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The Effect of Visitors on the Welfare of Zoo-Housed Primates

By

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Abstract

An animal's welfare is directly impacted by its mental state, shaped by individual interpretations of experiences within an environment over a lifetime. For zoo-housed animals, visitors to the zoo are a fluctuating variable within that environment. To examine the impact of zoo visitors on five species of zoo-housed primates, this study uses each animal's location within its habitat as an indication of internal mental state. Distance from visitor viewing glass is considered an indication of comfortability in the presence of visitors, and analysis considers primate-visitor proximity across increasingly large groups of zoo visitors. Analyses reveal a statistically significant but insubstantial decrease in primate distance from visitor viewing glass when visitors are present at each primate habitat, even as the number of visitors increases. This is thought to indicate no decrease in welfare due to the presence of zoo visitors.

Introduction

Zoos and aquariums increasingly aim to be a harbor for animal conservation, research, and education, with over 700 million visitors worldwide each year (Gusset & Dick, 2011). The Association of Zoos and Aquariums (AZA), for example, consists of over 240 facilities including approximately 8,700 different animal species (Marcy, 2021). The accredited zoo community at large, as well as researchers focused on animal welfare, seek opportunities to enhance welfare from the group to the individual level whenever possible.

A framework for assessing welfare is the Five Domains Model. These five domains include those that are physical: nutrition, environment, physical health, and behavior, with overall welfare determined by an animal's individual interpretation of these experiences (Mellor

& Beausoleil, 2020). This interpretation of experiences through the individual animal's personal lens forms the affective state and is referred to as the mental domain. It is both formed by the culmination of past experiences and used to interpret future experiences as either positive or negative. In this way, the welfare—the quality of life—of an individual animal is determined by the specifics of that animal's experiences.

The experiences and individual states of an animal across its lifetime can be most easily measured in captive environments, with such data potentially granting new insights into welfare. While welfare is determined by an internal mental state that is not directly observable, animals do exhibit many measurable behaviors that researchers use as an indication of that internal mental state (e.g. Ward, Sherwen, & Clark, 2018). Throughout an animal's life it may experience events such as relocation, changes in cohabitation, varying weather, or construction in a zoo setting. Additionally, an individual may be affected by sickness or injury. These are all experiences that can impact an animal's welfare, and while these events can be directly recorded by researchers, the impact on welfare must be inferred by observation of behaviors and changes in an animal's activity.

The presence of zoo visitors is a fluctuating variable in the environment of zoo-housed animals, and the impact of visitors on welfare is a prevalent concern for zoo animal welfare research (e.g. Binding, Farmer, Krusin, & Cronin, 2020; Davey, 2007; Sherwen & Hemsworth, 2019). Visitor effect studies look to determine what relationship, if any, exists between visitors and the welfare of animals. Typically, studies record data about the behavior of animals that may be positive (e.g. play), negative (e.g. aggression), or neutral, though behaviors can also be classified as unclear as to whether indicative of positive or negative mental state (e.g. Sherwen & Hemsworth, 2019). In visitor effect studies, recorded behaviors are correlated with information about the visitors when the behavior took place. Sometimes, reported visitor data consists solely of whether any visitors are present or not, but can also include exact counts for number of visitors or approximate group sizes, and even the activity of the visitors themselves (Hashmi & Sullivan, 2020).

The conclusions researchers have drawn about the impact of visitors on zoo-housed animals is varied (Davey, 2007; Sherwen & Hemsworth, 2019). Recent reviews of welfare research have identified mixed results in visitor effect studies and call for greater unity in the approach to animal welfare science (Hosey, Ward, Ferguson, Jenkins, & Hill, 2020). Studies may be contradictory or conclude in points that oppose one another or are unclear and open to interpretation. In one example of contradictory conclusions, two studies looked at the effect of visitors on black-and-white ruffed lemurs and red-fronted lemurs. The first concluded animal movement around the habitat increased while the second found a decrease across this same metric (Jeffery & Price, 2004; Hutchings & Mitchell, 2003). In circumstances where the same behaviors are observed in subjects as a response to visitors, the conclusion about whether these behaviors indicate positive or negative mental state can still be debated (Wood, 1998; Choo, Todd & Li, 2011).

An inherent weakness in using behavioral data to infer welfare is the complex nature of interpreting meaning from observed actions. Researchers cannot know the internal states of animals and must therefore rely on interpretation of the displayed behaviors and actions of subjects. While useful, behavioral interpretation can be fallible. Environmental or internal variables can impact behavior in ways that do not necessarily reflect mental state or welfare, and observers can incorrectly record an animal’s actions or mistake the meaning of a behavior. Instead, animal location can be used as a straightforward alternative to behavioral data analysis

(Ross, Schapiro, Hau, & Lukas, 2009). Applicable across a broad number of species, as a measure of animal choice, location is not subject to observer interpretation and can be an indication of internal state that more clearly reflects welfare.

Within a habitat, every individual moves about and makes decisions about where to be at any given point in time. With full access to all parts of the exhibit, where an animal chooses to be at any point in time is an indication of where that animal is most comfortable given the current circumstances of the environment and the animal's internal state. Animals tend to avoid things that induce physical or psychological discomfort (Costa, Sousa, & Llorente, 2018). In efforts to avoid environmental variables that cause psychological discomfort, animals may move away from what would otherwise cause a negative mental state. If an animal is far from visitor viewing glass when visitors are present, this can be an indication that visitors induce a negative mental state and negatively impact welfare in the animal. While neither welfare nor mental state can be measured directly, the location of each individual and their distance from the viewing glass can be recorded objectively across many time points and analyzed in relation to the presence of visitors. With analysis dependent on location data that does not require the interpretation of a diverse array of behaviors, this study benefits from straightforward and consistent measurement using distance data.

