

Supporting Information: Cognitive capacities for cooking in chimpanzees
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Subject Information

Name	Sex	Age	Testing Year 1				Testing Year 2								
			1	2	3	4	5a	5b	5c	6a	6b	7	8	9	
Binda	F	9			X	X									
Botsomi	F	20	X												
Chinoc	M	20								X					
Cheri	F	17	X												
Elikia	M	23	X	X	X	X	X	X	X	X	X	X	X	X	
Imphondo	F	17	X												
Kaoka	M	5	X		X	X	X	X	X	X	X	X	X	X	
Kefan	M	11	X	X	X	X	X	X	X	X	X	X	X	X	
Kimenga	M	8			X	X	X	X	X	X	X	X	X	X	
Koyamba	M	8			X	X									
Kouilou	M	4								X					
Kudia	F	6					X	X	X*	X					
Likabou	F	10	X												
Likouala	M	3								X					
Loufoua	M	10	X	X	X	X	X	X	X	X	X	X	X	X	
Louise	F	7	X	X			X*			X					
Luc	M	8	X												
Lufino	M	6	X												
Lufumbu	M	9	X	X	X	X									
Lusingou	M	6	X		X*		X	X	X*	X					
Manisa	F	5			X	X	X	X	X*	X					
Maya	M	17			X	X	X	X	X	X	X	X	X	X	
M'Bolo	F	15	X	X	X	X									
M'Pili	M	20								X					
M'Vouti	F	9	X		X	X	X	X	X	#	#	#	X	X	
N'Gao	F	9	X	X						X					
N'Golo	M	20								X					
N'Goro	F	6					X*			X					
N'Tsere	M	16					X	X		X					
N'Zambi	F	9	X	X	X	X									
Ouband	F	11	X	X	X	X	X	X	X	X	X	X	X	X	
Pema	F	9	X	X	X	X									
Pembele	F	19	X				X	X	X	X	X	X	X	X	
Pougou	F	5					X	X	X*	X					
Shanga	M	5					X	X	X*	X					
Silaho	F	13	X				X	X	X	X	X	X	X	X	
Tabonga	M	12			X	X									
Talian	M	11	X												
Tambikiissa	F	7	X	X	X*		X	X	X	X	X	X	X	X	
Tchivgna	F	7	X	X	X	X	X	X	X	X	X	X	X	X	
Tiki	M	10	X												
Ulemvouka	F	11	X	X	X	X	X	X	X*						
Ulengue	M	7	X	X	X	X	X	X	X	X	X	X	X	X	
Wolo	M	14					X	X	X*	X					
Womin	F	11	X	X											
Wounda	F	9			X	X									
Yoko	M	15	X	X	X	X	X	X	X*	X					
Zimbana	F	6								X					
N			29	16	23	21	24	22	21	29	12	12	13	13	

Table S1: Subject characteristics and participation. Age refers Experiments 1-4; Experiments 5-9 were conducted one year later. (*) Indicates failed to meet criteria to proceed to subsequent task, and (#) indicates pilot subject.

Experiment 1: Preference for cooked food

Setup

The side assignment of the raw and cooked food was counterbalanced (see Fig. S1) and pseudo-randomized (such that a given food type did not appear on the same side on more than 3 consecutive trials). The experimenter (E) always placed the leftmost option first. If subjects had a side bias when completing the preference session (meeting the criterion of more than 10 out of 12 choices on the same side), we repeated the session. Two subjects met this side bias criterion in their first session, but passed the criterion in a second session.



Fig. S1: Setup for Experiments 1 and 2. The ape sat across from the experimenter at a table with a sliding top. In experiment 1, the chimpanzee chose between a raw and a cooked slice of food. In experiment 2 (pictured here), the chimpanzee chose between one raw slice available immediately, and three slices (raw or cooked, depending on condition) that were available after a one-minute delay.

Data coding and analysis

Choices were both videotaped and coded live by the experimenter. To assess reliability, 20% randomly selected subjects were additionally coded from video by a research assistant blind to the research question and hypotheses. Reliability between live and video coding was perfect.

