Light, dark, exercise and the body clock

Dimana Atanassova
School of Psychology, University of Glasgow

Introduction

In every animal, including humans, there is an internal biological clock that dictates our patterns of sleep and activity, and which is crucial for a whole range of other functions, such as regulation of body temperature and hormonal release. The internal biological clock, or the circadian clock, receives light information from the retina and synchronises all bodily processes with respect to the environment.

Light is the primary environmental cue which the biological clock uses to synchronise, and it's not surprising that disruption of the light-dark cycle results in severe disturbances of the circadian rhythms. