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SUGAR GLIDER (PETAURUS BREVICEPS) BEHAVIOR IN RED VS BLUE LIGHTING

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SUGAR GLIDER (*PETAURUS BREVICEPS*) BEHAVIOR IN RED VS BLUE LIGHTING

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ABSTRACT

Sugar Glider Behavior in Red vs Blue Lighting

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Sugar gliders are an exotic pet that is increasing in popularity in households as well as in zoos. One challenge that caregivers have to manage is their nocturnal circadian rhythm. In order for people to view or interact with sugar gliders during their active time, many zoos will reverse their diurnal cycle with lights. The discovery of intrinsically photosensitive retinal ganglion cells (ipRGCs) which seems to have an increased sensitivity to blue light and how these cells affect the hypothalamic suprachiasmatic nucleus (SCN) and circadian rhythm has led to an increase in awareness on the health effects of being exposed to blue light from unnatural sources. While the ipRGCs have been studied mostly in mammals, little research has been completed in marsupials, and few studies have been completed on how the choice in light color will affect sugar glider behavior in captivity. In this study, two sugar gliders were observed in three different conditions of illumination; infrared (IR), red, and blue. It was found that red and blue lights were both disruptive to behavior evident by decreased activity, and blue light appeared especially disruptive and stressful evident by the decrease in the frequency of most behaviors and defecation in their feeding box.

Key words: marsupials, sugar gliders, *Petaurus breviceps*, intrinsically photosensitive retinal ganglion cells (ipRGCs), red light, blue light, behavior, artificial lighting

Contents

Introduction

As I was walking around at a fair, there was a booth that seemed to always have a crowd. When I finally decided to see what was so interesting, a woman from the booth walked up to me and places a small soft big-eyed creature in my hand. This was my first encounter with a sugar glider, and I have been fascinated ever since. After getting two of my own, I realized a common problem. It can be difficult to interact and bond with this social nocturnal marsupial. Nocturnal animals rest during the day and are active at night. As humans, we have diurnal sleep patterns which means we rest at night and are active during the day. While the lack of light will encourage humans to rest, the presence of light encourages sugar gliders to rest. While nocturnal animals' vision has adapted to low light conditions, human vision has adapted to be most effective in well-lit environments and is quite insensitive under low light conditions. Other sugar glider owners suggested on internet forums to use dim colored light to interact with them. Because one can't trust everything one reads on the internet, I decided it was time to see for myself if this colored lighting claim had any merit.

Weighing between 95-160 grams (Booth, 2003), many would describe the sugar glider a cute pocket pet. However, they are a lot of work for the average pet owner. They are colony creatures reaching up to twelve members in their natural habitat with one dominate male (Booth, 2003). These arboreal creatures have sharp incisors for penetrating tree bark for access to sap, gum, and insects (Booth, 2003). Their bite can be quite painful although not considered dangerous on its own, and if they are not handled regularly from a young age, they can be aggressive. There is also no accepted pelletized food that fits their dietary needs despite what some commercial companies advertise, and they need freshly prepared food nightly. Despite their small size, they need a large cage as well. Nethertheless, sugar gliders continue to grow more popular as exotic pets. Therefore, research into their appropriate environment in an artificial setting like a household becomes more important. More research is pointing to night light pollution as a cause of change in animal behavior and damage (Longcore and Rich, 2004). The problem is not only found in households but also nocturnal zoo exhibits. If the visitors cannot see the nocturnal animals, they have no reason to visit. Zoos often reverse nocturnal animals' circadian rhythm by artificially illuminating their exhibits at night which will drive them into rest, and then illuminate the exhibit during the day with dim colored lights such as red, yellow, or blue (Fuller, 2016). These techniques might also be used to help a pet owner bond better with their sugar glider but choosing the color of light could play an important role not only to the ability to bond, but also their health.

There is little research specifically on sugar glider vision, but there is research on other closely related diprotodon marsupials. It was found that the honey possum (*Tarsipes rostratus*) has trichromatic vision with long wavelength sensitivity at 557 nm, middle wavelength at 535 nm, and even ultra-violent (UV) sensitivity at 503 nm (Arrese, 2002). They also found that honey possums are insensitive to infrared light emitting diode (IR) light (Arrese, 2002) which is important to note because this permits nonintrusive observations of behavior using IR lighting and IR sensitive cameras.