Subset of subjects participating in Study 2

To confirm that the subset of 16 chimpanzees that completed Experiment 2 (patience) also showed this preference, we ran these analyses separately for this sample. Results showed similar results as in the full sample: the chimpanzees chose cooked slices on $89.0\% \pm 2.9$ of trials, significantly above chance level [$t_{15} = 12.09$, $p < 0.001$]. All 16 individuals that participated in Experiment 2 chose the cooked item more often than the raw item at the individual level (range 66% to 100% of trials).

Experiment 2: Patience when waiting for cooked food

Subjects

We were conservative in that we only tested individuals who were consistently willing to eat the raw food. An additional 3 subjects began the study, but stopped participating for two or more sessions. Ten additional subjects who had previously completed Experiment 1 were not tested because they either failed a number discrimination pretest ($n = 8$, see below) or had previously refused to eat the raw food ($n = 2$).

Number pretest

All subjects had to pass a number pretest to confirm they reliably choose one slice over three slices before they completed Experiment 2. Subjects completed numerical comparisons of both raw and cooked slices (in blocks of three per type; block order counterbalanced). On each trial, the subjects were first able to lick each food option (to detect if it was cooked). Then E placed the two options on the table, with side assignment counterbalanced within the session. The inter-trial-interval (ITI) was 20 seconds. Subjects had to correctly choose the larger amount on 5 of the 6 numerical trials, and took an average of 2.1 sessions (range 1 to 5) to pass the pretest.

Data coding and analysis

All sessions were videotaped and coded live. To assess reliability, 20% of subjects were randomly selected and independently coded from video by a research assistant blind to the research question and hypotheses, with perfect reliability. The main measure of the test session was the mean percentage of trials in which chimpanzees chose the delay option. One subject participated in only 6 of 10 trials of the raw delay; all other subjects were without missing data. One subject stopped participating in the first session, but then successfully completed all trials when the session was repeated another day.

Experiment 3: Preference for cooking device

Subjects

Three additional chimpanzees initially began the study but were excluded, one because he stopped participating during the test, and two because they did not reliably point to the cooked over the raw food in an initial preference test included at the beginning of the session.

Preference test

Chimpanzees first completed 6 food preference trials. The procedure was similar to that in Experiment 1, but after E placed the slices on the table, they covered both pieces with identical red bowls (15 cm in diameter and 7 cm high), in order to familiarize the apes with the experience of choosing food inside opaque containers as in the subsequent main test. Subjects had to choose the cooked over the raw slice in five or more of the trials, and met this criterion after an average of 1.3 tests.

Apparatus

The *cooking device* was 8.5 cm high, consisting of a main bowl-shaped container (15 cm in diameter and 7 cm high) and a black lid (18 cm in diameter) with a second bowl affixed to its

bottom (see Fig. S2-3). The *control device* consisted of the bottom part of a transparent plastic container (9 cm high and 9 cm in diameter). It was covered by a white opaque lid (10 cm in diameter). In between trials, E placed the devices behind and opaque barrier of 70 x 35 cm prepare and/or bait them for the following trial.

