

1 **FRONT MATTER**

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4 **Title:** Neuronal mechanism of the encoding of socially familiar faces in the striatum tail  
5 **Short title:** Encoding of familiar faces in the striatum tail

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32 **Abstract**

33 Although we can quickly locate a familiar person even in a crowd, the underlying  
34 neuronal mechanism remains unclear. Recently, we found that the striatum tail (STRt),  
35 which is part of the basal ganglia, is sensitive to long-term reward history. Here, we show  
36 that long-term value-coding neurons are involved in the detection of socially familiar  
37 faces. Many STRt neurons respond to facial images, especially to those of socially familiar  
38 persons. Additionally, we found that these face-responsive neurons also encode the  
39 stable values of many objects based on long-term reward experiences. Interestingly, the  
40 strength of neuronal modulation of social familiarity bias (familiar or unfamiliar) and  
41 object value bias (high-valued or low-valued) were positively correlated. These results  
42 suggest that both social familiarity and stable object-value information are mediated by a  
43 common neuronal mechanism. This mechanism may contribute to the rapid detection of  
44 familiar faces in real-world contexts.

45  
46 **Teaser**

47 The common mechanism mediating social familiarity and stable object-value information  
48 may contribute to rapid detection of familiar faces.  
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## 51 MAIN TEXT

### 52 53 Introduction

54 We can quickly find familiar people in a crowd. This search skill is critical, particularly for  
55 social animals, including humans. However, the underlying neuronal mechanism remains  
56 unclear. Facial information is one of the most important cues for identifying a person (1).  
57 Studies have suggested that there is a hierarchical organization of face processing along  
58 the posteroanterior axis of the temporal cortex in macaques (2, 3). The posterior area  
59 represents particular facial features (i.e., eye, nose, and lips), the middle area represents  
60 whole faces, and the anterior area represents identical faces, regardless of face  
61 orientation. In this manner, the face processing systems for identifying individuals have  
62 recently become clearer. However, most studies on face recognition systems have used  
63 unfamiliar faces. Therefore, it remains unclear how facial information is combined with  
64 social information (e.g., social familiarity) to identify individuals based on personal  
65 relationships.

66 Recently, our group reported that neurons in the striatum tail (STRt), including the  
67 caudate tail (CDt) and putamen tail, show different responses to fractal objects based on  
68 their associations with different reward sizes (4, 5). Interestingly, visual responses rarely  
69 changed across blocks in a reversal learning task; instead, visual responses gradually  
70 changed across days when each object was continuously associated with a fixed reward  
71 size (4-8). Macaque monkeys can learn the value of more than 500 objects and retain  
72 their value memories for more than 100 days (6). Monkeys can quickly distinguish high-  
73 valued objects among many objects and tend to look at high-valued objects or  
74 automatically avoid low-valued objects (9, 10). This automatic behavior is impaired by  
75 CDt inactivation (7). These results indicate that the STRt is involved in the rapid detection  
76 of valued objects based on long-term memory. Because the STRt receives dense inputs  
77 from the temporal cortex (TE and TEO), including from facial areas (11-14), it may also be  
78 involved in face detection. Previous studies have reported that patients in the early stage  
79 of Huntington's disease, whose brains have distinct neuronal loss and gliosis in the CDt  
80 (15), showed deficits in face recognition and discrimination (16).

81 These results raise several questions. Does the STRt encode facial information? If so,  
82 does this represent a face's social familiarity? Do the same neurons encode social  
83 familiarity and object values? We addressed these questions in the present study.

### 84 85 86 Results

87 This study aimed to examine whether the STRt shows face selectivity and encodes both  
88 facial social familiarity and object value. For this purpose, we tested neuronal responses  
89 to facial images under two conditions: social familiarity and object value. In the social-  
90 familiarity condition, we used 12 images that included three categories: a) facial images  
91 of socially familiar persons who took daily care of the subject monkeys for more than 1  
92 year [social familiarity (+)], b) facial images of socially unfamiliar persons [social  
93 familiarity (-)], and c) fractal objects associated with no reward as control (Fig. 1A). Eight  
94 fractal objects were used in the object-value condition (Fig. 1B). The monkeys learned  
95 the values of these objects using a previously employed stable object-value task (Fig.