As location of the animal and distance from visitor viewing glass is used to determine the potential effects of visitors, the type of visitor data recorded is important. Many visitor effect studies do not draw conclusions having to do with the number of visitors on a continuum (Sherwen & Hemsworth, 2019). Instead, these studies look at animal behavior when no visitors are at the zoo exhibit and compare with animal behavior when one or more visitors are present. This can be an effective way of studying changes caused by visitors, but may also result in missing substantial or more subtle effects caused by different quantities of visitors. By taking precise measurements of the numbers of visitors present, new insights into responses to visitors may be gained. The number of visitors can be analyzed as exact numbers or take the form of groups or bins, where one group may consist of anywhere from 1 to 5 visitors and the next group contains anything from 6 to 10 visitors, and so on (e.g. Rose, Scales, & Brereton, 2020). In some cases the precise number of visitors is counted and relationships between animal behavior and number of visitors can be examined at the most exact level, which may reveal a gradual behavioral change or something more significant when reaching a visitor count threshold (Choo et al. 2011).

In the present study, location data about distance of animals from viewing glass is analyzed with respect to a variety of different visitor count data types. As part of ongoing monitoring of animals housed at Lincoln Park Zoo, the location of this study, these data types are regularly recorded (Wark, Cronin, Niemann, Shender, Horrigan, Kao, & Ross, 2019). In preliminary analysis, exact visitor crowd sizes are analyzed, then for all collected data analyses are run for both binned visitor counts and the presence of 1 or more visitors. This visitor data is rich and extensive, complete with a vast amount of data about distance which should result in a complete picture of how visitors impact location of primates, which allows the most compelling evidence for mental state.

With this relatively simple dataset of visitor numbers and animal distance from a static point, being the visitor viewing glass, simple predictions can be made about an animal’s mental state. Retreating from the glass can indicate the animal is uncomfortable with the visitors on the other side (be it due to number of people, or the presence of any people). This finding would suggest proximity to visitors induces a negative mental state and reveals visitors may contribute to poor welfare overall. No change in location or observing an animal near the visitor viewing glass, by contrast, may indicate no negative welfare effect of visitors or possibly a positive impact on the animal.

Many previous studies have used behavioral measures that can be difficult to draw conclusions from due to the inherently complex nature of behavioral interpretation (Hosey et al., 2020; Sherwen & Hemsworth, 2019). Another limitation when taxed with such involved measures is that studies may be confined to a limited number of subjects and species due to the involved nature of such analyses, and studies that examined visitor presence but failed to closely control for and report visitor number may have missed additional insight into visitor effects (López-Álvarez, Sanjorge, Soloaga, Crailsheim, & Llorente, 2019). With non-behavioral measures and precise number of visitors recorded for each of these points of data, along with the ability to expand this streamlined process over five different species, powerful conclusions can be drawn, generalizable across a variety of species and situations.

Welfare by way of mental state can be measured in an objective and straightforward way. In many studies of visitor effect on animal welfare, conclusions have been largely contradictory and as such visitors in this study could not be predicted to be either positive or negative influences on welfare. There was the expectation of zoo visitors to be either a negative environmental factor, associated with an increase in the distance of animals from the viewing glass as the number of visitors increased, a positive factor associated with decrease in animal distance as number of visitors increased, or visitors may be a neutral variable within an animal's environment, not associated with significant change in animal distance in the presence of visitors.

Methods

Study Site and Subjects

This study involved 4 indoor enclosures at Lincoln Park Zoo in Chicago, IL, consisting of 5 species and 17 individuals, including 5 eastern black-and-white colobus monkey *(Colobus guereza)* and 2 Allen's swamp monkey *(Allenopithecus nigroviridis)* who share an enclosure, 4 DeBrazza's monkey *(Cercopithecus neglectus)*, 4 Bolivian gray titi monkey *(Callicebus donacophilus)*, and 3 crowned lemur *(Eulemur coronatus)*, all captive-born (Table 1). Animals had access to holding (off exhibit and behind-the scenes) intermittently throughout the study, though any data in which subjects were out of view has been excluded entirely from this study. The 4 exhibits vary slightly in dimensions and square footage available to the inhabitants (Figure 1). The glass of each enclosure was measured (Table 2).

Subjects	Sex	Birth Year	Number of Observations	Observation Start Date	Observation End date
Eastern Black-and-White Colobus			**224**		
Bea	M	1993	47	10/6/2019	*10/25/2020
E.B.	F	2016	50	10/6/2019	*10/25/2020
Ruk	F	2018	41	10/6/2019	*10/25/2020
Nol	F	2018	38	10/6/2019	*10/25/2020
Kut	F	2004	48	10/6/2019	*10/25/2020
DeBrazza's			**1845**		
Myl	M	2000	738	1/18/2018	*10/29/2020
Ros	F	2013	768	1/18/2018	*10/29/2020
Bom	M	2018	310	2/14/2019	*10/29/2020
Tik	M	2020	29	1/18/2020	*10/29/2020
Bolivian Gray Titi			**2095**		
A.J.	F	2012	4	7/24/2017	11/5/2017
Del	F	1991	697	7/24/2017	3/12/2020
Och	M	2011	687	7/24/2017	3/12/2020

Oca	M	1997	707	7/24/2017	3/12/2020
Crowned Lemur			**131**		
Sok	M	2007	44	10/6/2019	3/12/2020
Tsi	M	2017	43	10/6/2019	3/12/2020
Len	M	2016	44	10/6/2019	3/12/2020
Allen's Swamp			**1257**		
Kid	F	2008	635	6/8/2018	*3/5/2021
Bok	M	2006	622	6/8/2018	*3/5/2021

*No observations took place between 3/13/2020 and 8/12/2020

Table 1. Subject details by species name including individuals' sex, birth year, number of observations used in this study, and the dates corresponding with the beginning and end of the observation period for each subject.