A recent discovery in mammals has suggested that short wavelength blue light could be stimulating a retinal receptor that projects to the hypothalamic suprachiasmatic nucleus (SCN) which is in charge of their circadian rhythm (Pickard and Sollars, 2019).

When light enters the eye, it activates a G-protein-coupled protein receptor called melanopsin which causes a cascade of effects (Pickard and Sollars, 2019). These intrinsically photosensitive retinal ganglion cells (ipRGCs) work independently of cones and rods and seem to be especially sensitive to blue light in particular (Bailes and Lucas, 2013). With the input from the ipRGCs, the SCN controls the sleep and wake cycle. It makes sense that they are especially sensitive to blue light because sunlight is a natural source of blue light. Many common man-made lights like LED light and the light that comes from the flat panel displays also emit blue light. It's one reason why sleep experts encourage less use of any devices before trying to sleep as it will encourage arousal (Bunyalug and Kanchanakhan, 2017). However, considering sugar gliders are on a reverse cycle, one can assume that the mechanism is reversed causing the opposite reaction to blue light. Light would instead encourage rest in nocturnal animals.

Only having two test subjects can raise some obstacles. A N=1 reversal design was used to overcome this obstacle. Unlike most multiple group experiments, single subject research has one subject experience both the controlled and experimental conditions. The results are then compared to each other. A reversal design is the pattern in which a variable is repeatedly withheld and introduced. Often called ABA reversal designs, the "A" is the first observation period in which a baseline is obtained. During the "B" period, a variable is introduced. At this time, a change is expected. Finally the baseline "A" is reintroduced, and the change is expected to return to baseline. Returning to baseline after the variable was removed increases the validity that the variable was the cause of the change in the "B" period (*Research Methods in Psychology,* 2012). In this study, an ABABACAC design was used. “A” represented IR light setting, “B” as red illumination, and “C” as blue illumination.

Based on what is known about other nocturnal marsupials, it would make sense that adding illumination to the sugar gliders’ environment would decrease their behavior and encourage them to rest more often. With the ABABACAC design, there would be a predicted change in behavior seven times (found between each period). There are three things that could happen at each change of period: increased behavior, decreased behavior, or no change. Every time either blue or red light is introduced, behavior is predicted to go down. Every time the colored light is taken away, behavior would increase again. Given this experimental design and the fact that three possible outcomes could occur across each reversal in the conditions of the experiment, there were 2187 (i.e., 3^7) possible patterns of results that could be observed. It was hypothesized that the frequency of behavior would decrease for all transitions from baseline to lighted conditions and that it would increase across all transitions from the lighted conditions back to baseline. This pattern, if observed, equates to a p-value of less than 0.00046. In addition, due to the nature of the intrinsic retinal ganglion cells and their increased sensitivity to blue light, it is also predicted that blue light will cause a larger decrease in behavior than red light.

Methods

The participants included two sugar gliders: one female (5 years old) and one male (4 years old). While the light settings would be changed for the experiment, many things in their environment stay consistent with how they were for the past two years: cage, temperature-controlled building, natural light from a window, and diet replaced with fresh food every 24 hours at 11 P.M. As discussed in the introduction, sugar gliders are likely to be insensitive to IR lighting so two IR lights were positioned to illuminate the cage for the camera. A Wyze night vision camera was used to record the sugar gliders' behavior. The Wyze camera also had 4 LED IR lights, but did not provide enough illumination to accurately identify behaviors on its own. Two additional IR lights were directed towards the enclosure. For the entirety of the study, these IR lights remained on and in their same positions. Colored lights were scheduled according to the reversal design pattern to be on for two intervals of one full week with a week interval of IR only light between (Table 1). Two programable LED lights with red, blue, green color options and 3 dimming settings were set up. For week 2 and 4, the lights were set to red and dimmed to 11.4 lux. For week 6 and 8, the lights were set to blue and dimmed to 11.3 lux using a Minolta TL-1 lux meter. Behavior counts were collected using an ethogram purposed for sugar gliders (Table 2). They were observed between 6 P.M. and 8 A.M. during their usual active hours. Behaviors were noted in one-hour intervals.