96 S1A, (4-7, 9, 17). In each trial of the stable object-value task (Fig. S1C), one fractal object  
97 was randomly selected from a set of eight objects and presented as the target. The  
98 monkey made a saccade to the target followed by reward delivery. Each object was  
99 associated with a fixed amount of reward (small or large) across trials and sessions. Four  
100 of the eight objects were always associated with a large reward [high-valued objects,  
101 object value (+)], and the other four objects were always associated with a small reward  
102 [low-valued objects, object value (-)]. We then examined the monkey's eye movements  
103 with a free-viewing task (Fig. 1C, left) from a few days to a few months after the stable  
104 object-value learning took place (Fig. S1B). In this task, four objects were randomly  
105 selected from a set of eight and presented simultaneously. The monkeys were then  
106 allowed to look at them for 2 s. A fixed amount of reward was delivered independent of  
107 the looking behavior or presented objects. Therefore, looking bias would reflect the long-  
108 term object-value memories. Figure 1C right panel illustrates the first saccade bias in the  
109 free-viewing task after several learning sessions (> five sessions). The monkeys mostly  
110 made first saccades to value (+) objects and avoided value (-) objects ( $p = 4.82 \times 10^{-10}$ ,  
111 unpaired t-test). These results suggest that the monkeys had learned and retained stable  
112 object values and thereby found value (+) objects automatically.

113 We tested whether STRt neurons responded to facial and fractal images using a passive-  
114 viewing task (Fig. 1A). In this task, each object was presented at the neuron's receptive  
115 field while the monkey was fixating on the center. The object was randomly selected  
116 from 12 (in the social-familiarity condition) or eight images (in the stable object-value  
117 condition, Fig. 1B). A fixed amount of reward was delivered after 2–4 sequential  
118 presentations. In this manner, neuronal responses would reflect long-term object-value  
119 memories rather than predicted rewards. We recorded the activity of putative medium  
120 spiny neurons during the passive-viewing task (22 from monkey W, 27 from monkey S,  
121 and 19 from monkey Z). Figure 2A shows the activity of a representative neuron in the  
122 STRt that responded to the facial images. The neuron showed a stronger response to the  
123 social familiarity (+) faces (top) than to the social familiarity (-) faces (middle;  $p < 0.05$ ,  
124 Fisher's test), although the responses to the social familiarity (+) faces varied. This  
125 neuron also showed a stronger response to the value (+) objects than to the value (-)  
126 objects (Fig. 2B,  $p = 0.01$ , Wilcoxon rank-sum test). Responses to valued objects also  
127 widely varied. These results are consistent with those of our previous studies, which  
128 showed that STRt neurons encode stable object values but are sensitive to particular  
129 objects (5, 18). The neuron with low visual selectivity also showed strong responses to  
130 the socially familiar faces and high-value objects ( $p < 0.05$ ,  $p = 6.94 \times 10^{-4}$ ; Fig. S2).

131 First, we analyzed the responses during the social-familiarity condition to examine the  
132 property of facial responses of STRt neurons. Among 68 recorded neurons, 52 (75%)  
133 showed a significant visual response (Fig. 3A,  $p < 0.05$  with Bonferroni correction, paired  
134 t-test). Fifty percent of neurons responded to the facial images (face-responsive  
135 neurons). We quantified the strength of social-familiarity coding for each neuron  
136 (modulation index, see Methods) and showed their distributions among all face-  
137 responsive neurons (Fig. 3B). The index was often away from 0.5, indicating that many  
138 neurons encoded social familiarity for facial images. A receiver operating characteristic  
139 (ROC) area of  $> 0.5$  indicated that the neurons showed a stronger response to social  
140 familiarity (+) faces than to social familiarity (-) faces. In all, STRt neurons discriminated  
141 the socially familiar faces from the socially unfamiliar faces ( $p = 0.0051$ , unpaired t-test).

