathy is affected by price – or other variables known to affect reward value (e.g., magnitude, delay, or probability) about which social reward makes clear and testable predictions. And if predictions could be derived from an empathy account (e.g., by assuming that empathy mirrors social reward functions), they would be indistinguishable from the more parsimonious social reward account, and would therefore add little to the explanation. This is not to deny the importance of empathy as a topic worthy of scientific study; it is, rather, to demand more stringent tests of it, especially in domains in which simpler explanations already exist.

**Acknowledgements**

*Funding:*

**References**

Carpenter B, Gelman A, Hoffman MD, Daniel L, Goodrich B, Betancourt M, Brubaker MA, Guo J, Li P, Riddell A. (2017). Stan: A probabilistic programming language. *Journal of Statistical Software*, 76, 1-32.

Gelman A, Carlin JB, Stern HS, Dunson DB, Vehtari A, Rubin DB. (2014). *Bayesian Data Analysis, Third Edition*. Boca Raton, FL, USA: CRC Press.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Phase** | **Condition** | **Pellets per response** | **Home Cage Chow** | **Food Collection Period** | **# of sessions** | | |
|  |  |  |  |  | R4 | R6 | R8 |
| 1 | 1 | 1 (Tray) | Restricted | N/A | 11 | 11 | 5 |
|  | 2 | 2 (Tray) | Restricted | N/A | 9 | 9 | 4 |
|  | 3 | 4 (Tray) | Restricted | N/A | 13 | 9 | 5 |
|  | 4 | 4 (Tray) | Freely Available | N/A | 5 | 5 | 8 |
| 2 | 5 | 5 (Right Tube) | Freely Available | 30-s | 7 | 5 | 7 |
|  | 6 | 5 (Right Tube) | Freely Available | Unlimited | 6 | 6 | 6 |
|  | 7 | 5 (Right Tube) | Freely Available | 30-s | 6 | 7 | 5 |

Table 1. Sequence of conditions and number of sessions conducted at each.

Figure Legends

Figure 1. Apparatus

Figure 2. Mean proportion total choices allocated to food and social options across the four conditions of Phase 1. Error bars represent 95% confidence intervals.

Figure 3. Mean shared and unshared food consumption of across the four conditions of Phase 1. Error bars represent 95% confidence intervals.