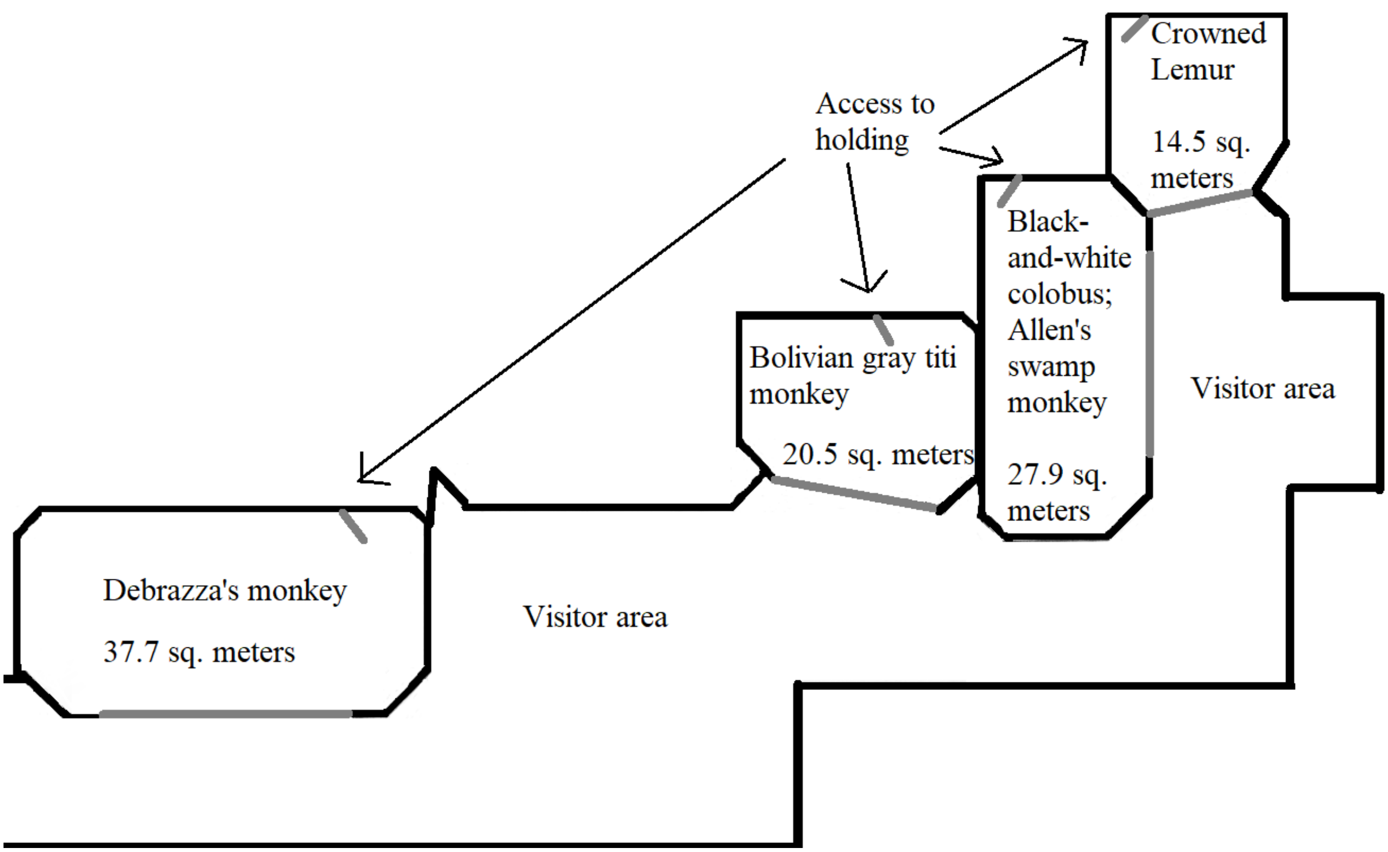

Figure 1. Depiction of the Helen C. Brach Primate House visitor area and studied habitats. Square meters (m^2) of each habitat are denoted, and holding access is represented by a small diagonal line. Viewing glass is denoted by solid gray line. Other exhibits not examined in this study are not depicted.

	Glass Width (meters)	Glass Height (meters)	Visible area of glass (square meters)
*** Eastern Black-and-White Colobus**	6.16	2.50	15.41
DeBrazza's	7.69	2.50	19.23
Bolivian Gray Titi	4.65	2.50	11.63
Crowned Lemur	3.09	2.50	7.73
***Allen's Swamp**	6.16	2.50	15.41

*Shared enclosure

Table 2. Dimensions of viewing glass by habitat. Note the viewing glass for each exhibit sits approximately 0.6 meters above the ground.

All enclosures are located in the Helen C. Brach Primate House, with typical hours of operation resulting in visitor access for approximately 8 hours per day, 7 days per week. On March 12th, 2020, indoor facilities at Lincoln Park Zoo closed to the public as a result of the COVID-19 pandemic, and the Helen C. Brach Primate House remained closed to visitors until the completion of this study. Given this study's focus on primate response to visitor presence, a portion of the included data were recorded during the zoo's closure, during which time no visitors were present.

Data Collection: Animal Space Use and Zoo Visitors

Space use data were collected as part of routine behavioral monitoring by trained volunteers passing inter-observer reliability tests with 85% agreement using Apple® iPad mini® (iOS 9.3.5, Cupertino, CA, USA) and ZooMonitor software (Tracks Software®, Salida, CO, USA), developed by Lincoln Park Zoo (Lincoln Park Zoo, 2020). Animal space use was recorded during 10-minute observation sessions at 1-minute intervals. These observations took place between 10:00 AM and 4:00 PM up to seven days per week.

When recording location of subjects throughout a given habitat (Figure 2), observers used a digital map in the ZooMonitor app to plot each individual animal's coordinates on a two-dimensional 600 x 600 coordinate point system (Figure 3). At the beginning of each session, observers also recorded crowd size. This value was recorded differently throughout the study, either as an exact number of people (e.g., 4) or a range of values (e.g., 1 to 5). The impact of these two data types is discussed later in this study.