Table 1: Light schedule

Week	1	2	3	4	5	6	7	8
Light	IR	IR + Red	IR	IR + Red	IR	IR + Blue	IR	IR + Blue

Table 2: Ethogram for behavior data collection

Behavior	Operational Definition
Social	Social play/grooming, reproductive behaviors.
Move	Motion in any direction such as climbing or backing up.
Feed	Eating or drinking (or in feed box - assumed to be eating).
Self-Directed	Self-grooming (scratching the self-using grooming claw or nails, facial rubbing on an object other than the other sugar glider).
Object Examination	Interacting with an object.
Rest	No motion – may have eyes open or closed – but is not in nesting pouch.
Other	Behavior that has not been defined above.
Not Visible (pouch)	No movement inside of nesting pouch for over a minute (assumed to be resting).
Not Visible (out)	Out of sight, but not in the nesting pouch.

Results

Figure 1: Frequency of activity in one week

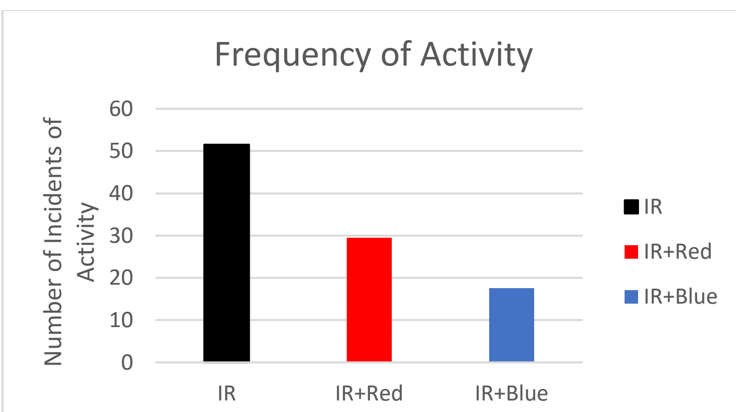

Figure 1 shows the frequency of activity per week of observation for each of the three experimental conditions. Activity was defined as any behavior that occurred outside of the nesting pouch.

Figure 2: Average nightly routine of activity

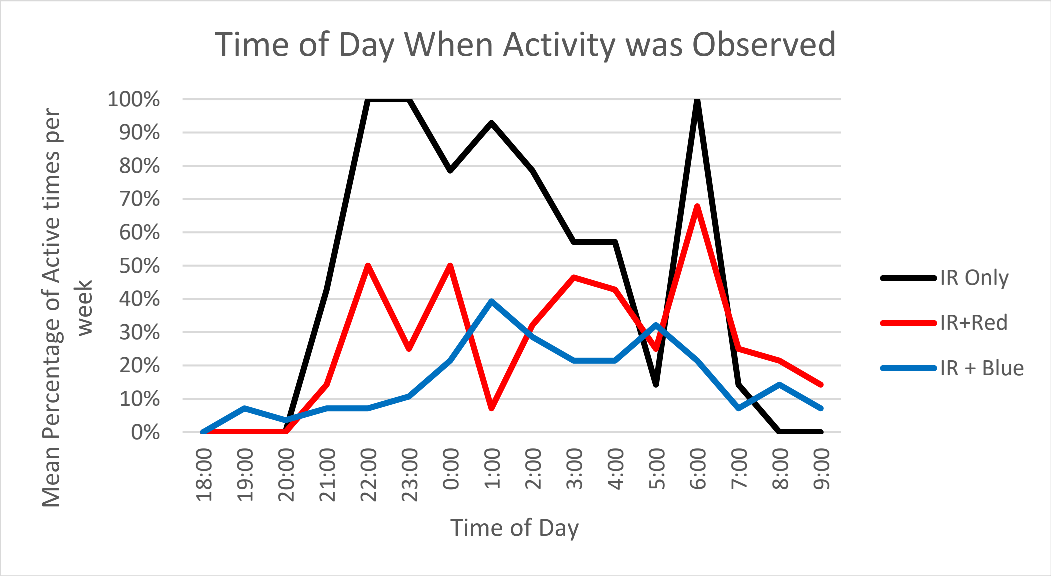

Figure 2 shows how often on average the sugar gliders were active during a particular time. When average percentage is 100%, it represents that there was always some type of activity at that time.

