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HUSBANDRY REPORT

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Case study: Visual barriers reduce pacing in captive tigers

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Abstract

Captive large felines are prone to abnormal repetitive behaviors like pacing, which are associated with welfare issues. Visual contact without the opportunity to engage in appropriate behavior is known to increase pacing. To better understand the relationship between pacing and conspecific visual contact, we investigated this effect by conducting a barrier experiment on a male-female pair of Sumatran tigers (*Panthera tigris sumatrae*) in Rotterdam Zoo, the Netherlands. The tigers were exposed to four consecutive housing treatments: (i) housed in the same enclosure (baseline), (ii) housed in separate enclosures with visual contact, (iii) housed in separate enclosures without visual contact, and (iv) housed in the same enclosure after the separation. We used focal and scan sampling to measure pacing and recorded the number of visitors. Moreover, we applied scan sampling to measure activity. Overall, our results indicate that the tigers paced significantly more when housed in separate enclosures with conspecific visual contact. Moreover, our results suggest that limiting visual contact between neighboring tigers can mitigate pacing. Implementing these findings in tiger husbandry and enclosure design has the potential to improve animal welfare zoo populations of large felines.

KEYWORDS
large felines, welfare, zoo

1 | INTRODUCTION

Keeping animals in captivity constitutes challenges regarding their physical, behavioral, and social needs (Mellen, 1991). This can lead to the development of abnormal repetitive behaviors (ARBs) (i.e., functionless, repetitive, and unvarying patterns of behavior (Mason, 1991) such as stereotypic pacing (McPhee & Carlstead, 2010). The display of ARBs in captive animals is generally associated with welfare issues like deprivation and stress (Mason & Rushen, 2006). Therefore, mitigating ARBs has become pivotal for accredited zoos. Large felines with extensive home ranges are particularly predisposed to pacing (Clubb & Mason, 2003). While several factors have been identified as drivers of ARBs in large felines (e.g., enclosure size and social housing), there are still knowledge gaps as these factors do not fully explain the occurrence of this behavior (e.g., Vaz et al., 2017). Visual contact with conspecifics has been shown to affect pacing in tigers, but remains relatively understudied (De Rouck et al., 2005).

Large felines housed directly adjacent to—but physically separated from—conspecifics display more ARBs (De Rouck et al., 2005; Quirke et al., 2012). This suggests that physical prevention of interactive behaviors (e.g., aggression or affiliation) or triggering territorial behavior may lead to pacing (Quirke et al., 2012). To mitigate visual contact-induced pacing in large felines, zoos have

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used visual barriers yielding contradictory results (Bashaw et al., 2007; Miller et al., 2008).

Although there was no direct welfare concern, pacing had been observed in a pair of Sumatran tigers (*Panthera tigris sumatrae*) in Rotterdam Zoo J. Kappelhof (personal communication, 2020). To test if visual barriers could mitigate this behavior, we conducted a case study in which we observed the frequency of and time spent on pacing by both tigers when they were housed together, separated with visual contact, and separated without visual contact. We also measured the frequency of activity during these treatments. Given that captive tigers exhibit a wider range of behavior when kept socially, they are expected to spend less time pacing when kept together in contrast to solitary housing, and spend less time pacing without visual contact compared to with visual contact (De Rouck et al., 2005; Jenny & Schmid, 2002; Miller et al., 2008). Moreover, a decrease in pacing would be accompanied by an increase in other active behaviors such as locomotion, or an increase in inactive behaviors such as sleeping. A better understanding of the effect of conspecific visual contact on pacing in tigers can provide insight to mitigate ARBs in zoos and potentially improve the welfare of captive tigers.

