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1 Visitor effects on zoo-housed Sulawesi crested macaque (*Macaca nigra*)  
2 behaviour: can signs with 'watching eyes' requesting quietness help?

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## 21 Abstract

22 Visiting public can cause changes in the behaviour of zoo-housed primates. These effects, if  
23 indicative of stress, can be of welfare concern. However, few options to mitigate visitor effects through  
24 modulating visitor behaviour have been explored. Here we evaluated the effects of visitor number and  
25 visitor noise level on the behaviour of five UK groups of Sulawesi crested macaques. We also  
26 investigated whether visitor behaviour can be effectively modulated through targeted signage  
27 requesting visitors to be quiet, and assessed the use of signs incorporating salient 'watching' human  
28 eyes, novel to a zoo setting, alongside 'control' signs lacking eyes.

29 We used scan sampling to collect over 100 h of behavioural observation data, analysis of  
30 which indicated that Sulawesi crested macaques were significantly affected by both visitor number  
31 and noise level at all five zoos. We found that active behaviours, such as locomotion or foraging, and  
32 behaviours identified as negative for welfare, such as vigilance, increased with increasing visitor  
33 number and noise levels, whereas resting and social huddling decreased. The extent to which these  
34 behavioural changes reflect welfare, particularly the increase seen in active behaviours, is not clear.  
35 We also found that both sign treatments, with and without salient eyes, slightly but significantly  
36 reduced visitor noise levels compared with no sign, although signs displaying human eyes were not  
37 more effective than the control signs.

38 Our results highlight a need for further research into active behaviours to assess whether  
39 increases in these behaviours are associated with stress. While we found signage to be a promising  
40 tool to mitigate against these visitor effects, our results also suggest areas in which signs  
41 incorporating salient human eyes could be adapted for the zoo environment in order to realise their  
42 full potential.

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44 Keywords: Primates, Animal behaviour, Animal welfare, Visitor effects, Noise effects, Zoo animals

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## 47 Highlights

- 48 • Activity and vigilance in *Macaca nigra* increased with visitor numbers at five zoos
- 49 • Louder visitor noise also increased activity and vigilance in *Macaca nigra*
- 50 • Signs requesting visitors to be quiet slightly but significantly reduced noise
- 51 • Signs with 'watching eyes' appeared no more effective than control signs

## 52 Introduction

53 Education, awareness raising and fundraising, in which the visiting public play an integral role, are  
54 amongst the primary goals of many zoos. Yet the daily influx of unfamiliar visitors can cause concern  
55 for the well-being of the animals within. Indeed, the effect of visiting public on the welfare of zoo-  
56 housed primates has been of research interest for decades. Behavioural and physiological changes  
57 can occur in primates on show to visiting public (see supplement S1 for a summary of relevant  
58 literature). However, the potential impact on welfare has been in contention, with findings suggesting  
59 primate lives may be enriched (Cook and Hosey, 1995), unaffected (Hosey, 2000), or be negatively  
60 impacted (Birke, 2002). Despite these conflicting findings, a review suggested that more often than  
61 not visitors influence changes for the worse, including changes indicative of stress (Davey, 2007),  
62 although evidence of this being severe may be rare (Hosey, 2017). Behavioural change in zoo-  
63 housed primates has been observed in response to a variety of visitor-variables, including visitor  
64 density, number, noise, position, activity and presence (Hosey, 2005; Davey, 2007), and impacts on  
65 behaviour vary both between visitor-variables and between species (Davey, 2007).

66 One of the more frequently studied visitor-variables has been visitor number, which has consistently  
67 been shown to affect the behaviour of zoo-housed primates. For example, in Diana monkeys  
68 (*Cercopithecus diana*) visitor group size displayed a positive correlation with frequency of active-type  
69 behaviours, such as foraging or playing, and a negative relationship with relaxed behaviours, such as  
70 resting, sleeping or grooming (Todd et al., 2007). In male white handed gibbons (*Hylobates lar*) larger  
71 visitor group sizes resulted in increases in communicative behaviours interpreted as responses to  
72 threats, such as 'look at mate', 'look at visitors' and open mouth displays (Cooke and Schillaci, 2007).  
73 Physiological responses can also occur due to higher visitor number; for example, Davis et al. (2005)

74 recorded increased cortisol levels (a hormone used as a marker for stress, although it can reflect  
75 activity and arousal more generally) in Columbian spider monkeys (*Ateles geoffroyii rufiventri*) with  
76 increased visitor numbers.

77 Visitor noise is less frequently studied, but it has been associated with behavioural responses in  
78 primates (Hosey, 2005). When sound levels outside orang-utan (*Pongo pygmaeus*) enclosures were  
79 experimentally manipulated by verbally asking visitors to be either silent or loud, the orang-utans  
80 responded negatively to higher noise levels, with increases in adults looking at visitors, and infants  
81 holding on to adults (Birke, 2002). Furthermore, a study of the effect of noise on a range of zoo-  
82 housed mammals found that noise levels outside certain enclosures, such as western lowland gorillas  
83 (*Gorilla gorilla gorilla*) and golden-bellied capuchin monkeys (*Cebus xanthosternos*), at times  
84 exceeded 70dB (the recommended limit for human well-being (WHO, 1999)), and concluded that as a  
85 consequence these species were experiencing negative welfare (Quadros et al., 2014).