Figure 2. The shared enclosure of Eastern black-and-white colobus and Allen’s swamp monkeys at Lincoln Park Zoo.

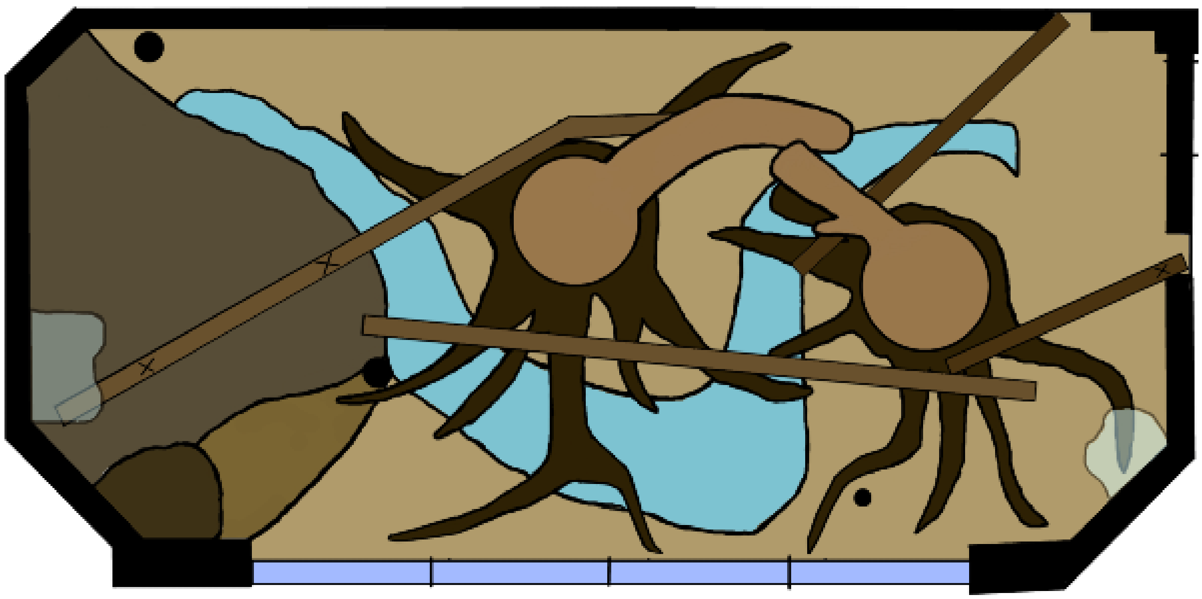

Figure 3. A top-down graphical representation of an exhibit's space used on the ZooMonitor application. A subject's location may be recorded at any place throughout the exhibit on the pictured 2D image. Viewing glass is represented by the segmented line. Pictured is the shared enclosure of Eastern black-and-white colobus and Allen's swamp monkeys.

Data Collection: Observation Period

The total observation period is varied between species and individuals (Table 1). During this study two male Debrazza's monkeys were born and one female Titi monkey died. Due to the COVID-19 pandemic, no data collection occurred between 3/13/2020 and 8/12/2020.

During a 10-minute observation period consisting of 10 1-minute intervals, volunteers recorded the precise number of zoo visitors observing an exhibit preceding the first observational scan. As the number of visitors may fluctuate during the 10-minute observation period, and this study directly examines the relationship between visitor presence and primate location, only the first observational scan with the most accurate visitor count was retained for analysis.

Data Analysis

Distances from viewing glass were calculated for each observation using the coordinate map from the ZooMonitor application. These coordinates exist on a plane, consisting of a value of location in the form of (x, y). After giving the visitor glass a range of x- and y- values to measure from, the shortest distance from the glass to each animal data point was calculated (Figure 3). Note that distance to visitor glass has been measured, though individual visitors may be located throughout an exhibit's particular observation area.