142 Our previous study revealed that there are two groups of neurons in the STRt: a)  
143 positive-value coding and b) negative-value coding neurons (4, 5, 7). Accordingly, we  
144 analyzed the time course of population activity of these face-responsive neurons  
145 according to each face-coding type (positive or negative) (Fig. 3C). Social-familiarity  
146 coding started approximately 50 ms after the appearance of the image in both groups.  
147 These results suggested that STRt neurons quickly detect socially familiar persons. To  
148 examine whether these neurons also encode stable object values, we analyzed the  
149 activity of 33 face-responsive neurons in the STRt during the passive-viewing task with  
150 long-term reward-associated objects. Figure 3D shows the population activity of negative  
151 and positive-value coding neurons (the neuron types were defined by the response to  
152 socially familiar and unfamiliar faces). The value modulation index of individual STRt  
153 neurons was biased toward 1.0 ( $p = 0.023$ , unpaired t-test), which would indicate the  
154 absolute preference for positive value objects. Interestingly, the detection of social  
155 familiarity preceded that of stable object value in both coding types.

156 From the above, we demonstrated the encoding of two types of information in STRt  
157 neurons: a) social familiarity, b) object value. We then asked whether these signals are  
158 encoded by different or the same neurons in the STRt. Figure 4 shows that the strengths  
159 of social familiarity bias and object value bias were significantly correlated (Pearson's  $r =$   
160  $0.41$ ,  $p = 0.02$ ). These results indicate that social information and value information are  
161 co-encoded in the STRt and that these signals are mediated by the same neuronal  
162 mechanism.

## 163 Discussion

164 Although the basal ganglia play a key role in reward value-guided behavior based on  
165 experience (19), it is less clear whether they are involved in social behavior. This was the  
166 first study to report neuronal signals in the basal ganglia in relation to face recognition.  
167 We first found that many STRt neurons responded to facial images (Fig. 2). The response  
168 to socially familiar faces was stronger than that to socially unfamiliar faces (Fig. 3). Then,  
169 we compared the response to objects based on long-term memory with the response to  
170 faces based on social familiarity. The modulations of social familiarity and stable object  
171 value were positively correlated (Fig. 4). Our results suggest that the posterior basal  
172 ganglia circuit co-encodes social familiarity and stable object value.  
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174 Research on human face perception is a major neuroscience topic. Multiple face-  
175 responsive areas have been found in the primate temporal cortex (2, 3).  
176 Microstimulation of face-selective sites in the inferior temporal cortex (IT) around the  
177 image presentation period biased monkey decision toward faces during a face  
178 categorization task (20). These findings suggest that the temporal cortex plays a key role  
179 in face identification. Furthermore, the TE and temporal pole show strong responses to  
180 personally familiar faces (21-23). These studies raise the question on which neuronal  
181 circuit encodes socially familiar faces? In this study, we observed that neurons in the  
182 STRt, which is robustly connected to the TE, showed face selectivity (Fig. 2, (11, 12, 24,  
183 25)). The basal ganglia encode object values based on gradual change in synaptic weight,  
184 which is modulated by the reward signal of dopamine (26-28). Especially, our previous  
185 studies suggested that short-term and long-term value memories are mediated by the  
186 anterior and posterior parts of the basal ganglia circuit, respectively (29). It is possible

187 that the basal ganglia circuit for social familiarity is similar to the circuit for stable object  
188 value because the subjects recognized persons based on emotional and reward  
189 experiences, social familiarity is based on long-term experience and long-term value  
190 memory, and the same STRt neurons are involved in both processes. Indeed, we found a  
191 positive correlation between social familiarity and stable object value modulations (Fig.  
192 4).