86 Zoo-housed primates may experience reduced welfare due to their inability to escape visiting public or  
87 exert control over their environment (Wells, 2005). For example, larger, more naturalistic enclosures,  
88 which afford increased refuges and distance from visiting public, could lessen visitor effects (Davey,  
89 2007), although providing larger enclosures may not always be feasible due to financial and space  
90 constraints. Alternatively, to mitigate the effect of noise level specifically, signage could be used to  
91 encourage visitors to be quieter outside enclosures. Signs have previously been effective at  
92 modulating visitor behaviour in a zoo setting. For example, three signs displaying different messages  
93 were tested to discourage visitors from banging on aquarium windows, and all three signs significantly  
94 reduced the level of banging compared to when no sign was displayed (Kratochvil and Schwammer,  
95 1997).

96  
97 An option previously untested in a zoo setting is to modulate visitor behaviour by using signage which  
98 incorporates salient human eyes as if 'watching' the reader. This method has been applied  
99 successfully in non-zoo settings to promote cooperative behaviour in people. For example, people  
100 gave more generously to a donation box when asked to via a sign showing salient eyes than via a  
101 sign showing a control image (Bateson et al., 2006). This effect is assumed to work by giving people  
102 the impression they are being watched (Bateson et al., 2006; Ernest-Jones et al., 2011).

103

104 The effect of visitor number and noise level on the behaviour of the Sulawesi crested macaque  
105 (*Macaca nigra*) is examined in the present study. Currently listed as critically endangered, they are  
106 semi-terrestrial and frugivorous, and native to north-eastern Sulawesi (Supriatna & Andayani, 2008).  
107 At the time of the present study there were approximately 167 Sulawesi crested macaques housed in  
108 21 zoos across Europe (ZIMS, 2015), and the species is part of the European Endangered species  
109 Programme. Sulawesi crested macaques have previously been part of a multi-species study into the  
110 effect of visitor activity on behaviour, but not visitor number or noise level (Hosey and Druck, 1987).  
111 Locomotion increased in all species, including Sulawesi crested macaques, in the presence of more  
112 active visitors.

113

114 The aims of this study are to provide an understanding of how visitor number and noise level affect  
115 the behaviour of Sulawesi crested macaques, and whether visitor noise can be mitigated through  
116 signs, especially those with salient eyes. If results suggest visitor numbers and noise impact  
117 negatively on the macaques then recommendations could be made for how signage could be adapted  
118 to improve welfare. This study tested two overarching hypotheses. Firstly, and based on previous  
119 findings of a range of primate species, if individuals are affected by visitors, they would carry out more  
120 active (e.g. locomotion, play, foraging, interacting with furniture, begging, mounting and social  
121 behaviour) or negative (e.g. aggression, vigilance, stereotypy, hiding) behaviours and fewer relaxed  
122 (e.g. resting, grooming, huddling) behaviours in the presence of larger groups of visitors or higher  
123 noise levels. Secondly, that visitor noise would be highest when no sign is present and lowest when a  
124 sign requesting them to be quiet and including salient eyes is present.

## 125 Methods

### 126 Sites and subjects

127 Five UK zoos, each with an on-exhibit group of Sulawesi crested macaques, participated in the study,  
128 which took place in 2015, including a pilot study at one of the zoos from 13<sup>th</sup> to 15<sup>th</sup> May 2015. The  
129 number, age and sex ratio of macaques in each zoo differed, as did the size of macaque enclosures  
130 (Table 1).

131 Prior to commencing data collection a short questionnaire was sent to the appropriate keeper at each  
 132 zoo, to record zoo-specific husbandry details. Questions included diet, feeding times, times of  
 133 restricted access to parts of enclosure, types and times of enrichment, and whether keepers had  
 134 noticed any undesirable behaviours in the macaques (e.g. self-biting, body-slaming, over-grooming  
 135 or begging to visitors), or behaviours expressed by the macaques when either stressed or relaxed.  
 136 The answers to these questions helped with ethogram design.

137 *Table 1. Dates of study and macaque details for each of the five participating zoos.*

	Zoo A	Zoo B	Zoo C	Zoo D	Zoo E
Dates of study, 2015	1 <sup>st</sup> to 6 <sup>th</sup> July	24 <sup>th</sup> to 29 <sup>th</sup> June	20 <sup>th</sup> to 25 <sup>th</sup> May	10 <sup>th</sup> to 15 <sup>th</sup> June	3 <sup>rd</sup> to 8 <sup>th</sup> June
Number of macaques	20	5	8	12	10
Male:Female	8:12	2:3	5:3	5:7	7:3
Age range of macaques	1 - 15 yrs	3 - 10 yrs	10 mths - 19 yrs	2 - 16 yrs	2 - 17 yrs

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139

140 [Behavioural Observations and Recordings of Sound Levels and Visitor Numbers](#)

141 A 3 day pilot was conducted to test the study design, ethogram and sampling method, and allowed for  
 142 necessary changes to be made. A total of 6 days (Wednesday to Monday) were then spent at each  
 143 zoo, with the same observer (AMMB) conducting all observations. The first day was spent habituating  
 144 the macaque group to the observer’s continuous presence outside the enclosure and for determining  
 145 the most suitable locations for observation. Data collection took place over five days at each zoo, with  
 146 a mixture of weekdays (Thursday, Friday and Monday) and weekend days (Saturday and Sunday)  
 147 representing a range of visitor numbers. These days were kept consistent across zoos.

148 Behavioural observations were collected using instantaneous scan sampling with 5 min intervals and  
 149 one-zero sampling. The group was scanned from left to right of the enclosure at each 5 min sample  
 150 point and the behaviour of each macaque was recorded using a pre-designed ethogram (adapted  
 151 from published ethograms, see Baker, 2012; Nickelson and Lockard, 1978; Thierry et al., 2000)

152 (Table 2). Between sample points, during sample intervals, event behaviours relevant to the study  
153 were also captured using one-zero recording. The macaques were observed for three 1h 30min  
154 sessions per day (10:00 – 11:30, 12:00 – 13:30, 14:30 – 16:00), totalling 4h 30min of observation per  
155 day, per zoo. Times when keepers fed or were otherwise interacting with the macaques were also  
156 recorded.

157 *Table 2. Ethogram of behaviours for Sulawesi crested macaques. The symbol '↘' denotes behaviour*  
158 *predicted to decrease, '↗' denotes behaviour predicted to increase with increasing visitor number or*  
159 *noise level and '?' denotes that predicted behaviour change with increasing visitor number or noise*  
160 *level is not known. The ethogram is adapted from published ethograms, see Baker, 2012; Nickelson*  
161 *and Lockard, 1978; Thierry et al., 2000.*

<b>Behaviour</b>	<b>Status/ Sampling method</b>	<b>Predicted direction</b>	<b>Description</b>
Allo-grooming	State/ Scan	↘	An individual picks through and examines the fur and skin of another individual.
Auto-grooming	State/ Scan	↘	An individual picks through and examines their own fur and skin.
Fighting	State/ Scan	↗	Aggressive behaviour towards another member of the group; chasing initiated by an individual displaying the open-mouth bared-teeth threat followed by running at another individual. This is often accompanied by the chased giving a screaming vocalisation. Fighting may include biting, hitting or one or more individuals open-mouth bared-teeth 'threat'.
Foraging & Feeding	State/ Scan	↗	Actively looking towards and picking through vegetation/ feeding devices, and consuming food items.
Hiding	State/ Scan	↗	Animal behind refuge, obscured from view of public. Not obviously carrying out other behaviours.
Interaction with furniture/ enrichment	State/ Scan	↗	Interaction with enclosure furniture (e.g. hammocks, swings) or with enrichment items in enclosure, e.g. mirrors.
Locomotion	State/ Scan	↗	Movement around enclosure. Including: walking, running, climbing, jumping and swinging, all without foraging.
Play	State/ Scan	↗	Wrestling, including play biting (gentle gnawing) and chasing resulting in either wrestling or reciprocal chasing. Usually occurs between younger individuals.
Resting	State/ Scan	↘	Individual sitting or reclining in a relaxed position, without scanning the enclosure or looking fixedly at a point or individual. May have closed or half-closed eyes.



Social huddle	State/ Scan	↘	Sitting in contact with other individuals, consisting of extensive contact of body trunk, possibly with arms around each other, either sitting or lying.
Social Interaction	State/ Scan	↗	An individual interacts with another individual which is not play, aggression or allo-grooming (e.g. touching, approaching another individual whilst looking at it or retracting scalp whilst looking at another to invite an affiliative interaction).
Vigilant	State/ Scan	↗	Individual with alert, stiff posture, visually scanning inside or outside the enclosure, or an individual (sitting or standing).
Begging	Event/ One-zero	↗	Individual approaches bars or window of enclosure and holds hand/s out to a visitor.
Body-slamming	Event/ One-zero	↗	Slams part of own body against walls of enclosure.
Mounting	Event/ One-zero	↗	An individual grips legs of another with hind feet and grasps the waist with hands. May be accompanied by a thrusting action.
Scratching	Event/ One-zero	↗	Repetitive raking of the skin or fur using fingers or feet.
Self-directed behaviour	Event/ One-zero	↗	Any self-directed behaviour which can be repetitive with no obvious function, including self-touching, body shaking and hair plucking.
Lipsmack	Event/ One-zero	?	Lips pursed and lower jaw moves up and down rapidly with the lips often producing an audible sound. Used during affiliative interactions, to end conflicts and as a signal to appease or reassure.
Open mouth bared-teeth threat	Event/ One-zero	↗	Mouth wide open, exposing teeth. Often accompanied by staring and screaming vocalisations. Occurs in agnostic contexts.
Other	State or Event	?	Any other behaviours not covered in ethogram.
Out of sight	State	?	Out of sight to the observer