2 | METHODS

We observed a male-female pair of Sumatran tigers, (male "Emas" born in 2009 in Dublin Zoo, and female "Alia" born in 2005 in Der Grüne Zoo Wuppertal) in Rotterdam Zoo from September 14 to November 18 in 2020. The pair has been housed together for a majority of the time since the arrival of the male. The tigers never reproduced as the female is contracepted. The enclosure consisted of two connected outdoor areas, each connected to a pair of indoor enclosures (see appendix S1). At the start of the study, both tigers had access to all enclosures. During pilot observations from September 14 to September 25 the only ARB observed using ad libitum sampling was pacing. Therefore, pacing behavior was used as a proxy of ARBs. We used Jenny and Schmid's (2002) definition of pacing: "locomotion on a distance to and fro, immediately after this distance has been paced once in both directions." We observed the animals from the public viewing area and during public opening hours.

2.1 | Behavioral sampling

We used two 3-h sessions of continuous focal sampling per day to record each pacing bout in detail, noting starting time, duration and individual. Furthermore, we used instantaneous scan sampling to record activity patterns following an ethogram based on Stanton et al. (2015) (see appendix S2). Pacing was also observed to cross-check the continuous focal sampling (see appendix S3). We used a

TABLE 1 Raw values of pacing during continuous sampling, in seconds per 15-min period.

Treatments	μ	SD
Same enclosure	283.0	222.7
Separate enclosure with visual contact	295.1	247.6
Separate enclosure without visual contact	190.0	164.2
Same enclosure after separation	128.1	145.7

Abbreviations: μ, mean; SD, standard deviation.

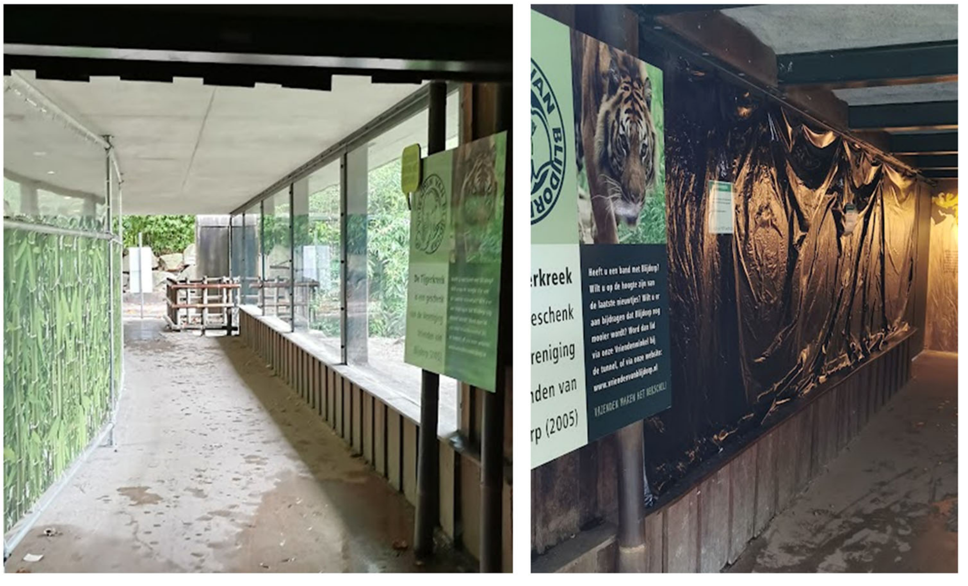

FIGURE 1 Photographs of visual barrier during treatment three. Image of the situation during the third treatment. Here, the window of the indoor enclosure of the male was covered with canvas and a fence was present between the outdoor windows. [Color figure can be viewed at wileyonlinelibrary.com]