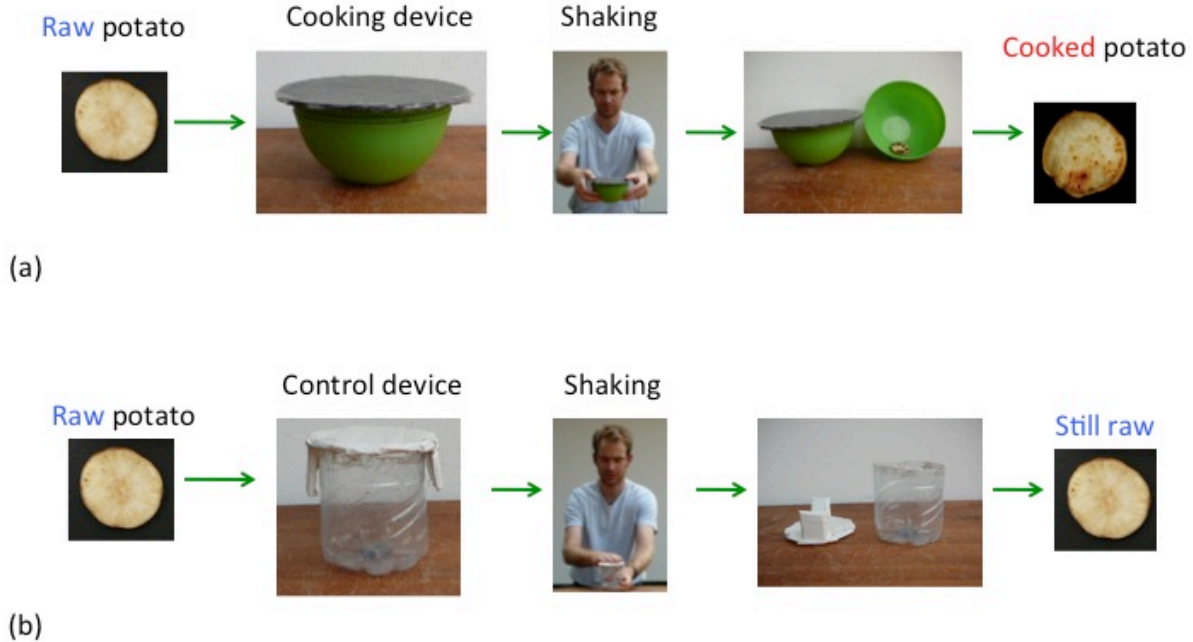


Fig. S2: Cooking device and control device. (a) When a raw piece of food was placed in the novel cooking device and shaken, it produced a cooked piece of food. The cooked slice was concealed in the device through the use of a false bottom. (b) Although the same series of shaking actions were performed on the control device, a raw slice was produced by this device.



Fig. S3: Choice trial setup for Experiment 3. In choice trials, the experimenter baited each device with raw food and shook them, as in the demonstrations. However, chimpanzees chose between the control device (left) and cooking device prior to seeing their current contents.

Coding and data analyses

All sessions were videotaped and coded live by E1. To assess reliability, 20% of subjects were randomly selected and coded from video by a coder blind to the research question and hypotheses, with perfect agreement.

Experiment 4: Will chimpanzees choose to cook their own food?*Procedure*

Across the 4 blocks, we counterbalanced whether the cooking device or the control device was demonstrated first, using an ABBA design. For each block, the side assignment of the two devices was kept constant across both the demonstration and test trials in that block, with side assignment counterbalanced across blocks. Chimpanzees completed 4 test trials at the end of each block (Fig. S4).

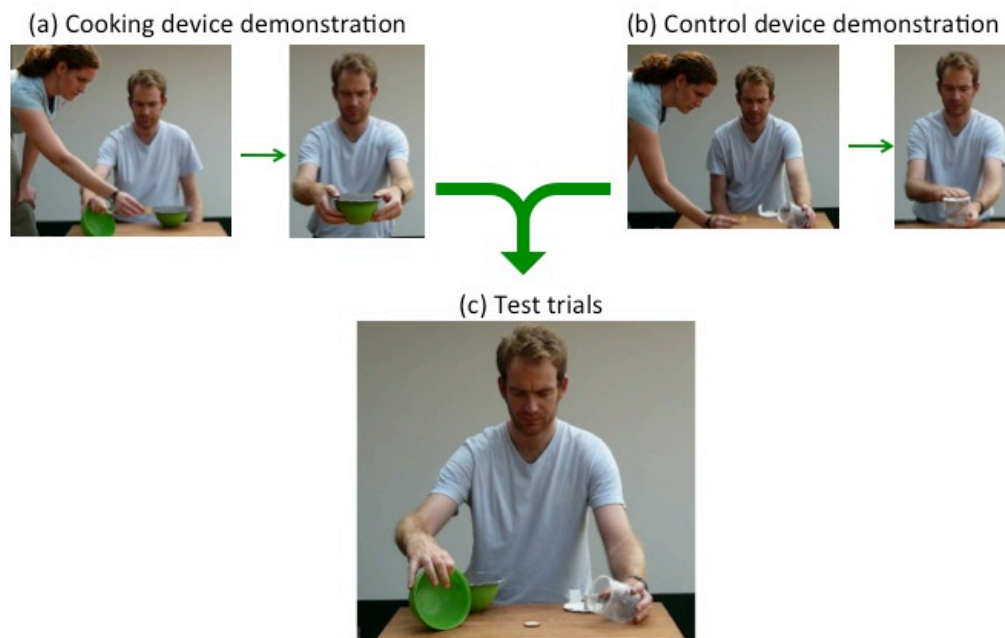


Fig. S4: Setup for Experiment 4. In the initial demonstration trials for (a) the cooking device and (b) the control device, experimenter 1 manipulated the devices and experimenter 2 demonstrated placing the raw slice in the containers. In subsequent test trials (c), experimenter 1 held the devices so they were both accessible, and experimenter 2 placed raw food in the chimpanzee's reach.