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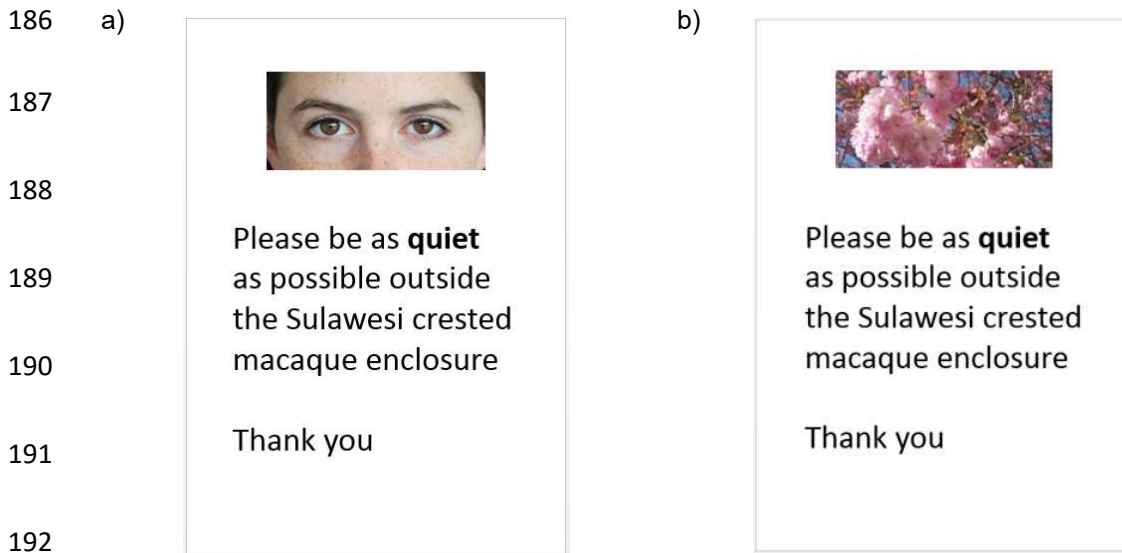
164 We were unable to recruit a second observer to allow the assessment of inter-observer reliability, so  
165 all the results reflect the standardised interpretation of a single observer. The observer was trained to  
166 masters-level in behavioural observation research techniques. To further familiarise themselves with  
167 the species the observer spent five days shadowing macaque keepers of one of the participating zoos  
168 and, during the process of ethogram design.

169 At each sample point sound level in decibels (dB) was also recorded using a sound level metre with  
170 data logger (CEM DT-815, CEM Instruments Ltd). The observer stood quietly approximately in the  
171 middle of the visitor viewing area, one metre back from the enclosure barrier. If there was both an  
172 indoor and outdoor viewing area the observer stood in the viewing area approximately in between the  
173 two. The sound level metre was held at arm's length towards the enclosure. At each sample point the  
174 number of visitors outside the enclosure (indoor and outdoor) was also recorded, excluding the  
175 observer.

## 176 Sign Treatments

177 Sign treatments were applied at four of the five zoos (Zoos B - E). Zoo A did not permit visitor  
178 manipulation due to an existing behavioural study. Two signs were designed, both with the same  
179 message "Please be as **quiet** as possible outside the Sulawesi crested macaque enclosure. Thank  
180 you". One sign displayed an image of salient human eyes, the other a control image of flowers (Fig.  
181 1).

182 The text was agreed in advance to meet zoo requirements. Zoos were permitted to apply final  
183 formatting and branding to encourage participation. Zoos C - E all agreed on the formatting shown in  
184 Figure 1; Zoo B added a border and logo to each sign. The signs were printed size A2 and displayed  
185 in an A-frame.



193 *Figure 1. The two designs of sign. (a) 'Eyes' sign: sign with image of salient human eyes; and (b) Control sign*  
194 *with image of flowers.*

195 For each 90 min session either the sign with the image of salient eyes, the sign with the control  
196 image, or no sign was present. The order of treatments was balanced across the five days per zoo to  
197 control for time of day. During each treatment two identical signs were displayed; one outside the  
198 outdoor enclosure and one outside the indoor enclosure. At Zoo B, which had no indoor enclosure, a  
199 sign was placed at each end of the outdoor enclosure. Only one sign was displayed at Zoo C, due to  
200 restricted space, placed outside the outdoor enclosure. However, visitors approached via a one-way  
201 route passing first the outdoor and then indoor enclosure, so all visitors passed the sign. Signs were  
202 positioned in front of enclosure barriers where paths joined visitor viewing areas.

