Supplemental methods

1 Modification extension instructions for the food dispenser, model Feeder Compact X42 (Dörr GmbH, Neu-Ulm, Germany) including hints for cleaning

Several machines of the model Feeder Compact X42 (Dörr GmbH, Neu-Ulm, Germany) were converted for the study. The conversion can be simpler or more complicated, depending on the degree of gluing (see below), which varied greatly between the individual machines. The feeder consists of a storage chamber (fabric bag), to which a funnel is attached leading the feed into the rotating chamber. Since the Compact X42 was designed for feeding game for hunting, the ejection volume is too large for meerkats. It can be reduced by an insert into the funnel, manipulating the final volume remaining in the rotating ejection chamber.

Placement of the machine for reconstruction: volume bag on the bottom, rotating chamber at the top (Fig. A). The rotation chamber is attached to a central iron axle by a horizontally oriented screw (Fig. B). Depending on the model, this screw is not or additionally secured by glue. In unglued machines, it is possible to remove the rotating chamber directly by loosening the screw. In glued machines, a trial-and-error approach showed that first heating and then shock-cooling allowed the loosening of the screw, probably because it increases and decreases the volume of the metal. Alternatively, corrosive substances, such as vinegar, or force (hammer, vice, attachments) may work. In some machines, the motor was accidentally damaged during this process. Fig. C shows the remaining housing with the axis of rotation in the centre, to which the removed rotating chamber (Fig. B) was originally attached. The 3D printed element shown in Fig. D is inserted onto this axis of rotation. To fix it, 3 screws are used (Fig. D). The matching holes must be pre-drilled on the housing of the machine (Fig. E). The 3D printed object is inserted into the housing of the machine around the axis of rotation (Fig. F) and fixed with the 3 screws (Fig G).

Additional recommendation: Modification of the rotating chamber with a de-balancing device. The aim is to disturb the symmetry of the rotating chamber so that vibrations are created by the de-balancing item. This causes the whole machine, including the feed pellets, to vibrate every time the machine runs, which allows them to slide into the rotation chamber easily without clogging. Without the modification, pellets can occasionally clog inside the funnel. One possibility is to attach a screw with 2 opposing nuts to only one corner of the rotating chamber (Fig. H), creating a good vibration. Fig. I shows the rotating chamber and its unbalancing screw attached back to the machine. The machine now has a very small ejection volume and can be programmed to feed meerkats. If larger quantities of feed are required, this can be easily achieved by enlarging the two gates of the 3D printed insert (e.g. with a file), or by having different versions of the 3D printed insert. An .stl file of the insert used in the present study is given in the electronic supplement and can also be requested from the corresponding author.

The following hygienic considerations apply: the device should only be used with dry food. It should not be exposed to rain or other sources of moisture to avoid mould in the fabric reservoir part. The rotating chamber (Fib. B) is the part most at risk to the accumulation of feed residues. After removing it from the machine, it as well as the other plastic parts can be cleaned using a moist cloth and also a disinfectant. In theory, the rotating chamber could also be placed in a dishwasher (use stainless screws). When not in use, the machine should be disassembled, all food residues should be removed, and the different parts cleaned.