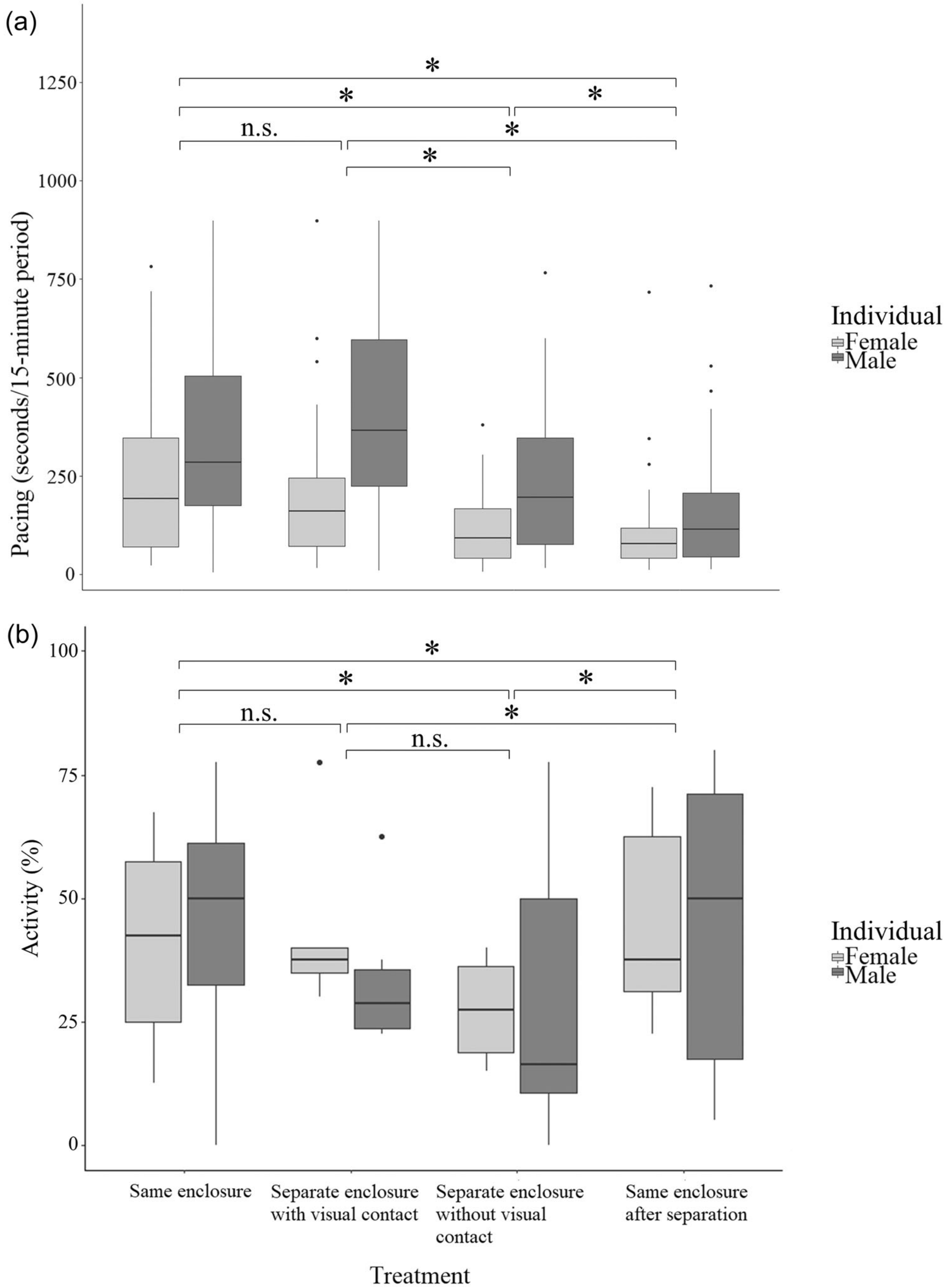

FIGURE 2 Boxplots of pacing and activity of one female and one male Sumatran tiger in Rotterdam Zoo during four different treatments. Constructed with a generalized linear model. (a) Time tigers spent pacing per 15-min period per treatment. Quasi-Poisson distribution. (b) Percentage of scans tigers spent on activity per day. Activity = 40—lying—sleeping—pacing—not visible. Poisson distribution.

fixed time interval of 3 min between scans and a 30 s maximum time delay to find the tigers, with a total of 40 scans per day. For each observation a random individual was selected to start with. We calculated activity by subtracting inactive behaviors (lying, sleeping), pacing, and non-visibility from the total number of scans, following similar studies (Mallapur & Chellam, 2002; Margulis et al., 2003). Besides tiger behavior, we also noted visitor numbers and feeding days. Visitor numbers were quantified as the total number of visitors walking through the corridor of the enclosure during the observation time.