203

## 204 [Statistical Analysis](#)

### 205 [Behavioural observations](#)

206 Behaviours were analysed if they showed sufficient variation in performance, being neither too rare  
207 nor too frequent (recorded on 10-90% of observations). Begging, Body-slammimg, Fighting, Hiding,  
208 Lip-smacking, Mounting, Scratching, Self-directed behaviour and Teeth-baring were too rare for  
209 analyses, even when combined into meaningful categories (e.g. Body-slammimg and Self-directed

210 behaviour being summed to comprise 'abnormal behaviour'). Other and Out of Sight were also  
211 excluded due to their ambiguity. This left 11 behaviours for analysis.

212 Relationships between behaviours and visitor number or noise level were assessed by fitting  
213 Generalised Linear Mixed Models (GLMM, SPSS, with significance at the  $p < 0.05$  level) to the data,  
214 with each behaviour in turn as the binary response variable, using a binomial link function. Visitor  
215 noise and number were included as explanatory variables in separate models, because of their  
216 correlation with each other. Also included in every model were Observation day (a random categorical  
217 variable), Observation time-point (a continuous fixed factor), and Zoo (a fixed categorical variable,  
218 because there were too few zoos to constitute a random factor). Models were checked for inflated  
219 standard errors that could indicate autocorrelation problems, but no such problems were observed.

220 Sample points with potential confounding factors were removed before analysis, including those  
221 points where a keeper was present and attracting begging or vigilance from macaques, and  
222 immediately after a group had been fed and >50% of macaques were consequently feeding. For the  
223 latter, points were removed until the proportion of individuals feeding dropped below 50% for >1  
224 sample point.

## 225 Sign treatment

226 Data from the four zoos in the treatment study were analysed using a GLMM as above, but noise  
227 level as the continuous response variable meant that an identity link function was appropriate. Model  
228 assumptions were checked via examination of the residuals. The explanatory variables included  
229 Treatment, Weather and Visitor number, in addition to those included above as before (Observation  
230 day, Observation time-point, and Zoo).

## 231 Results

### 232 Effects of visitor number on behaviour

233 Visitor numbers ranged from a median (IQR) of 4 (0-8) at the least visited of the five zoo enclosures  
234 (Zoo D) to 13 (7-23) at the most visited (Zoo A). As the number of visitors increased, the likelihood of  
235 active behaviours being observed significantly increased: Autogrooming, Foraging, Furniture use,  
236 Locomotion, and Vigilance (Table 3). Correspondingly, with more visitors, Resting and Huddling

237 decreased in likelihood. All effects were relatively subtle as indicated by odds ratios close to one for  
 238 each additional visitor.

239 *Table 3. Statistically significant effects of visitor numbers and noise levels on Sulawesi macaque behaviour. The*  
 240 *behaviour category reflects suggested behavioural interpretations, although other interpretations are possible*  
 241 *as outlined in the Introduction.*