193 Humans can detect familiar faces more quickly and accurately than unfamiliar ones (30,  
194 31). Our recent studies showed that the visual responses in STRt neurons lead to quick  
195 detection of high-value objects (7). STRt responses to high-valued objects are  
196 accomplished with high object selectivity (5, 18). Similar high object selectivity was also  
197 found in the STRt response to facial images (Fig. 2). This may be based on numerous  
198 inputs from many neurons in the temporal cortex to single STRt neurons. Moreover, in  
199 the STRt, neurons are divided into two groups: positive neurons strongly responsive to  
200 value (+) objects and social familiarity (+) faces and negative neurons strongly responsive  
201 to value (-) objects and social familiarity (-) faces (Fig. 3). Previous studies have suggested  
202 that these preferences are related to the neuronal process of oculomotor control. The  
203 STRt projects to two local regions in the basal ganglia [caudal–dorsal–lateral part of the  
204 substantia nigra pars reticulata (cdISNr) and caudal–ventral part of the globus pallidus  
205 externus (cvGPe); (8, 10)]. The inhibitory connection to the cdISNr, which acts as the  
206 direct pathway, conveys the high-valued object-dominant signal and inhibits cdISNr  
207 neurons, leading to the disinhibition of neurons in the superior colliculus (SC) to facilitate  
208 saccades toward high-valued objects (32, 33). The inhibitory connection to the cvGPe,  
209 which acts as the indirect pathway, conveys the low-valued object-dominant signal and  
210 inhibits cvGPe neurons (8). As cvGPe neurons have inhibitory connections to cdISNr  
211 neurons (34–36), the output of the CDt disinhibits cdISNr neurons, leading to enhanced  
212 inhibition of SC neurons to suppress saccades toward low-valued objects (8, 33). The  
213 same mechanism may be underlying the facilitation and suppression of saccades toward  
214 facial images.

215 In this study, we used human facial images to test the neuronal representation of social  
216 familiarity in monkeys because, in the laboratory, human–monkey interaction is  
217 relatively simpler and clearer than monkey–monkey interaction. Close interaction  
218 between species is commonly encountered between owners and companion animals.  
219 Our results comprise evidence regarding the neuronal mechanism of these interactions.  
220 It is unclear whether the monkeys behaviorally distinguished the socially familiar facial  
221 images from the unfamiliar ones used in the present study (Fig. 1). In real-world settings,  
222 person identification relies both on facial and on physical-characteristic, voice, and odor  
223 cues. Therefore, grayscale facial images may not contain sufficient information to  
224 identify individuals. However, a previous study reported that it is possible to identify a  
225 familiar face from a poor-quality image (37). Monkeys may be able to distinguish facial  
226 images of familiar versus unfamiliar persons without clearly identifying these persons.

227 Previous studies have reported that patients in the early stage of Huntington's disease,  
228 who have degeneration of CDt neurons (15), show deficits in face recognition and  
229 discrimination (16). These reports are consistent with our findings in that the STRt  
230 is involved in face representation. In contrast, patients with Parkinson's disease, which is  
231 caused by dopamine deficits, have normal face-detection abilities despite having

232 impaired facial-emotion recognition ability (38). The loss of dopamine typically leads to  
233 dysfunction of the anterior part of the striatum, including the nucleus accumbens (39,  
234 40). Notably, people with autism, who have impaired social communication abilities,  
235 show no deficits in the recognition of familiar faces (41). This report supports our  
236 conclusions that the same mechanism is responsible for the encoding of socially familiar  
237 faces and stable object values in the STRt, independent of the circuit of social behavior.

## 238 **Materials and Methods**

### 239 **Animal Model**

241 Three adult male rhesus monkeys (*Macaca mulatta*, 8–11 kg, 6–8 years old) were used  
242 for all experiments. All procedures for animal care and experimentation were approved  
243 by the Animal Care and Use Committee of the National Eye Institute (Bethesda, USA) and  
244 complied with the Public Health Service Policy on the humane care and use of laboratory  
245 animals.

### 246 **General Procedures**

247 We implanted a plastic head holder, eye coil, and plastic recording chamber under  
248 general anesthesia and sterile surgical conditions. After the monkeys fully recovered  
249 from surgery, we started training them in the oculomotor tasks. Several procedures,  
250 including the surgery, behavioral task, and statistical analysis, were identical between  
251 this and our previous studies (5, 42) .