2.2 | Treatments

We observed the tigers during four treatments with 6 or 7 days per treatment. In the first treatment ("same enclosure"), the animals were kept together as a pair (baseline). In the second treatment ("separate enclosure with visual contact"), the animals still had visual contact through fences and windows. In the third treatment ("separate enclosure without visual contact"), visual contact between the tigers was blocked by constructing a barrier (Figure 1). During the fourth treatment ("same enclosure after separation") the animals were kept together again. Between treatments the animals were given at least 3 days to acclimate, though practical constraint made this impossible between the second and third treatment.

2.3 | Statistics

We performed statistical analyses in R (R Core Team, 2020). For the continuous focal sampling, with pacing data organized into 15-min blocks to align it with visitor numbers, we used a generalized linear model assuming a Quasi-Poisson distribution with individual and visitor number as explanatory variables. For instantaneous scan sampling, we used a generalized linear model assuming a Poisson distribution. Individual, visitor numbers and feeding days were included as explanatory variables. For both methods, the four treatments were independent variables. We used the "glm" function for the model and the "lsmeans" function for post hoc comparisons (Lenth, 2016).

3 | RESULTS

Overall, we conducted 165 h of continuous focal sampling during which we recorded a total of 533 pacing bouts, comprising 25 h of pacing (7.6% of observed time) between the tigers. However, pacing differed across the treatments (Table 1). Pacing levels did not significantly change when the animals were separated but still had visual contact ($z = -0.742$, $p = .458$), but decreased significantly when conspecific visual contact was blocked ($z = -4.640$, $p < .001$), and decreased significantly again when the animals were reunited ($z = 2.080$, $p = .038$) (Figure 2a and Table 2). Visitor numbers did not significantly influence ARB ($t = -1.185$, $p = .237$) but the male tiger paced significantly more than the female ($t = 6.659$, $p < .001$). We furthermore performed 1040 scans in total, in which the Sumatran tigers spent on average 39.2 ± 3.1% of the scans on active behaviors per day. The number of scans spent on active behavior also varied between the treatments (Table 3). Activity levels did not significantly change after separating the animals while maintaining visual contact ($z = 1.739$, $p = .082$) or when blocking visual contact during separations ($z = 1.331$, $p = .183$), but activity did significantly increase when reuniting the tigers after separation ($z = -4.791$, $p < .001$) (Figure 2b, Table 4). Activity was also influenced by feeding days ($z = 11.974$, $p < .001$) and visitors ($z = 3.383$, $p < .001$), but did not differ between the individuals ($z = -0.280$, $p = .779$).

4 | DISCUSSION

Visual contact with conspecifics is known to affect pacing in large felines. Overall, our findings show that the tigers in Rotterdam Zoo paced significantly less when conspecific visual contact was avoided compared to a situation where they did have visual contact. While the general pattern over the treatments was highly similar, there were significant differences between the individuals as the male tiger paced significantly more than the female. Besides pacing, the tigers performed less active behavior in general when the visual barriers were in place, implying an increase in inactive behavior.

The relationship between visual contact and pacing is supported by the wider literature (De Rouck et al., 2005; Quirke et al., 2012). However, most studies so far have compared animals in different enclosures of zoos, and the few that experimentally added barriers showed contradicting results (Bashaw et al., 2007; Miller et al., 2008). Our results provide evidence for the hypothesis that limiting visual contact can mitigate pacing. Both focal sampling and scan sampling methods yielded similar results and patterns. This shows the findings

TABLE 3 Raw values of activity during instantaneous sampling, in percentage of scans per day.