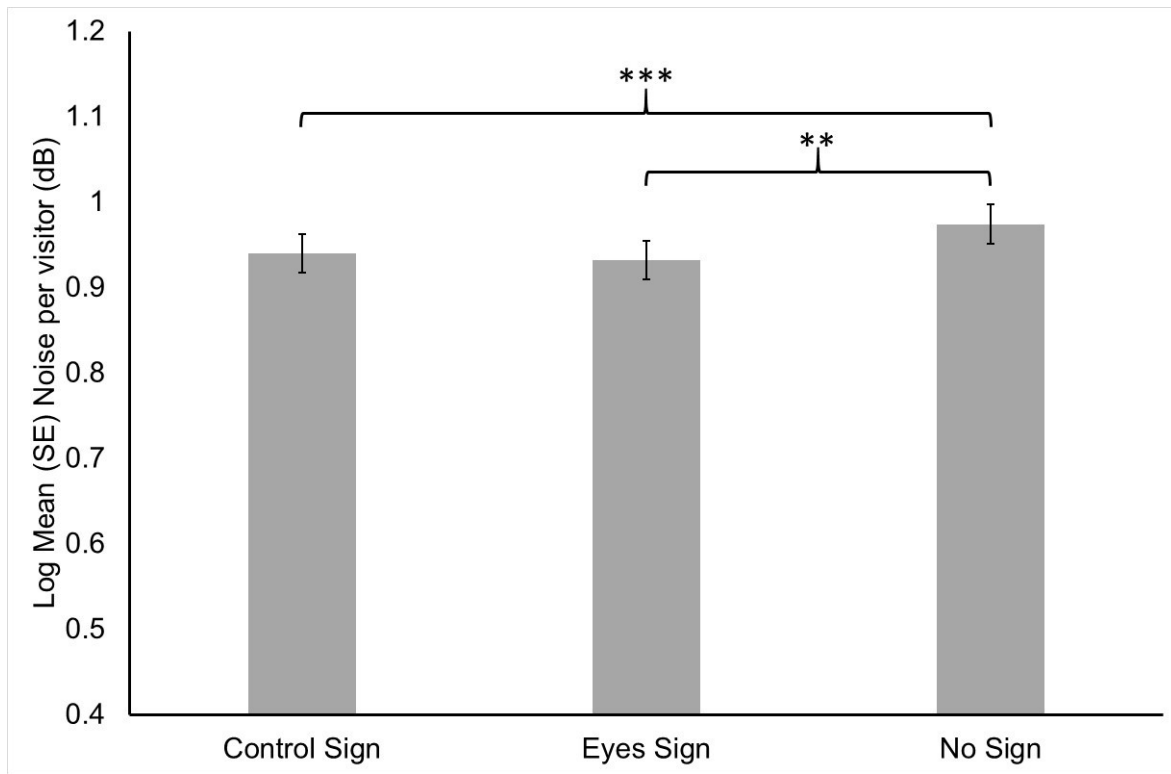
Predictor	Behaviour category	Behaviour	Effect direction	Odds Ratio	s.e.	F (DF)	P-value
Number of visitors	Active	Foraging	↗	1.02	1.01	8.472 (1, 1179)	0.004
		Furniture use	↗	1.03	1.01	10.464 (1, 1179)	0.001
		Locomotion	↗	1.02	1.01	11.404 (1, 1179)	0.001
	Relaxed	Autogrooming	↗	1.02	1.01	4.922 (1, 1179)	0.027
		Huddling	↘	0.98	1.01	8.875 (1, 1179)	0.003
		Resting	↘	0.98	1.01	10.920 (1, 1179)	0.001
	Negative	Vigilance	↗	1.07	1.01	78.890 (1, 1179)	<0.001
Noise levels (dB)	Active	Foraging	↗	1.03	1.01	7.105 (1, 1169)	0.008
		Furniture use	↗	1.03	1.01	5.890 (1, 1169)	0.015
		Play	↗	1.04	1.01	8.767 (1, 1169)	0.003
	Relaxed	Resting	↘	0.97	1.01	8.149 (1, 1179)	0.004
	Negative	Vigilance	↗	1.07	1.01	39.401 (1, 1169)	<0.001

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243



261 4.36;  $P = 0.005$ ), because it was quieter during sunshine (coeff  $\pm$  s.e. =  $-0.016 \pm 0.005$ ;  $P < 0.001$ ) and  
262 sunny intervals (coeff  $\pm$  s.e. =  $-0.011 \pm 0.005$ ;  $P = 0.016$ ) than when it was raining.



263

264 *Figure 3. Effect of signage on mean noise levels. The data are logged to reflect the statistical analysis. To*  
265 *correct for the significant effect of visitor number on sound levels, data are presented as dB per visitor. The*  
266 *minimum value on the y-axis was selected as the 5<sup>th</sup> percentile value (because sound was never zero).*

## 267 Discussion

268 The results from this study indicate that the behaviour of Sulawesi crested macaques is significantly  
269 affected by increases in both visitor number and visitor noise levels, with an increase in active-type  
270 and negative behaviours, such as locomotion and vigilance, and both decreases and increases in  
271 certain relaxed-type behaviours. Although visitor noise was not significantly reduced by signs with  
272 salient eyes when compared to the control signs, visitor noise was reduced by both signs when  
273 compared with having no sign present.

## 274 Effect of visitor number

275 Of the seven behaviours included in the analysis categorised as active-type, three (foraging/feeding,  
276 interaction with furniture/enrichment, and locomotion) significantly increased with visitor number. This  
277 corresponds to findings from numerous other studies (Davey, 2007). Specifically, activity increased  
278 with increased visitor numbers (Todd et al., 2007), visitor activity (Hosey and Druck, 1987; Mitchell et  
279 al., 1992) and visitor presence (Mallapur et al., 2005). However, this effect is not consistent across  
280 species; for example, western lowland gorillas significantly reduced foraging and feeding with  
281 increasing visitor numbers (Clark et al., 2012).

282 The hypothesised decrease in relaxed-type behaviours with higher visitor numbers was only seen for  
283 resting and social huddling, as auto-grooming increased with higher visitor numbers. Previous studies  
284 have found that resting behaviour decreases in western lowland gorillas with high visitor density  
285 (Wells, 2005), and in Diana monkeys with increased visitor number (Todd et al., 2007).

286 The increase in grooming behaviours was not expected because we classed it as a 'relaxed'  
287 behaviour rather than an active behaviour. Looking at the detailed microstructure of the grooming in  
288 future studies could help to evaluate which interpretation is more appropriate because, in some  
289 species, grooming occurs as an action pattern that becomes disarranged in stressful situations (e.g.  
290 in rats: Komorowska and Pisula, 2003). Some studies have found increases in auto-grooming similar  
291 to the current study, e.g. in western lowland gorillas grooming increased with visitor density (Wells,  
292 2005), but in other species, such as Diana monkeys, grooming behaviours decreases with increased  
293 visitor numbers (Todd et al., 2007).