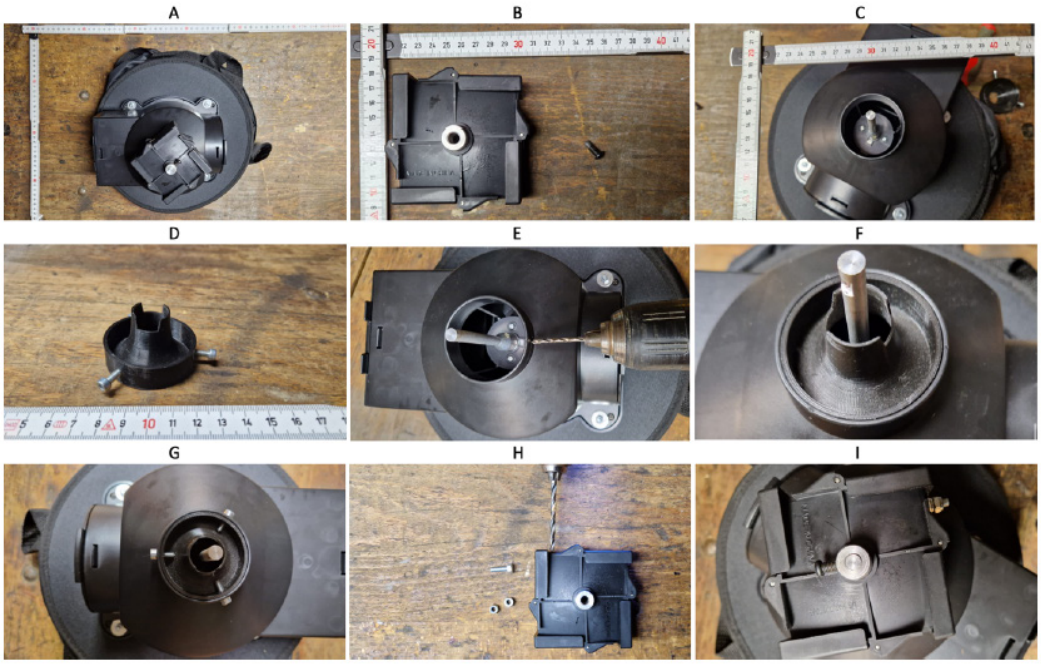

Figure S1. A-I; A Food dispenser, model Feeder Compact X42 (Dörr GmbH, Neu-Ulm, Germany), straight out of the package; B Dismounted rotating chamber with the loosened horizontally-oriented screw; C Remaining main part of the machine without rotating chamber, in the middle the axis of rotation; D 3D printed insert with screws in position; E Pre-drilling the three holes in the shell of the machine shaft; F 3D piece placed into machine shaft; G Inserted 3D piece fixed by screws; H Asymmetric attaching of a screw to cause an imbalance on the rotating chamber; I Reinstalled rotating chamber after inserting the 3D printed piece and attaching the imbalance screw.

2 Additional notes on statistical analysis

To account for repeated measures (per zoo, per period, per day), mixed effects linear models were used with a random factor (typically displayed as *1*|*Factor*). Due to the hierarchical nature of the repeated measures, if more than one is accounted for (e.g., the period in each zoo), these have to be nested hierarchically (e.g., period in zoo, displayed as *1*|*Zoo/Period*).

Due to the study design with 5 observation periods per zoo, a modelling approach that comprises the three zoos is feasible with one average value per period (analysis reported in the main text), but it is also possible to use one average value per day (accounting by 1|Zoo/Period) or to use one average value per hour (*1*|*Zoo/Period/Day*). Due to the hierarchical nesting, the degrees of freedom do not increase regardless of the increasing number of observations included in the analysis.

The different levels of data aggregation (period, day, hour) affect the distribution of the data. At finer resolution (e.g. hour vs. period), absence of a behaviour ('not observed') becomes more likely, making the data more likely to be not normally distributed and hence also affecting the distribution of model residuals. Then, alternative approaches, such as using ranked data, are necessary. Therefore, at finer data resolution, ranking the data had to be employed more often (Table 5 vs. Table S1).

In the case of normal distribution of residuals, the results of analyses at different levels of nesting of the random effect are identical (cf. Table S1 below and Table 5 of the main text); when ranked data have to be used, results are similar but not identical.

When assessing effects within a single zoo, repeated measures correction needs to be applied for study period (when data are aggregated per day) and additionally for day (when data are aggregated by hour).

The corresponding analyses are reported in Tables S2. Again, at the finer data resolution (per hour), model residuals are generally not normally distributed and hence, ranked data had to be used.

Table S1. Results of statistical comparisons of treatments (lumped feeding versus scatter feeding) using mixed effects linear models with different random effects to account for repeated measures, based on averages of percentage of individuals observed performing the behaviour per study day or per hour. A positive t value indicates more frequent behaviour under the scatter feeding treatment; see also Figure. 7. For a definition of behaviours, see the ethogram Table 4

Model:	Behaviour ~Treatment + (1|Zoo/Period)		Behaviour ~Treatment + (1|Zoo/Period/Day)	
Data:	Average per day (4 data/period; n=60)		Average per hour (8-10 data/day; n=560)	
Behaviour	t	P	t	P
Active	5.76	<0.001	° 5.74	<0.001
Not visible	° -2.57	0.026	° -1.94	0.078
Foraging	15.69	<0.001	° 13.98	<0.001
Eating	-9.08	<0.001	° -5.92	<0.001
Feeding	12.90	<0.001	° 12.93	<0.001
Food guarding	° -4.48	<0.001	° -3.87	0.002
Social	-0.30	0.767	° -0.16	0.879