### 252 **Behavioral Procedure**

253 The behavioral procedure was controlled by a C++ based real-time experimentation data  
254 acquisition system (Blip: available at <http://www.robilis.com/blip/>). The monkey sat in a  
255 primate chair, facing a frontoparallel screen in a sound-attenuated and electrically  
256 shielded room. Visual stimuli generated by an active matrix liquid crystal display  
257 projector (PJ550, ViewSonic) were rear projected on the screen. Facial images ( $10^\circ \times 10^\circ$ )  
258 were provided by a member of the laboratory. Four persons [experimenters and animal  
259 caretakers, social familiarity (+)] were involved in monkey daily care and were familiar  
260 with each monkey. The other four persons [social familiarity (-)] had not met the  
261 subjects. We created the fractal objects ( $\square 10^\circ \times 10^\circ$ ) using fractal geometry (18).

### 262 **Passive-Viewing Task (Social-Familiarity Coding Test)**

263 The purpose of this task was to examine the response property of the striatal neurons to  
264 facial images. We used grayscale images of faces (socially familiar and unfamiliar  
265 persons' faces) and of fractal objects (no value association) to test the neuronal response  
266 to facial images (Figure 1A). In this task, two to four facial images (facial images or fractal  
267 objects) were sequentially presented in the receptive field (presentation time, 400 ms;  
268 interval, 400 ms) while the monkey fixated on a central white dot (Figure 1D). A fixed  
269 liquid reward (0.2 ml) was delivered 300 ms after the last presentation. The reward was  
270 thus not contingently associated with any facial image. Each image was presented at  
271 least seven times in each session.

## 272 **Stable Object Value Task**

273 We used the stable object value procedure to examine the long-term effect of object  
274 value learning (5, 6). Eight fractal objects were divided into four high-valued objects  
275 [object value (+)] associated with a large reward (0.3 ml) and four low-valued ones  
276 [object value (-)] associated with a small reward (0.1 ml) (Figure 1B). The monkey learned  
277 each object value by making a saccade to each object followed by large or small reward  
278 delivery (Figure S1C). One learning session consisted of 80 trials. The monkey was trained  
279 for each set of objects with one learning session each day. The same sets of objects were  
280 repeatedly used across at least five learning sessions.

## 281 **Free-Viewing Task**

282 The free-viewing task was used as a behavioral test to examine monkey preference for  
283 value (+) or value (-) objects (5, 6). After the monkey fixated on a central white dot for  
284 300 ms, four objects were simultaneously presented in four symmetric positions (15°  
285 from center) (Figure 1C). The four objects were pseudo-randomly selected from eight  
286 objects used in the stable object value task. The monkey was free to look at the objects  
287 for 2 s without a reward outcome. After a blank period (500 ms), another white dot was  
288 presented at one of eight positions. When the monkey made a saccade to it, a fixed  
289 reward was delivered (0.2 ml). Each object was presented at least 10 times in each  
290 session.

## 291 **Passive-Viewing Task (Stable Object Value-Coding Test)**

292 Once the monkey showed significant behavioral preference for value (+) objects in the  
293 free-viewing task, we tested neuronal responses to the objects with the passive-viewing  
294 task (5, 6). This was the same as the passive-viewing task for the social-familiarity coding  
295 test except for the presented images. Two to four objects used in the stable object value  
296 task were sequentially presented in the receptive field while the monkey fixated on a  
297 central white dot. A fixed liquid reward (0.2 ml) was delivered after the last presentation.  
298 Therefore, each object was no longer associated with a large or small reward in this task.  
299 We usually used two to three sets of well learned objects.

300 The behavioral test (free-viewing task) and the neuronal test (passive-viewing task) were  
301 conducted on different days. To remind the monkey of the object value memory, we  
302 conducted the stable value task at least once per 60 days after the initial learning.

## 303 **Recording Procedure**

304 Based on a stereotaxic atlas, a recording chamber was placed over the parietal cortex,  
305 tilted laterally by 25° (monkey W and Z) or 0° (monkey S) and aimed at the STRt.  
306 Magnetic resonance images (4.7 T; Bruker) were then obtained along the direction of the  
307 recording chamber, which was visualized by filling a recording grid with gadolinium.