Figure 3: Activity per day

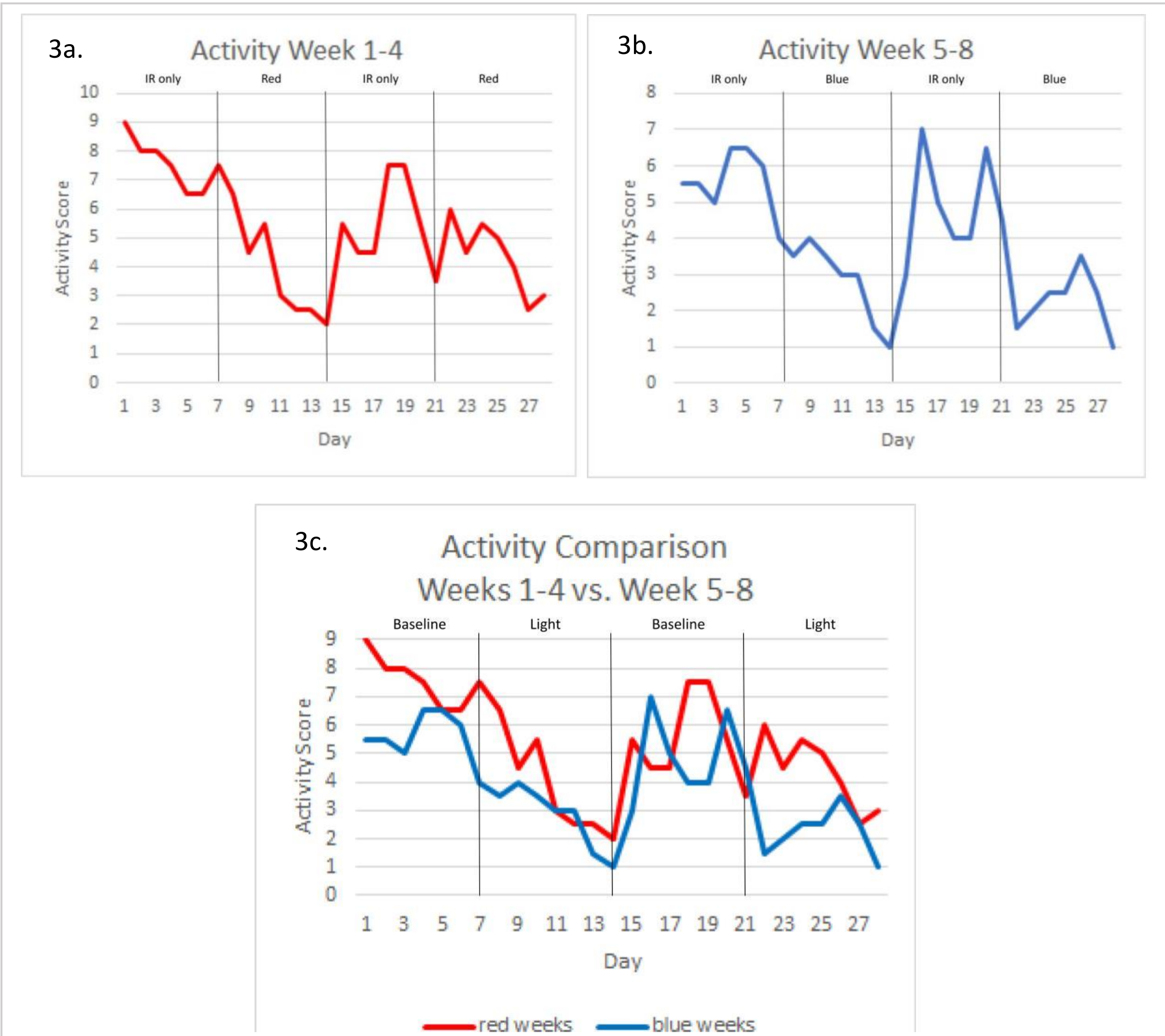

Figure 3 groups the data by each day of the experiment. The first week red light was introduced, activity decreased. The second week red light was introduced, the decrease was not quite as remarkable (3a). There was a relative decrease in activity for both weeks that blue was introduced (3b). This predicted pattern of the colored lights decreasing activity each time it was introduced and activity returning to normal when the light was removed was exactly as predicted and only had a 1/2187 possibility of happening by chance (i.e. $p < 0.00046$). When overlapped and compared, it can be noted that there was usually slightly more activity occurring most days during the red phase from day eight to fourteen, however from day twenty-one to twenty seven, behaviors in the red light occurred more frequently everyday (or equally which occurred once on day twenty-seven) (3c).