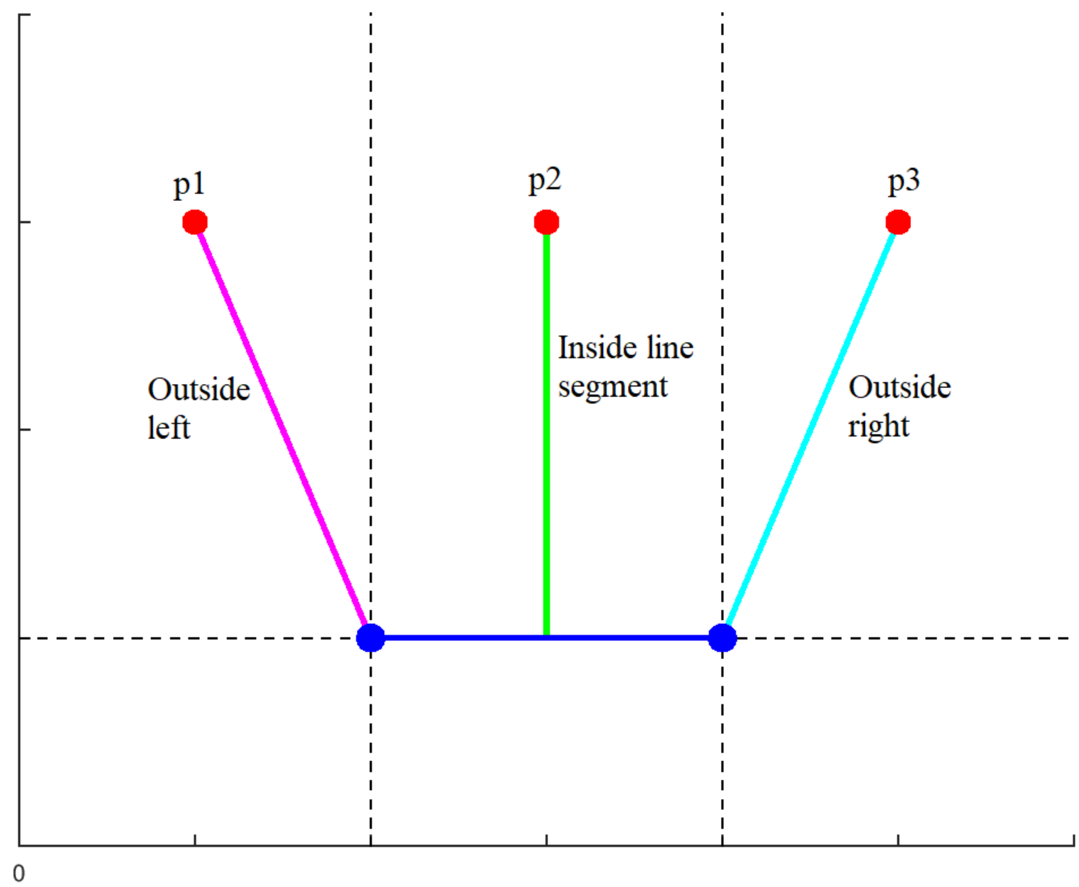

Figure 3. A representation of how primate distance to glass was calculated. The horizontal line in blue represents the viewing glass. Subject location may be inside the line segment (p2), for which cases a perpendicular line is the shortest distance to the glass, or location may fall outside the boundaries of the line segment representing the glass, denoted by the vertical dashed lines (p1, p3), in which case the shortest distance to the viewing glass is calculated as the distance to the line segment's end points.

A linear mixed model regression was conducted to examine space use as it relates to crowd size, with crowd size as the predictor variable for fixed effects and both species and individual as predictor variables for random effects. Maximum Restricted Maximum Likelihood (REML) was used as the estimation method of model fit and models were found not to violate assumptions of independence or homoskedasticity. This analysis was carried out using Python 3 (Van Rossum & Drake, 2009). Effects were preliminarily explored on a dataset using a continuum of exact crowd sizes ranging from 0 to 29, a 3,813 point dataset (Table 4). Two main analyses were carried out on a dataset of 5,552 observations (Table 6) that included binned crowd sizes as well as this same data synthesized to look only at the differences between the complete presence and absence of visitors (i.e., visitor count equal to zero compared with visitor count greater than zero).

Results

Exact Crowd Sizes (Preliminary Investigation)

Using a generalized linear mixed model with crowd size as the fixed effect predictor variable and species and individual as random effects, number of visitors was not found to be a significant predictor of distance from viewing glass (Table 3).

Predictor	**Coefficient**	**Standard Error**	**z-value**	***p*-value**	**Confidence interval [0.025 0.975]**
Intercept	186.713	19.753	9.452	0.000	147.997 225.428
Crowd size (Exact)	-2.242	2.810	-0.798	0.425	-7.750 3.266

Table 3. Summary of the generalized linear mixed model predicting primate distance from glass by exact number of zoo visitors observing.

	Number of Observations	Max distance	Min distance	Mean distance	Median distance
Eastern Black-and-White Colobus	**224**	**254.00**	**21.00**	**154.54**	**157.50**
Bea	47	234.97	67.00	166.00	185.00
E.B.	50	254.00	21.00	143.39	130.50
Ruk	41	231.00	37.00	148.23	147.00
Nol	38	249.21	50.00	157.69	162.00
Kut	48	252.11	68.00	157.83	154.60
DeBrazza's	**1243**	**274.23**	**9.00**	**159.89**	**161.00**
Myl	470	274.23	15.00	159.62	158.00
Ros	493	273.00	10.00	160.85	163.11
Bom	251	267.00	15.00	158.24	162.00
Tik	29	267.42	9.00	162.02	150.66
Bolivian Gray Titi	**1423**	**269.67**	**12.93**	**167.71**	**155.40**
A.J.	1	167.81	167.81	167.81	167.81
Del	475	269.67	12.93	153.98	144.34
Och	460	265.53	19.79	176.99	168.46
Oca	487	264.18	17.79	172.34	155.52
Crowned Lemur	**132**	**524.13**	**19.01**	**340.54**	**425.40**
Sok	44	503.23	19.01	210.28	81.35
Tsi	44	511.90	37.74	398.62	461.41
Len	44	524.13	29.53	414.04	476.18
Allen's Swamp	**791**	**269.86**	**4.00**	**123.04**	**109.66**
Kid	400	269.68	9.00	128.05	115.50
Bok	391	269.86	4.00	117.92	100.42
All	**3813**	**524.13**	**4.00**	**161.06**	**153.10**

Table 4. Reported for each individual, averaged across species, and averaged in “all” are the number of observations in this dataset as well as maximum, minimum, mean, and median distances from the viewing glass.

Presence or Absence of Visitors

Using a generalized linear mixed model with the fixed effect predictor variable being whether a crowd of any size (>0) was present, and species and individual as random effects, total number of visitors was found to be a significant predictor of distance from viewing glass (Table 5).

Predictor	**Coefficient**	**Standard Error**	**z-value**	*p*-value	**Confidence interval [0.025 0.975]**
Intercept	182.541	19.788	9.225	0.000	143.757 221.325
Visitor Presence	-5.065	1.823	-2.778	0.005	-10.129

Table 5. Summary of the generalized linear mixed model predicting primate distance from glass by the presence of 1 or more visitors.