308 For single-neuron recording, a tungsten electrode (Alpha Omega Engineering or FHC) was  
309 lowered into the striatum through a guide tube using a micromanipulator (MO-97S;  
310 Narishige). The recording site was determined using a grid system, which allowed



311 electrode penetrations at every 1 mm. We amplified and filtered (0.3–10 kHz; Model  
312 1800, A-M Systems; Model MDA-4I, BAK) the signals obtained from the electrodes and  
313 collected at 1 kHz. Single neurons were isolated online using custom voltage–time  
314 window discriminator software (Blip).

### 315 **Statistical Analysis**

316 We defined the putamen tail as the region 0–3.5 mm from the ventral edge of the  
317 putamen and the cdPUT as the region above it (Kunimatsu et al., 2019; Kunimatsu et al.,  
318 2021). Because the putamen tail and CDt share the same anatomical pathway (10, 12)  
319 and showed similar long-term value coding in a previous study (5), we combined neurons  
320 in these areas as STRt neurons. The offline analyses were performed using Matlab  
321 (MathWorks). We defined visual neurons as neurons showing a significant difference in  
322 activity between the baseline period (400 ms before object onset) and visual period (50–  
323 350 ms after object onset; paired t test,  $p < 0.05$  with Bonferroni correction). We  
324 considered “face-responsive” and “object-responsive” neurons showing a significant  
325 response to the faces and fractal objects, respectively. The time course of neuronal  
326 activity for each condition is shown after smoothing with a Gaussian kernel ( $\sigma = 15$  ms).  
327 We only used the data in correct trials for the behavioral and neuronal analyses.

328 To examine neuronal discrimination, we measured the magnitude of the response to  
329 each visual stimulus by counting the numbers of spikes fired (on single trials) within a  
330 test window (50–350 ms after visual stimulus onset). A value modulation index was  
331 defined as the area under the ROC curve based on the response magnitude of the neuron  
332 to facial images [social familiarity (+) vs. (-)] or fractal objects [object value (+) vs. (-)].

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442 Study design: J.K. and O.H.

443 Experiments: J.K and H.A.

444 Data analysis: J.K.

445 Writing: all authors

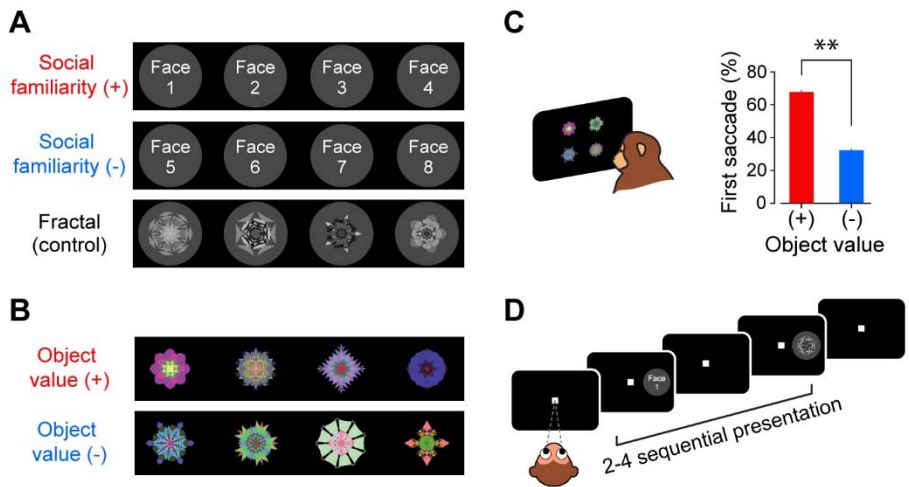
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447 **Competing interests:** Authors declare that they have no competing interests.

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**Data and materials availability:** The data that support the findings of this study are available from the corresponding author upon reasonable request.