Treatments	μ	SD
Same enclosure	43.00	23.00
Separate enclosure with visual contact	38.33	16.25
Separate enclosure without visual contact	28.75	22.25
Same enclosure after separation	45.18	25.24

Abbreviations: μ, mean; SD, standard deviation.

TABLE 2 Pairwise comparisons between treatments of the ARB-treatment model, which looked at the effect of treatments, individual, and visitor numbers on pacing.

Treatments	Estimate	Standard error	z-ratio	*p* Value
Same enclosure versus Separate enclosure with visual contact	−0.0794	0.107	−0.742	.4580
Same enclosure versus Separate enclosure without visual contact	0.4761	0.125	−3.800	<.0010***
Same enclosure versus Same enclosure after separation	0.8174	0.147	−5.558	<.0010***
Separate enclosure with visual contact versus Separate enclosure without visual contact	0.5556	0.120	−4.640	<.0010***
Separate enclosure with visual contact versus Same enclosure after separation	0.8969	0.154	−5.822	<.0010***
Separate enclosure without visual contact versus Same enclosure after separation	0.3413	0.164	2.080	.0380*

Note: Focal sampling method.

*$p < .05$; **$p < .01$; ***$p < .001$.

TABLE 4 Pairwise comparisons between treatments of the activity-treatment model, which looked at the effect of treatments, individual, feeding days, and visitor numbers on activity.

Treatments	Estimate	Standard error	z-ratio	*p* Value
Same enclosure versus Separate enclosure with visual contact	0.190	0.109	1.739	.0821
Same enclosure versus Separate enclosure without visual contact	0.349	0.107	3.249	.0012**
Same enclosure versus Same enclosure after separation	−0.286	0.115	−2.479	.0132*
Separate enclosure with visual contact versus Separate enclosure without visual contact	0.159	0.119	1.331	.1833
Separate enclosure with visual contact versus Same enclosure after separation	−0.476	0.154	−3.094	.0020**
Separate enclosure without visual contact versus Same enclosure after separation	−0.635	0.133	−4.791	<.0001***

Note: Activity consisted of all visible behaviors except for lying, sleeping, and pacing. Scan sampling method.
*$p < .05$; **$p < .01$; ***$p < .001$.

hold up across observation methods, making a stronger case for the importance of visual contact in ARB in felines. Pacing furthermore decreased below base-line levels when the tigers were separated without visual contact, despite other aspects of the treatments (e.g., solitary housing and smaller enclosure size) being associated with more instead of less pacing (see e.g., Breton & Barrot, 2014; De Rouck et al., 2005; Jenny & Schmid, 2002; Vaz et al., 2017). This suggests that the finding was not merely the result of habituation, but that there's some effect inherent to the treatment.

Activity patterns also showed significant differences between the treatments The tigers were more active when kept together, but when separated, the visual barrier did not significantly alter activity. The present study is however unequipped to differentiate between potential explanations for this observation. Given that this study represents a case study on only two individuals in one zoo, the findings on both activity and pacing should be taken with caution. The characteristics of the individuals, their housing conditions, the husbandry protocol, and other such factors might have skewed the results. This underlines the importance of larger multi-zoo experimental studies to further elucidate patterns observed during case studies, such as the link between visual contact and ARBs.

In conclusion, our findings indicate that limiting visual contact can mitigate pacing in neighboring tigers. While the connections between ARBs like pacing and welfare are complex, it is clear that there is a link (Mason et al., 2007). Therefore, the decrease in pacing may signal a positive impact on animal welfare. However, further research is necessary to show if our findings hold true in the larger population of zoo-kept tigers across situations and facilities. Implementing these findings in captive tiger husbandry and enclosure design has the potential to mitigate pacing and improve the welfare of zoo-living tigers and other large felines.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Not applicable.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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