Coding and data analyses

All trials were coded first live by E1 for 1) whether the chimpanzee placed the food into either device; 2) whether the slice was intact or partial when placed in the device; and 3) whether the chimpanzee ate the raw slice. In addition, all trials were coded from digital video by coders who were blind to the research question and hypotheses, as well as the characteristics of the cooking device and the control device. Using the coding software INTERACT, one coder selected the testing events starting from the moment the potato slice was placed on the table and

ending before E1 started to manipulate the bowls. Another coder then assessed whether the chimpanzees placed a whole or partial raw slice into the device. Thus, the second coder never saw the actual cooking or non-cooking event or any feeding. Agreement between the live coding the video reliability was perfect. In addition, we coded whether the potato slice was intact when they put it in the cooking device. There was only one disagreement in 336 trials [Cohen's Kappa = 0.99]. Lastly, we coded whether they ate the potato slice [Cohen's Kappa = 0.98].

Pilot study

Six of the 21 subjects participated in a pilot study prior to completing the main test. This pilot study had involved up to 8 demonstrations of the cooking device and the control device and up to 8 trials with the opportunity to maneuver food into the bowls through a different mechanism than the one used in the main study (ramps that the food had to slide down); chimpanzees found these ramps very difficult to utilize. These few subjects were thus not completely naïve to the procedure of Experiment 4. To ascertain whether this had any effect, we conducted separate analyses comparing the performance of this subsample with the other subjects in the main study. An ANOVA showed that there was no difference between the two groups [$p > 0.7$]. Similarly, the ratio of chimpanzees using the cooking device at least once was virtually the same in both samples [Fisher's exact test, $p = 1.0$].

Supplementary results

In addition to the results reported in the main text, we also examined a more conservative criterion of whether the chimpanzees placed whole, intact pieces of food in the devices. This showed a similar pattern: 10 of 21 chimpanzees put whole slices of potato in the cooking device at least once. Apes that transferred food in a device (at least once) chose the cooking device over the control device in $81.3\% \pm 8.0$ of trials [$t_9 = 3.90$, $p < 0.01$], as in the main results.

We next used multilevel logistic regression to assess how the chimpanzees performed over trials (see Fig. S5). Our first question was whether chimpanzees kept the food versus put it into one of the devices by creating a binary response variable with (collapsing across placing it into the cooking device or the control device). We used keep vs. place as binary response (number of observations: 336), and fitted a model including subject as random factor and trial (1 through 16) as fixed continuous factor. This was compared to a more parsimonious model including only subject as the random factor. A likelihood-ratio-test showed that including trial as factor significantly increased the fit of the model [$\chi^2 = 64.1$, $df = 1$, $p < 0.0001$]. Thus, trial number had a substantial prognostic value, showing that chimpanzees became significantly less likely to keep the food as the session progressed [estimated model parameter for trial as factor = -0.44 , $Z = -6.04$, $p < 0.0001$].

Our second question was whether chimpanzees discriminated between containers: did they choose the cooking-device or the control device? For this analysis, we created a binary response variable with the values 'cooking device' vs. 'control device' (excluding trials where the chimpanzee kept and ate the food). This multilevel logistic regression comprised $n = 98$ such trials. Once again, we computed a model with subject as random factor and trial as fixed factor, and compared it to the random factor model. Results showed that adding trial to the model increased the fit significantly [$\chi^2 = 8.6$, $df = 1$, $p < 0.01$], showing that trial had predictive value [estimated model parameter for trial as factor = 0.23 , $Z = 2.8$, $p < 0.001$]. Thus, chimpanzees rarely put food in the control device, and this did not change across the session (see Fig. S5). Rather, they became more likely to put the raw food in the cooking device across the session.

Overall, these analyses confirm that the tendency to keep the food decreased while the tendency to selectively put it in the cooking-device increased.