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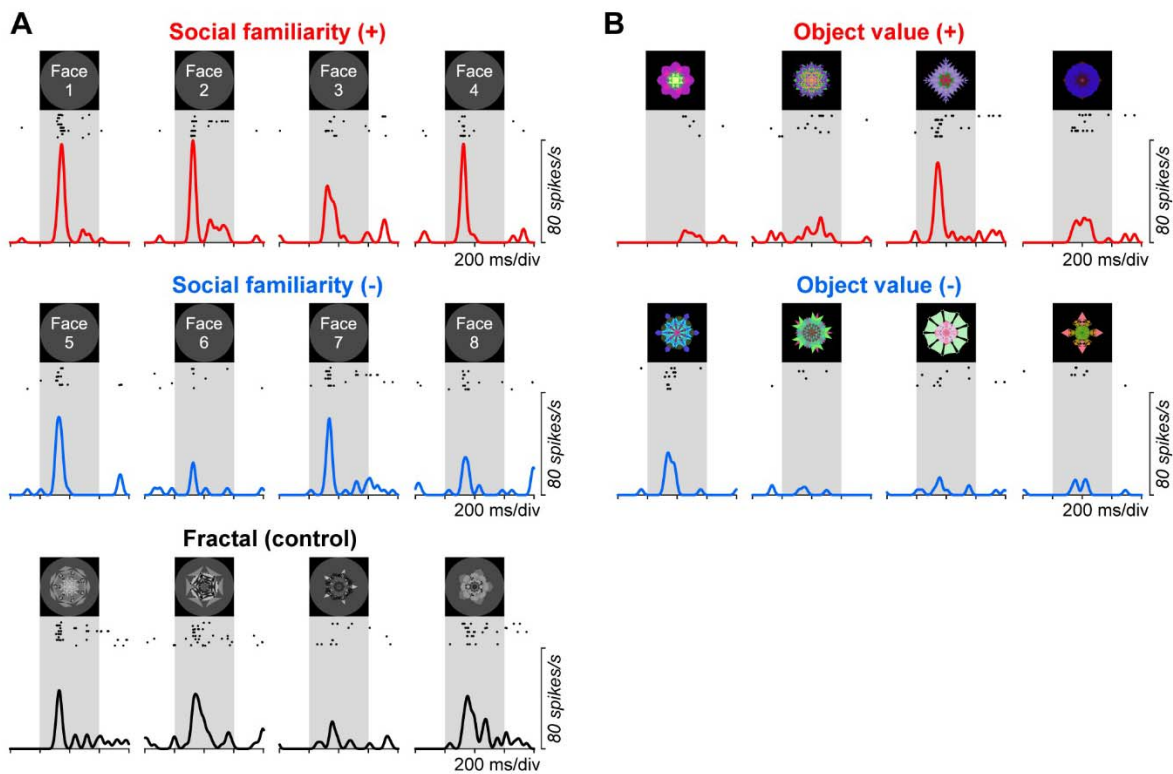
**Fig. 1. Behavioral and neuronal tests for social familiarity and stable object value.**

(A) In the social-familiarity condition, facial images were divided into the following three categories: (1) socially familiar persons' faces [social familiarity (+), top], (2) socially unfamiliar persons' faces [socially familiarity (-), middle], and (3) fractal objects associated with no reward (bottom). Face photographs were omitted.

(B) In the stable object-value condition, facial images were divided into the following two groups: (1) fractal objects consistently associated with a large reward [object value (+), top] and (2) fractal objects consistently associated with a small reward [object value (-), bottom].

(C) During the free-viewing task, four fractal objects were simultaneously presented (left). The monkeys were free to look at these objects for 2 s without feedback. The first saccade to value (+) or value (-) objects in 94 sessions of the free-viewing task (right; mean  $\pm$  SEM; three monkeys).