°ranked data, degrees of freedom for 'treatment' = 11

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Table S2. Results of statistical comparisons, in each individual zoo, of treatments (lumped feeding versus scatter feeding) using mixed effects linear models with different random factors to account for repeated measures, based on averages of percentage of individuals observed performing the behaviour per study day or per hour. A positive t value indicates more frequent behaviour under the scatter feeding treatment; see also Figure 7. For a definition of behaviours, see the ethogram Table 4

Model: Behaviour ~Treatment + (1|Period); run individually for each zoo						
	Walter Zoo		Zoo Zurich		Parken Zoo	
Behaviour	t	P	t	P	t	P
Active	3.95	0.029	2.97	0.059	3.06	0.055
Not visible	-1.96	0.145	° -0.72	0.525	-3.08	0.007
Foraging	5.87	0.010	12.01	0.001	11.76	0.001
Eating	-5.46	0.012	° -4.74	0.018	° -7.06	<0.001
Feeding	5.27	0.013	8.08	0.004	8.42	0.004
Food guarding	-2.38	0.098	-1.42	0.252	° -2.97	0.059
Social	1.47	0.237	-4.36	0.022	1.25	0.299
Stereotyping	not observed		not observed		-1.50	0.231
Model: Behaviour ~Treatment + (1|Period/Day); run individually for each zoo						
Data: average per day (8-10 data/day; n=160-200)						
	Walter Zoo		Zoo Zurich		Parken Zoo	
Behaviour	t	P	t	P	t	P
Active	° 4.28	0.023	° 3.46	0.041	3.06	0.055
Not visible	° -2.13	0.123	° -0.17	0.875	° -0.77	0.444
Foraging	° 7.16	0.006	° 11.12	0.002	° 7.85	0.004
Eating	° -2.43	0.093	° -4.79	0.017	° -16.41	<0.001
Feeding	° 5.75	0.010	8.08	0.004	° 6.50	0.007
Food guarding	° -3.73	<0.001	° -0.94	0.417	° -3.20	0.049
Social	° 1.76	0.176	° -4.21	<0.001	° 1.05	0.371
Stereotyping	not observed		not observed		° -1.30	0.195

°ranked data, degrees of freedom for 'treatment' = 11

Things to consider - personal recommendations by the first author

The ground

The flooring/subsoil ideally should be of an irregular and diverse surface and a compact structure that can be shaped (e.g., not loose sand), so that the animals can dig into it and constantly reshape the ground assuring that the pellets roll to different places.

Enclosure structure

The lower part of the enclosure (up to knee height) should have a lot of structure, making it more challenging for the meerkats to find pellets, and motivating them to not only use their eyesight. But higher parts are recommended to allow long distance views, as they like to scan their surroundings.

The scatter area

The bigger the area where pellets are scattered, the bigger the distance between the pellets. If the enclosure is big, the scattering area of the machine can be enlarged by hanging the machine higher, for example with cable lines - allowing an easy refilling of the machine. If the enclosure is smaller, then care must be taken that pellets are not scattered outside the enclosure. Pellets will bounce back into the enclosure from walls (for example glass), while they might pass nets/electric fences. Hanging the machine low, or (if the use machine can be programmed) putting it on a lower battery / power level may help decrease the scattered radius. Otherwise, with tilting the axis of the scatter-machine a decrease in one direction can be achieved.

The feeding amount

The amount of pellets needs to be adjusted constantly. Observing the animals and their surrounding is important to adapt the ideal feeding amount. It is not possible to motivate meerkats to forage the scattered pellets if they are fed at the same time for ad libitum consumption from a bowl. Given that choice, they will choose the easy option and eat out of the bowl (IB pers. observation). Measuring the weight of the animals regularly helps to get feedback about suitable the amount fed is for the group. Adjusting the amount due to conditions of the animals should be a dynamic and constantly ongoing process. as a lot of factors influence the needed amount (for example age of the individuals, lactating individuals, group dynamics, weather, temperature, stress due to current construction work etc.).

°ranked data, degrees of freedom for 'treatment' = 11

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