	Number of Observations	Max distance	Min distance	Mean distance	Median distance
Eastern Black-and-White Colobus	**224**	**254**	**21.00**	**154.54**	**157.50**
Bea	47	234.97	67.00	166.00	185.00
E.B.	50	254.00	21.00	143.39	130.50
Ruk	41	231.00	37.00	148.23	147.00
Nol	38	249.21	50.00	157.69	162.00
Kut	48	252.11	68.00	157.83	154.60
DeBrazza's	**1845**	**434.00**	**7.00**	**160.73**	**162.08**
Myl	738	274.23	12.00	163.00	162.72
Ros	768	434.00	7.00	160.61	163.00
Bom	310	423.36	15.00	155.53	158.50
Tik	29	267.42	9.00	162.02	150.66
Bolivian Gray Titi	**2095**	**279.65**	**12.85**	**166.30**	**153.93**
A.J.	4	167.81	49.65	110.12	111.50
Del	697	269.67	12.85	150.97	143.36
Och	687	279.65	19.79	176.36	166.83
Oca	707	264.18	17.79	171.95	155.89
Crowned Lemur	**131**	**524.13**	**19.01**	**340.54**	**425.40**
Sok	44	503.23	19.01	210.28	81.35
Tsi	43	511.90	37.74	398.62	461.41
Len	44	524.13	29.53	414.04	476.18
Allen's Swamp	**1257**	**269.86**	**4.00**	**120.26**	**105.00**
Kid	635	269.68	8.00	120.39	106.00
Bok	622	269.86	4.00	120.13	104.56
All	**5552**	**524.13**	**4.00**	**157.66**	**150.93**

Table 6. Reported for each individual, averaged across species, and averaged in "all" are the number of observations in this dataset, and maximum, minimum, mean, and median distances from the viewing glass.

Binned Visitor Counts

Using a generalized linear mixed model with the fixed effect predictor variable being binned crowd size and species and individual as random effects, total number of visitors was found to be a significant predictor of distance from viewing glass (Table 7). The dataset analyzed matched that of the dataset used in the presence or absence of visitors analysis (Table 6). As crowd size increases, primate distance from visitor glass slightly decreases (Figure 4).

Predictor	**Coefficient**	**Standard Error**	**z-value**	*p*-value	**Confidence interval [0.025 0.975]**
Intercept	182.380	19.608	9.301	0.000	143.950 220.810
Crowd size (binned)	-5.237	1.874	-2.795	0.005	-10.474

Table 7. Summary of the generalized linear mixed model predicting primate distance from glass by number of visitors observing binned into standardized visitor counts.

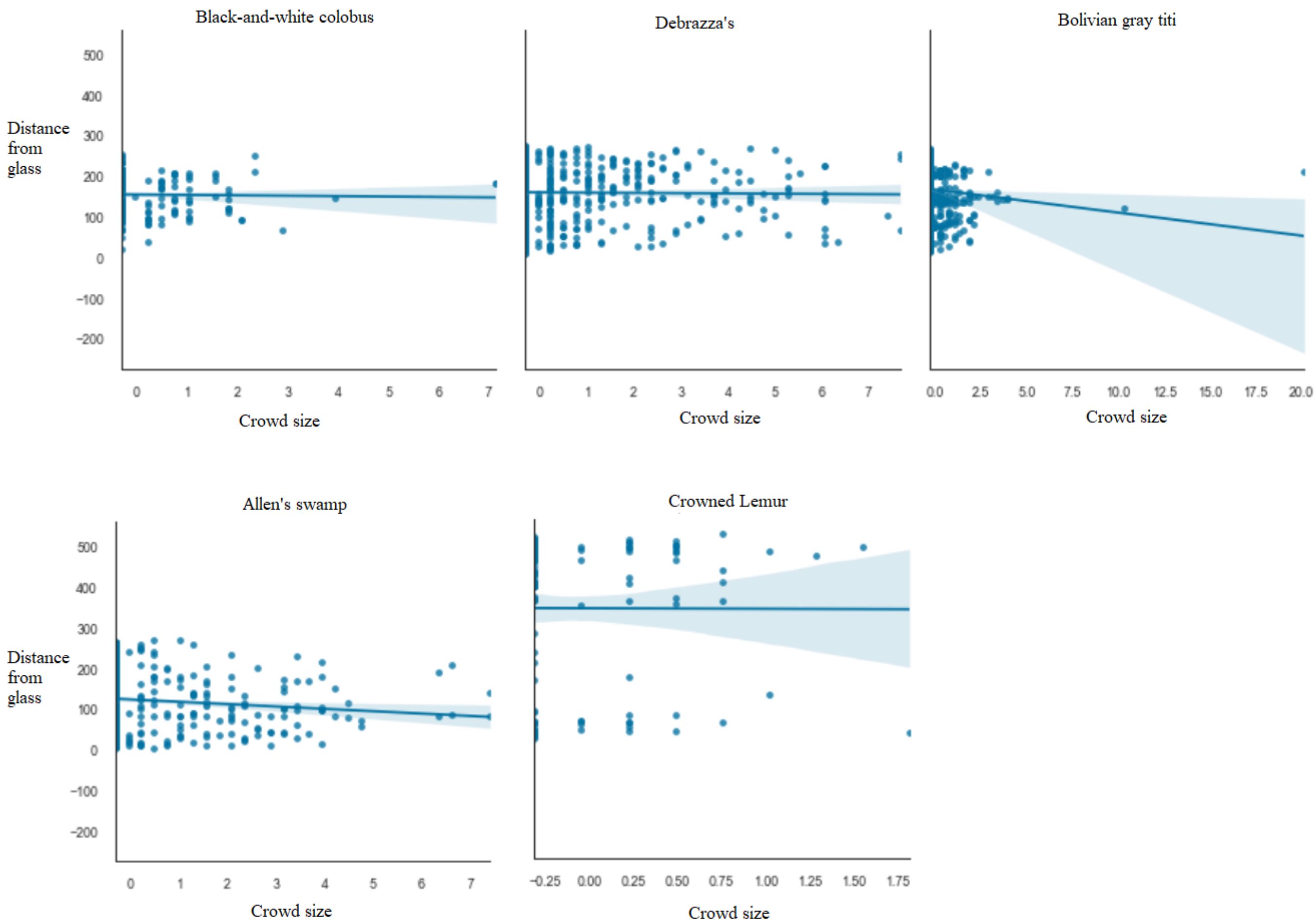

Figure 4. As number of visitors increases (x-axis) distance from glass (y-axis) slightly decreases across all species.