Table 3: Average times an activity was recorded per week

Average Times an Activity was Recorded per Week (N=2)			
Behavior	IR	IR + Red	IR + Blue
Social	4	1	0
Move	22.25	16.5	4.5
Feed	33.25	28	24
Self-Directed	6.75	4.5	0
Object Examination	11.25	3	0
Rest	3.75	3.5	6.5
Other	0	0	0
Not Visible (pouch)	141.5	167.5	189
Not Visible (out))	0.5	0	0

Table 3 was calculated by the number of times and activity occurred and averaged out by the number of weeks. This is not per sugar glider and counts total activity seen by both. IR and blue light consistently saw decreased activity for every behavior except in the categories rest and not visible (pouch).

Discussion

Compared to the IR only environment, red and blue both appeared to decrease the activity of the sugar gliders. However, blue light seemed to decrease their activity relatively more (figure 3c). The sugar gliders exhibited considerably less activity during blue light phases and were noted to move less often and more slowly. These results are consistent with a similar study completed with the nocturnal primate aye-aye (Daubentonia madagascariensis) that showed increased lethargy and decreased activity (Fuller, 2016). The aye aye also experienced increased stress in the colored environments evident by cortisol levels (Fuller, 2016). While the sugar gliders' cortisol levels were not being collected, there is reason to believe they also experienced increased stress. Sugar gliders are certainly not well-mannered eaters and are actually quite known for the mess they make as they eat, but they do not defecate or urinate in their feeding box. However, the sugar gliders were noted to defecate and urinate in their feeding box multiple times during the blue phase.

In fact, the majority of their time spent outside of their nesting pouch was spent in their feeding box (table 3). They were not noted to take part in many enrichment activities such as social play and resorted to only leaving their nest pouch for basic needs like eating. Although it was not represented in the tables and figures, the sugar gliders tended to freeze after exiting their nesting pouch as if adjusting and then either return to their pouch or make their way to the feeding box where they stayed for long periods of time even when they were noted to no longer be eating. These types of behaviors were noted to be similar in Fuller's study as well in the blue setting (2016). These moments of freezing and/or adjusting did not seem as evident during the red phase or dark phase suggesting the blue light was extremely disruptive.

Each figure and table displayed in the previous pages consistently told the same story, but there are two noteworthy things that can be seen from Figure 2; their schedule disruption and decreased overall activity. As noted in Figure 2 in the IR only light phase, the high and low percentages showed consistencies in their schedule. Even across 4 weeks, they were active every time at 2100, 2200 and 0600. At 0500, there was a one in seven chance that they would be active. During the red and blue phase, their active times became difficult to predict, and they were inactive more often than not which is especially apparent in the blue light phase.

Due to the especially disruptive nature of blue light on sugar glider's circadian rhythm, there is reason to believe they also pRGC have intrinsic cells that are especially sensitive to blue light. They seemed to have increased periods of arousal during the daytime when natural light through a window was shining as well, but because this study did not closely monitor daytime activity, there is not numerical evidence to support this. If the study were to be repeated, monitoring and data collection should occur for all twenty-four hours of the day.

Earlier in the discussion, it was noted that the sugar gliders had defecated in their kitchen during the blue light phase. This behavior is difficult to attribute to the blue light only due to the reversal design pattern chosen. One could claim the defecation was due to prolonged manipulation because the blue phase was towards the end of the study. To combat this alternative explanation, a pattern of ABACABAC or ABCABC should be tested with "A" being baseline, "B" as red light, and "C" as blue light. In order to further explore the differences between blue and red light while also avoiding prolonged manipulation, BCB is another pattern that should be tested.

There are several areas of this study where improvement could be made. First, longer periods of each phase should have been observed until the behaviors became more consistent. In figure 3, the line tends to trend down as activity decreases, but there was not enough time allowed for the line to level out and become more consistent. Second, during daytime hours, day light was the main source of light and therefore unpredictable. Zoos use artificial white light to drive their nocturnal animals into rest and therefore it is more reliable and predictable for gathering evidence. It would be interesting to also add enrichment activities such as hidden treats to see if this would encourage activity in each setting. Another question that should be studied is which, dim blue light or dim white light (which contains blue light in it as well), is more effective at driving the sugar gliders into rest.

This is a relatively new idea, but it is important to continue researching. It's long been known that light is causing sleep disruption and many studies have been done to confirm this. Little research has been done and published about the color of light also having an impact. Many animals are affected by this lack of knowledge not only in households, but also zoos. As caretakers, it is their jobs to mitigate the stresses of captivity as much as possible.

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