294 The above increases in activity and decreases in inactivity are difficult to interpret in terms of  
295 macaque welfare, because they could indicate that the visitors were either stressful or providing  
296 welcome stimulation for the animals (Fureix and Meagher, 2015). In future, distinguishing between  
297 resting with eyes open versus closed could help distinguish whether this was likely to be 'boredom'-  
298 related behaviour that the visitors relieved, or truly 'relaxed' sleep that the visitors disturbed. That the  
299 huddling here decreased, rather than increased, when more visitors were present suggests that it is  
300 unlikely to be a negative defensive response and may indeed be a 'relaxed' behaviour. If so, this  
301 suggests that visitors may have disturbed the macaques somewhat. In future, there are many other  
302 welfare relevant behaviours and physiological measurements that could help elucidate whether



303 visitors are stressful or enriching, as reviewed using elephants as an example by Mason and Veasey  
304 (2010).

305 Of the behaviours which have been established to indicate stress and were categorised as negative,  
306 vigilance increased with visitor number. Similar findings have been observed in mandrills (*Mandrillus*  
307 *sphinx*) (Chamove et al., 1988), and orang-utans (Choo et al., 2011), both of which increased time  
308 spent in a stiff posture watching visitors with higher visitor numbers. The effect increasing visitor  
309 number has on increasing negative vigilant behaviour could suggest that the macaques are under  
310 increased stress as a result, which could have implications for Sulawesi crested macaque welfare.  
311 Visitor number showed no effect on aggression, which could have been because it was not affected  
312 by visitor number, or because there was always a visitor present in the form of the observer. Remote  
313 video analysis or use of a hide could assist with this issue in future. Also a larger sample size or more  
314 time spent observing may help, especially as the remaining negative behaviours, stereotypic  
315 behaviour and hiding, were too rare for analysis here.

316 In summary, Sulawesi crested macaque behaviour is significantly affected by the number of visitors  
317 outside their enclosures. The increase seen in one of the negative behaviours implies that visitors in  
318 part, are of welfare concern. However, whether increases in active-type behaviours and grooming or  
319 decreases in resting and huddling are suggestive of stress is not known, and as yet it is unclear from  
320 the literature what, if any, the implications of those changes are for welfare (Furiex and Meagher,  
321 2015).

322

### 323 [Effect of visitor noise](#)

324 Visitor noise in the viewing area could be loud, regularly reaching above 70dB (the recommended  
325 limit for human well-being (WHO, 1999)). Even so, visitor noise had less of an effect on the macaque  
326 groups than visitor number, but three active-type behaviours (foraging, furniture use, and play)  
327 increased with increasing noise level. Increases in foraging and play behaviours have been observed  
328 previously in primates; Todd et al. (2007) saw increases in both behaviours with visitor group size in  
329 Diana monkeys, while increases in foraging and play was observed in both olive baboons *Papio*  
330 *anubis*) and gorillas with visitor number and noise level (Snider, 2016). It is not clear what increases in  
331 these seemingly positive active type behaviours, such as play, may mean in terms of welfare (Held

332 and Špinka, 2011; Ahloy-Dallaire et al. in press, 2017). Indeed, the macaques may be enriched by  
333 increased noise levels and so stimulated to play (Hosey, 2000; Snider, 2016). However, if the noise is  
334 stressful, play may provide short term stress relief (Antonacci et al., 2011) or distraction. Conversely,  
335 it is also worth considering that playful or more active behaviours may draw in a larger crowd of  
336 visitors and subsequently higher noise levels, rather than the behaviours being a direct result of the  
337 visitors.

338 Vigilance increased with visitor noise level, again indicating potential welfare concern as above. In a  
339 study of 12 mammal species by Quadros et al. (2014) vigilance increased with noise in half the  
340 species. Similarly, Clark et al. (2012) observed an increase in visitor directed vigilance with increased  
341 noise levels in gorillas, an effect also found in zoo-housed orang-utans (Birke, 2002). Thus, this result  
342 is robust despite here being fairly subtle.

343 Resting behaviour again reduced with visitor noise level, but as explained above, it is not clear  
344 whether this was positive or negative. The fact that it seems to have been replaced with vigilance and  
345 playful active behaviour suggests that it may include negative and possibly some positive aspects,  
346 respectively. Furthermore, whether the resting behaviour was replaced by either vigilance or play  
347 could be partially dependent on the age of the individual macaques, with younger individuals more  
348 likely to play.