Discussion

Environment and an animal's experiences in that environment are key factors that impact mental state, which is a vital aspect of welfare. Visitors are a large part of the environment of animals living in zoos. This study uses a largely objective measure of individuals' location within a given habitat to examine mental state. Given that negative experiences would lead to avoidance, the distance of animals from the visitor viewing glass was examined to determine the extent of potential positive, negative, or neutral mental state resulting from visitor presence.

This study examined five different primate species including 5 eastern black-and-white colobus monkeys, 2 Allen's swamp monkeys, 4 DeBrazza's monkeys, 4 Bolivian gray titi monkeys, and 3 crowned lemurs. The time period during which observations took place varied between species, taking place between 2017 and 2020, and individuals' coordinate data within the exhibit was calculated to find the shortest distance to the viewing glass at each recorded point in time. Visitor numbers were concurrently recorded, and analyses were conducted to observe the relationship between number of visitors present and the distance of animals from the viewing glass. Zoo visitors were predicted to be a negative environmental factor that would be associated with an increase in the distance of animals from the viewing glass as the number of visitors increased. Analyses did not support this hypothesis.

In preliminary investigations of a smaller dataset consisting of visitor counts precisely measured to single individuals, no significant relationship was found between number of visitors and subject distance from viewing glass. The bulk of analyses were carried out on a dataset containing more recordings of subject locations paired with estimates of the number of visitors. With this larger dataset, two analyses were run, both of which provided similar results.

The first of two analyses were conducted to address the question of whether the presence of visitors in any quantity results in any significant change in the animals' distance from the viewing glass. This analysis revealed a statistically significant but likely inconsequential decrease in the distance of the subjects from viewing glass, (closeness to visitor viewing glass when one or more visitors are present). The difference in calculated distance, however, was determined to correspond with about .83% of the size of the total enclosure. While enclosures vary in size, this change in distance corresponds to recorded locations of monkeys approximately 5 cm closer to the glass in the presence of visitors. This is a detectable change in behavior of the animals, but bearing in mind this distance is smaller than the length of some of the subject's palms, likely not consequential in observing welfare status. A useful way to visualize the average change in distance is demonstrated in Table 8. While not wholly representative, a simple numerical comparison of primate distance from glass with and without the presence of visitors demonstrates the minute, though measurable, changes.

	Visitors Present	**No Visitors Present**	**Unit Change**
Eastern Black-and-White Colobus	143.20	162.50	-19.30
DeBrazza's	162.54	162.05	0.49
Bolivian Gray Titi	148.27	157.86	-9.59
Crowned Lemur	426.83	425.40	1.43
Allen's Swamp	96.81	112.64	-15.83

Table 8. Median distance from viewing glass

The second analysis of the dataset aimed to observe any difference in distance behavior when data about visitors is grouped into binned crowd sizes (1-5, 6-10, etc.). This type of grouping is typical when making observations about groups (Davey, 2007). In a similar analysis to those previously conducted, a statistically significant but miniscule relationship was found between increasing crowd sizes and a decrease in the distance between monkeys and viewing glass. Statistically, this was about .87% of the total the distance within the exhibits, and depending on the habitat measured, this value again amounts to about 5 cm of distance change.

Analyses do not reveal primate distance from visitor glass to be substantially greater or smaller in the presence of greater number of visitors. Instead, there is evidence of a very slight decrease in recorded distances as number of visitors increases. The presence of visitors may have a statistical effect on the animals described in some analyses, but not a practical one. Initial analyses of exact number of visitors observing animals did not have any significant impact on the distance of animals from visitor glass, but using methods of binned data established by past studies, aided by a more robust dataset, did show a statistically significant effect of slight decrease in distance of animals to glass. Using multiple methods for data analysis allows the fullest scope of understanding, and demonstrates that in the presence of visitors, even as the number of those visitors increases, there is no withdrawal as would be expected from a negative mental state as induced by the visitors outside the glass. There may even be a slight approach of animals, though this change is so small it is likely not meaningful as welfare is concerned. What this does demonstrate is that visitor presence likely does not negatively impact mental state or overall welfare.

The benefits of using location choice and distance from the viewing area extend beyond this study. This practice represents a relatively simple method of gathering data about any species, made easier still as the ZooMonitor program is already used in zoos worldwide and free to any accredited zoo, aquarium, sanctuary or museum. Furthermore, the location of animals and their distance from a point of interest in their environment is an objective and simple measurement that can be used in contexts beyond the zoo. This type of monitoring of space use can help to explain the effect of many different environmental variables on the welfare of the animals observed. This dataset can be constructed consistently across many different species, and the ability to take an objective account of the effect of environmental factors has far-reaching benefits in unifying an area that encompasses many disparate specifics but has a shared goal. Animal welfare is a concern and a priority, and this design is a straightforward way to measure the relationship between stimuli and welfare.

Of importance in considering the impact of these findings are the other factors that may contribute. All of the studied individuals were born in zoos, many at Lincoln Park Zoo in family groups. As each of these animals, like most primates found in zoos today, were born and raised among humans, they are likely accustomed to the presence of groups of observers outside of a large pane of glass, and this environment is typical of their life experiences, even as visitor groups change or increase in size.

The habitats of these primates vary between species, both in size and shape as well as availability of objects to climb or perch on. Furthermore, species and individuals have preferences for utilizing vertical spaces or terrestrial spaces that are not directly recorded in the data. This study examines location on a 2D plane, and distance data is extracted from this information. Vertical distance could slightly alter the total distance from subject to glass, and the space above or below the glass or items in the habitat such as large logs may obstruct a sightline from animal to observing visitors, which may or may not affect the degree to which a negative stimulus might be reacted to. Reactions may also be influenced by factors outside the scope of this study, unable to be measured with current practices for recording location.