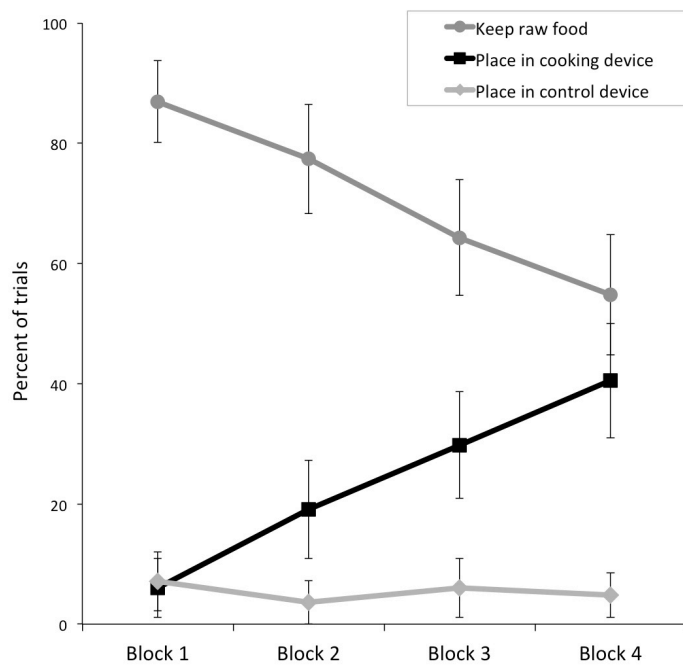


Fig. S5: Chimpanzees' willingness to cook their own food in Experiment 4. Percent trials where chimpanzees ate the raw food, placed it in the cooking device, or placed it in the control device over time. Error bars indicate SE.

Experiment 5a: Replication of Exp. 1 (Preference for cooked food)

Subjects

An additional three chimpanzees failed to participate in the test and were not included.

Setup and procedure

The procedure was the same as Experiment 1 conducted a year prior, with a few minor differences. Chimpanzees first completed 6 trials with only one option available to confirm that they would reliably point to food. They then 16 food preference trials (block of 8 trials with a small taste, followed by a block of 8 trials where they could only smell the food). Subjects completed trials without the 20 ITI. We set as criterion that chimpanzees had to choose the cooked slice in at least 12 out of 16 trials (binomial probability $p < 0.05$, two-tailed). Individuals who failed this criterion were tested in a second session.

Data coding and analyses

Choices were videotaped and coded live. To assess reliability, 20% randomly selected subjects were additionally coded from video by a research assistant blind to the research question and hypotheses, with perfect reliability.

Results

Looking at the overall results from the first session, chimpanzees chose the cooked food in $90.4\% \pm 2.4$ of trials, above chance [$t_{23} = 16.56, p < 0.0001$]. On an individual level, all 24 individuals chose the cooked item more often than the raw item (range 63% to 100% of trials in the first session). Twenty-one chimpanzees preferred the cooked food individually above chance in the first session; one additional subject reached the criterion in the second session.

Experiment 5b: Replication of Exp. 3 (Preference for cooking device)*Setup and Procedure*

We used the same setup and procedure as in Experiment 3, with the exception that we did not include another food preference test at the beginning of the session.

Coding and data analyses

All sessions were videotaped and coded live. To assess reliability, 20% of subjects were randomly selected and coded from video by a coder blind to the research question and hypotheses with perfect reliability.

Supplementary Results

Overall, in their first session chimpanzees selected the cooking device on $87.2\% \pm 3.7$ of trials, above chance [$t_{21} = 10.15, p < 0.0001$]. This pattern was apparent from the first trial, with 15 out of 22 chimpanzees choosing the cooking device. As in Experiment 3, chimpanzees had to choose the cooking device in at least 12 out of 16 test trials, corresponding to above-chance performance on a binomial test, to proceed to the subsequent study. Nineteen of 22 subjects reached criterion in the first session. Three additional chimpanzees passed in a second session.

Experiment 5c: Replication of Exp. 4 (Will chimpanzees choose to cook their own food?)*Subjects*

One additional subject from Experiment 5b failed to participate here, and was excluded.