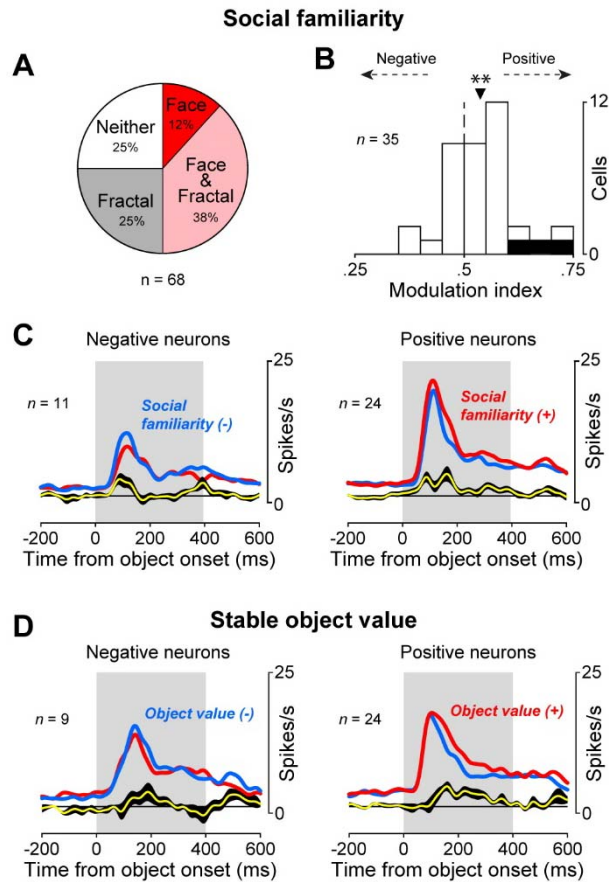
(D) In both the social-familiarity and stable object-value conditions, facial images were sequentially presented in the neuron's receptive field as the monkey was fixating on the center (passive-viewing task).



470 **Fig. 2. A representative face-responsive neuron in the striatum tail.**

471 (A) Neuronal response to the socially familiar (+) faces (top), socially familiar (-) faces (middle),  
 472 and fractal objects (bottom) in the passive-viewing task. Face photographs were omitted.

473 (B) Neuronal response to the value (+) objects (top) and value (-) objects (bottom). Same  
 474 neuron as (A).  
 475



**Fig. 3. Face-responsive neurons encode social familiarity.**

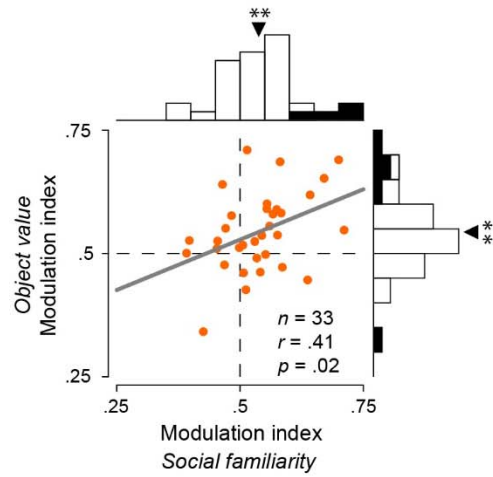
(A) Proportions of visual neurons in the striatum tail categorized by the passive-viewing task.

(B) Social familiarity modulation index of individual face responsive neurons in the striatum tail during the passive-viewing task. Filled bars indicate the neurons significantly modulated by social familiarity ( $p < 0.05$ , Fisher's exact test). A value modulation index score of 1.0 signifies that the neuronal response to familiar faces is always stronger than that to unfamiliar faces; 0.0 signifies the opposite response pattern. The triangle indicates the population average of the modulation index. Asterisks indicate a significant difference from 0.5 (\*\* $P < 0.01$ , paired t-test).

(C) Population neuronal activity in the social-familiarity condition; negative social-familiarity coding neurons (negative neurons, left) and positive social-familiarity coding neurons (positive neurons, right). Red and blue lines indicate the averaged neuronal responses to socially familiar faces and unfamiliar faces, respectively. The yellow line indicates the difference in response to the socially familiar faces and unfamiliar faces (mean  $\pm$  SEM).

(D) Population neuronal activity in the stable object-value condition; negative-value coding neurons (negative neurons, left) and positive-value coding neurons (positive neurons, right). Red and blue lines indicate the averaged neuronal responses to value (+) and (-) objects, respectively. The yellow line indicates the difference in response to value (+) and (-) objects (mean  $\pm$  standard error of the mean).

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**Fig. 4. Correlation between social familiarity and stable object value.**

The correlation between modulation indices of social familiarity and stable object value. Numbers indicate Pearson's correlation coefficient and P value. Note that the strength of object-value coding is significantly correlated with that of social-familiarity coding.

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