Avenues for future study should keep in mind these potential external factors. Of key importance is finding ways to incorporate information about the individual’s height in the exhibit. While a measurement from any height within the scope of the glass would not impact the distance data greatly, an animal above the viewing glass or otherwise obstructed may not be considered engaging in the same level of willingness to be near visitors as front-and-center monkeys. Additionally, there is the possibility that subjects near visitor viewing glass may be displaying subtle signs of discomfort that could only be discovered through careful behavioral analysis, which might reveal visitors to be a negative experience despite proximity. The behavior and activity levels of the observing visitors could as well reveal more information, as one might expect a different response to an energetic child than a less active onlooker.

This method of observation is still a simple and straightforward way of observing the response of animals to an environmental factor. With the same data available regarding location for other species, analyses can easily be conducted for many other species to look at response to visitors or other environmental factors. Adaptable to any location where animals occupy a defined area and there is a question about how some external factor impacts the animals, these methods are adaptable. It may be of interest how animals respond to a new enrichment object or something more foreign like a camera for studies, but the response to new objects or changing outside factors is often of interest, and in most any situation where location data can be gathered over a period of time and across various circumstances, the potential insights gained are valuable.

References

Binding, S., Farmer, H., Krusin, L., & Cronin, K. (2020). Status of animal welfare research in zoos and aquariums: Where are we, where to next?. *Journal of Zoo and Aquarium Research*, *8*(3), 166–174. https://doi.org/10.19227/jzar.v8i3.505

Choo, Y., Todd, P. A., & Li, D. (2011). Visitor effects on zoo orangutans in two novel, naturalistic enclosures. *Applied Animal Behaviour Science, 133*(1-2), 78-86.

Costa, R., Sousa, C., & Llorente, M. (2018). Assessment of environmental enrichment for different primate species under low budget: A case study. Journal of Applied Animal Welfare Science, 21(2), 185-199.Davey, G. (2007). Visitors' effects on the welfare of animals in the zoo: A review. *Journal of Applied Animal Welfare Science*, 10(2), 169-183.

Davey, G. (2007). Visitors' effects on the welfare of animals in the zoo: A review. *Journal of Applied Animal Welfare Science*, 10(2), 169-183.

Gusset, M., & Dick, G. (2011). The global reach of zoos and aquariums in visitor numbers and conservation expenditures. *Zoo Biology*, 30(5), 566-569.

Hashmi, A., & Sullivan, M. (2020). The visitor effect in zoo-housed apes: the variable effect on behaviour of visitor number and noise. *Journal of Zoo and Aquarium Research*, 8(4), 268-282.

Hosey, G., Ward, S. J., Ferguson, A., Jenkins, H., & Hill, S. P. (2020). Zoo-housed mammals do not avoid giving birth on weekends. *Zoo Biology*.

Hutchings, K., & Mitchell, H. (2003). A comparison of the behaviour of captive lemurs subjected to different causes of disturbance at Marwell Zoological Park. In *Proceedings of the 5th Annual Symposium on Zoo Research, Marwell Zoological Park, Winchester, UK, 7-8th July 2003* (pp. 139-143). Federation of Zoological Gardens of Great Britain and Ireland.

Jeffery, S. B., & Price, D. J. (2004). The effect of environmental factors on the behaviour of captive red-fronted lemurs (Eulemur fulvus rufus). In *Proceedings of the 6th Annual Symposium on Zoo Research, Edinburgh Zoo, Edinburgh, UK, 8-9th July 2004* (pp. 280-291). Federation of Zoological Gardens of Great Britain and Ireland.

Lincoln Park Zoo (2020). *ZooMonitor* (version 3.2) [Mobile application software]. https://zoomonitor.org (accessed on 4 June 2021).

López-Álvarez, J., Sanjorge, Y., Soloaga, S., Crailsheim, D., & Llorente, M. (2019). Looking for visitor's effect in sanctuaries: Implications of guided visitor groups on the behavior of the chimpanzees at Fundació Mona. *Animals*, *9*(6), 347.

Marcy, K. (2021, May 26). *Interesting Zoo and Aquarium Statistics*. Association of Zoos & Aquariums. https://www.aza.org/connect-stories/stories/interesting-zoo-aquarium-statistics?locale=en.

Mellor, D. J., Beausoleil, N. J., Littlewood, K. E., McLean, A. N., McGreevy, P. D., Jones, B., & Wilkins, C. (2020). The 2020 five domains model: including human–animal interactions in assessments of animal welfare. *Animals*, 10(10), 1870.

Rose, P. E., Scales, J. S., & Brereton, J. E. (2020). Why the "Visitor Effect" Is Complicated. Unraveling Individual Animal, Visitor Number, and Climatic Influences on Behavior, Space Use and Interactions With Keepers—A Case Study on Captive Hornbills. *Frontiers in veterinary science,* 7, 236.

Ross, S. R., Schapiro, S. J., Hau, J., & Lukas, K. E. (2009). Space use as an indicator of enclosure appropriateness: A novel measure of captive animal welfare. *Applied Animal Behaviour Science, 121*(1), 42-50.

Sherwen, S. L., & Hemsworth, P. H. (2019). The Visitor Effect on Zoo Animals: Implications and Opportunities for Zoo Animal Welfare. *Animals : an open access journal from MDPI*, 9(6), 366. https://doi.org/10.3390/ani9060366

Van Rossum, G., & Drake, F. L. (2009). *Python 3 Reference Manual*. Scotts Valley, CA: CreateSpace.

Ward, S. J., Sherwen, S., & Clark, F. E. (2018). Advances in applied zoo animal welfare science. *Journal of Applied Animal Welfare Science*, *21*(sup1), 23-33.

Wark, J. D., Cronin, K. A., Niemann, T., Shender, M. A., Horrigan, A., Kao, A., & Ross, M. R. (2019). Monitoring the behavior and habitat use of animals to enhance welfare using the ZooMonitor app. *Anim. Behav. Cogn,* 6, 158-167.

Wood, W. (1998). Interactions among environmental enrichment, viewing crowds, and zoo chimpanzees (Pantroglodytes). *Zoo Biology: Published in affiliation with the American Zoo and Aquarium Association*, *17*(3), 211-230.