Setup and procedure

We used the same procedure as in Experiment 4 (where chimpanzees could choose to place their own food in the cooking device or control device), except that chimpanzees could complete up to three sessions. As this study aimed to identify chimpanzees who cooked their food at high rates, we set as criteria that chimpanzees 1) had to put a piece of raw potato in one of the devices in at least 8 trials of a given session and 2) discriminate between devices by putting at least 75% of the raw pieces into the cooking-device over the control device. Chimpanzees that did not initially meet these criteria could complete up to two additional sessions.

Coding and data analyses

We coded live whether the chimpanzee placed the food into either device and whether the slice was intact or partial when placed in the device (as in Experiment 4). In addition, coders examined the behaviors from video while being to the research question and hypotheses, as well as the characteristics of the cooking device and the control device. As in Experiment 4, two

coders used the software INTERACT (one coder selected the testing events, and the other assessed whether the chimpanzees placed a whole or partial raw slice into the device). Reliability between live and video coding was high for whether or not subjects put a piece of food in the cooking-device or the control device [Cohen's Kappa = 1.0 in either case], and whether they put an intact piece into the cooking device [Cohen's Kappa = 0.98].

Supplementary Results

In their first session, fifteen out of 21 chimpanzees put a raw piece into the cooking device at least once. Individuals that placed food in a device chose the cooking device on $84.7\% \pm 5.9$ of trials, more often than the control device [$t_{14} = 5.90, p < 0.001$]. These results replicate those in Experiment 4. Eight chimpanzees met our criteria in the first session, three subjects in the second session, and two in the third session. The remaining eight subjects did not meet the testing criteria within three sessions and were excluded from further testing.

Experiment 6a: Do chimpanzees prefer cooked carrots?

Coding and data analyses

All sessions were videotaped and coded live. To assess reliability, 20% of subjects were randomly selected and coded from video by a coder blind to the research question and hypotheses, with perfect agreement.

Supplementary results

We compared performance in the sample of 12 chimpanzees who proceeded to Experiment 6b (because they had demonstrated proficiency cooking in Experiment 5c) and the supplemental sample of $n = 17$ chimpanzees. The main sample chose cooked carrots on $58.3\% \pm 7.4$ of trials, and the supplemental sample on $61.3\% \pm 5.0$ of trials, which did not differ [$t_{27} = 0.34, p = 0.74$].

Experiment 6b: Do cooking skills generalize to other foods?

Subjects

One chimpanzee participated in a pilot version of the task and was excluded.

Coding and data analyses

All sessions were videotaped and coded live. The coding categories were the same as those from Experiment 4, measuring whether chimpanzees ate the presented food or placed some or all of it in the cooking device or the control device. We compared live and video coding for all trials. Reliability was high for whether subjects put a piece of food in the cooking-device or the control device [Cohen's Kappa = 1.0 in both cases], and whether they put an intact piece into the cooking-device [Cohen's Kappa = 0.93 for the cooking-device and perfect agreement for the control device]. Due to experimenter error, there were 2 missing trials in the total of 216 trials (both with cooked potato items). We thus used mean rate of trials as dependent measure.

Supplementary results

For all three types of food, if chimpanzees chose to put it into a device rather than eating it, they reliably chose the cooking-device over the control device (see Table S2). Furthermore, when we

counted only instances in which chimpanzees put an intact piece of food into the devices, we obtained the same pattern of results as those counting pieces of any size (as reported in the main text). Specifically, chimpanzees put an intact piece of raw potato in the cooking device on $63.9\% \pm 11.4$ of trials. In contrast, they placed whole pieces of cooked potato into the cooking device on only $13.9\% \pm 6.4$ of trials. Finally, chimpanzees placed an intact piece of raw carrots in the cooking device in $34.7\% \pm 9.1$ of trials.

	<i>N</i>	<i>M</i>	<i>SE</i>	<i>t</i>	<i>df</i>	<i>p</i> (2-tailed)
Raw carrot	12	87.5	8.9	4.2	11	< .01
Raw potato	12	88.3	5.4	7.2	11	< .0001
Cooked potato	7	95.2	4.8	10.7	6	< .0001

Table S2: Performance in Experiment 6b. Mean percentages of placements into cooking device. T-tests against 50% chance (Note that five chimpanzees always ate the cooked potato (thus $n = 7$ for testing against chance).

Experiment 7: Do chimpanzees selectively cook edible items?