349 The effects of visitor noise levels on behaviour may have been fewer than those of visitor number  
350 because noise levels heard by the macaque groups may not have been as loud as where recording  
351 took place, although levels will still have been relatively loud or quiet. Additionally, it is likely that  
352 Sulawesi crested macaques are affected by noise outside the human frequency range (which the  
353 noise level metre is designed to pick up) as the closely-related Japanese macaque's (*Macaca*  
354 *fuscata*) upper limit is 34.5-kHz, compared to 17.6-kHz for humans (Heffner and Heffner, 2007).  
355 Therefore, the sound meter may not have recorded the sounds that most affected the animals. Future  
356 research measuring noise levels within the macaques hearing frequency and inside enclosures could  
357 help.

358

## 359 Mitigation of visitor effects using signs

360 Visitor noise was significantly quieter in the presence of both the sign treatments than with no sign  
361 present. However, the effect was subtle. This may have been partly because, when large numbers of  
362 visitors (>12) were present, the signs could get crowded and blocked from view of any new  
363 approaching visitors. This was particularly true for Zoo C, which had a small visitor viewing area  
364 where visitors could often be several people deep in front of the enclosure. Furthermore, that  
365 macaque enclosure was situated opposite the zoo's gorilla enclosure in front of which large crowds  
366 would gather and, due to the gorillas' popularity, high noise levels would occur. Also, the signs could  
367 not reduce other background noises from visitors at other nearby enclosures, or from other sound  
368 sources entirely. These factors could have reduced the effectiveness of both sign treatments.

369 There was no significant difference in visitor noise levels between the two sign treatments. The  
370 effectiveness of the signs suggests that sign presence alone could be all that is required to modulate  
371 visitor behaviour. However, where signs displaying an image of salient eyes have proved successful  
372 at inducing cooperative behaviour in people, the signs have been displayed at eye level (Bateson et  
373 al., 2006). In the present study signs could not easily be displayed at eye level due to enclosure  
374 constraints at different zoos, and so were displayed on A2 A-frame boards, meaning that the signs  
375 were at approximately at waist height of most adults. Not having these signs at eye level may have  
376 reduced the effectiveness of the watching eyes. Other features of the signs, such as size, font and  
377 colours used could also influence their effectiveness in future. For example, in a study exploring  
378 whether different messages on signs could reduce visitors' banging on aquarium windows, signs  
379 which appealed more to people's emotions had a better effect than signs which were neutral but  
380 polite (Kratovichil and Schwammer, 1997). The potential seen in previous studies for signs displaying  
381 salient eyes to modulate visitor noise levels, coupled with the potential seen in this study of signs  
382 whilst displayed at a sub-optimal height, warrants further research that explores the influence of  
383 these aspects. Whether signs would have to be used sparingly for sensitive species, rather than at

384 every enclosure, and whether they should be varied, to avoid habituation in the viewing public are  
385 questions that would be useful to investigate.

386

## 387 Conclusions

388

389 This study showed that visitor number and visitor noise level significantly affected zoo-housed  
390 Sulawesi crested macaque behaviour, and increased vigilance suggests a welfare concern. Active-  
391 type behaviours were seen to increase with visitor number and to some extent with visitor noise level,  
392 although it is unclear from the literature what, if any, the implications of this change are for welfare.  
393 Further research is recommended to assess if increased active and inactive behaviours are  
394 associated with stress or instead with welcome stimulation (Mason and Veasey, 2010).

395 Signs requesting visitors to be quiet show promise but efforts should be made to increase their  
396 efficacy. Consequently, further research is also required to test whether the use of signs with salient  
397 eyes can be effective at modulating zoo-visitor noise levels when displayed at eye level, or with an  
398 emotion-affecting message, as all options to help reduce noise levels inside enclosures should be  
399 pursued.

400

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402

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409

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523

## 524 Captions

525 Table 1. Dates of study and macaque details for each of the five participating zoos.

526 Table 2. Ethogram of behaviours for Sulawesi crested macaques. The symbol '↘' denotes behaviour  
527 predicted to decrease, '↗' denotes behaviour predicted to increase with increasing visitor number  
528 or noise level and '?' denotes that predicted behaviour change with increasing visitor number or  
529 noise level is not known. The ethogram is adapted from published ethograms, see Baker, 2012;  
530 Nickelson and Lockard, 1978; Thierry et al., 2000.

531 Table 3. Statistically significant effects of visitor numbers and noise levels on Sulawesi macaque  
532 behaviour. The behaviour category reflects suggested behavioural interpretations, although other  
533 interpretations are possible as outlined in the Introduction.

534 Figure 1. The two designs of sign. (a) 'Eyes' sign: sign with image of salient human eyes; and (b)  
535 Control sign with image of flowers.

536 Figure 2. Effects of visitor noise on Sulawesi macaque (a) vigilance and (b) resting behaviour, taking  
537 zoo into account. The white bars represent the absence of the behaviour and the grey bars  
538 represent its presence.

539 Figure 3. Effect of signage on mean noise levels. The data are logged to reflect the statistical analysis.  
540 To correct for the significant effect of visitor number on sound levels, data are presented as dB per  
541 visitor. The minimum value on the y-axis was selected as the 5<sup>th</sup> percentile value (because sound was  
542 never zero).

543

544