Coding and data analyses

All sessions were videotaped and coded live. The coding categories were whether chimpanzees ate the food or placed some or all of it in the cooking device. We compared live and video coding for all trials. Reliability was high for all coding categories, with perfect agreement on whether subjects put any of the raw potato in the cooking-device [Cohen's Kappa = 1.0], whether they put an intact piece into the cooking-device [Cohen's Kappa = .91] and whether they put the piece of wood into the cooking-device [Cohen's Kappa = 1.0].

Supplementary results

As in the previous studies, we also examined chimpanzees placed whole, intact pieces into the cooking device (in addition to the main analyses of whether they put any piece into the device). The same result was obtained when including only whole pieces potato: chimpanzees placed whole slices into the cooking device on $66.0\% \pm 11.1$ of trials, more often than they placed the wood chip in the device [$t_{11} = 3.67$, $p < 0.005$].

Experiment 8: Will chimpanzees transport food to cook it?

Procedure and counterbalancing

Chimpanzees participated in the Near Condition and Far Condition (see Fig. S6) across two sessions. In each session, chimpanzees alternated between blocks of 4 trials in the *Near condition* and blocks of 4 trials in the *Far condition*. Half of the subjects started with the *Near condition* in the first session and the *Far condition* in the second session, and vice versa for the other half of subjects. We counterbalanced whether the cooking device or the control device was demonstrated first, using an ABBA design. The side assignment of the two devices was constant within a block and counterbalanced across blocks.

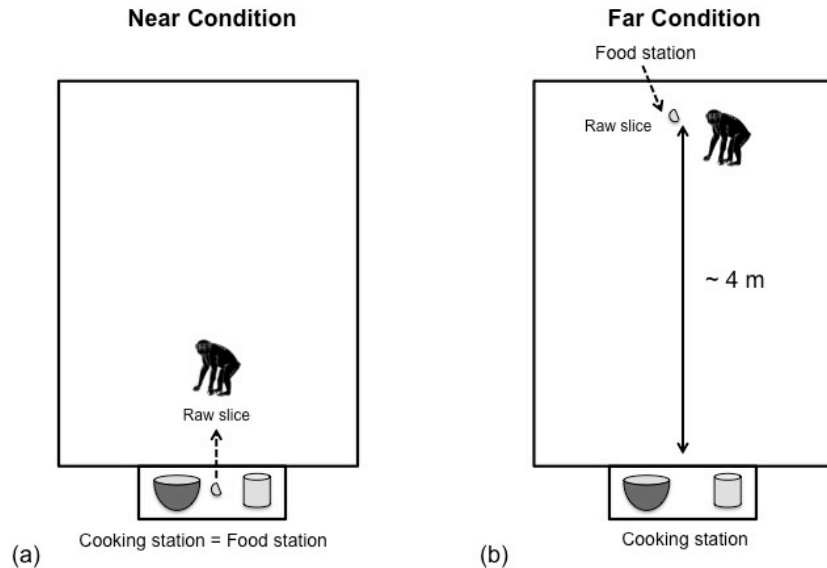


Fig. S6. Setup for Experiment 8 (Far condition). (a) In the *Near Condition*, subjects received three slices of raw food at the table with the devices. (b) In the *Far Condition*, subjects received raw potato slice at the food station, and had to transport them to the cooking station on the other side of the room.

Data coding and analyses

All sessions were videotaped and coded live. The coding categories were the same as those from Experiment 4, measuring whether chimpanzees ate the presented food or placed some or all of it in the cooking device or the control device. We compared live and video coding for all trials. There were 5 trials (out of a total of 832) in which live coding was ambiguous and thus coded from video instead. For the remaining trials, reliability between live and video coding was high for all coding categories, with no disagreement on whether or not subjects put a piece of food in the cooking-device or the control device, respectively (Cohen's Kappa = 1.0 in either case), and whether they put an intact piece into the cooking-device (Cohen's Kappa = .91). We used live coding for statistical analyses.

Supplementary analyses

The same condition effects were obtained when we analyzed how many whole pieces chimpanzees put into one of the devices. In the near condition, chimpanzees put a whole piece into the cooking device in on average $65.6\% \pm 9.2\%$ of trials as compared to $48.6 \pm 10.1\%$ in the far condition. They placed whole pieces into the control device in the near condition in $4.1\% \pm 3.3\%$ of trials and in $5.5\% \pm 2.4$ in the far condition. An analysis of variance showed a main effect of Distance [$F_{1,12} = 6.23$, $p < 0.05$, $\eta_p^2 = 0.34$], a main effect of Device [$F_{1,12} = 25.06$, $p < 0.001$, $\eta_p^2 = 0.68$], and an interaction of Distance and Device [$F_{1,12} = 6.72$, $p < 0.05$, $\eta_p^2 = 0.36$].

Experiment 9: Will chimpanzees save their food for future cooking?

Procedure

This study used the same basis setup as in Experiment 8. In the Anticipation Condition, E1 arrived with the devices three minutes after the chimpanzee received raw food (see Fig. S7).

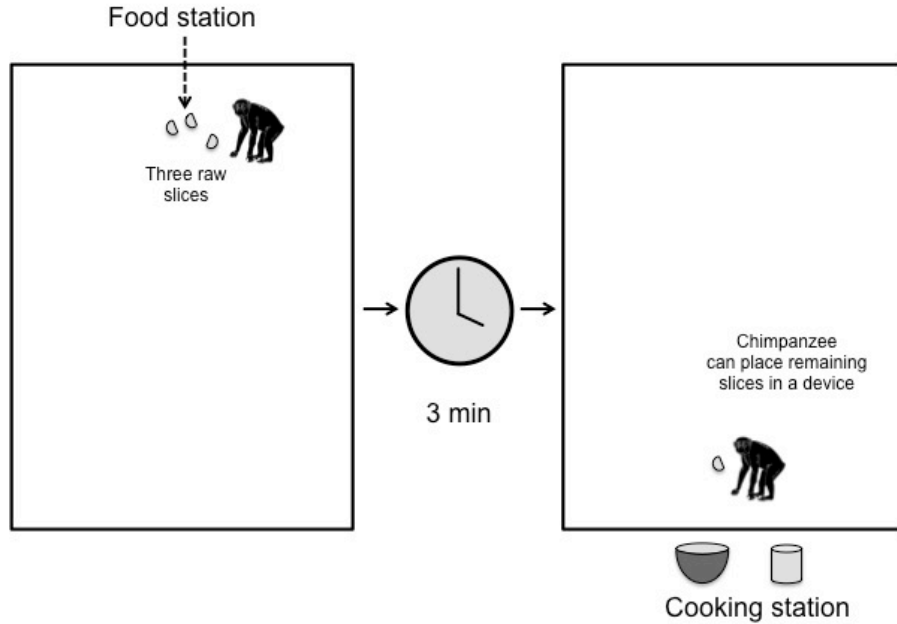


Fig. S7: Setup in Experiment 9. In the *Anticipation condition*, subjects first received three slices of food. After 3 min, the main experimenter appeared with the cooking device and control device on the other side of the room. In the *Control Condition* (not pictured), apes received food in the same location and temporal schedule, but the main experimenter never appeared with the devices.

Data coding

As in Experiment 4, we coded the number of slices that were put in the cooking device or the control device. At end of session, we recorded the number of raw potato pieces and slivers in the testing room and in front of the wire mesh (if any). Our main analyses assessed whether chimpanzees saved substantial pieces of food across conditions. Substantial pieces were defined as pieces that were at least half the size of the original intact piece they had received. This measure was conservative in that we did not include cooking of small potato pieces as successes, as there were often small pieces of food left in the room after chimpanzees consumes their food (given that in this study chimpanzees received larger quantities of food each trial).

All sessions were coded live and from video. We used video coding for final analyses. All videos were coded blind to hypotheses and a second coder independently coded all trials to assess reliability. There were no disagreements between coders on whether subjects put a piece of food in the cooking-device or the control device (Cohen's Kappa = 1.0). Because chimpanzees had been given 3 slices in a given trial, they could put multiple pieces of food into the cooking-device or the control device in a given trial. We thus used the number of slices per trial as dependent measure and used Cohen's Weighted Kappa (quadratic) to assess inter-rater reliability. Reliability was high in both cases, with Cohen's Weighted Kappa = .99 and .98 for the number of pieces put into the cooking-device or control device respectively. Reliability was similarly high when we measured the number of whole pieces put in the cooking-device (Cohen's Weighted Kappa = .97) or the control device (Cohen's Weighted Kappa = 1.0).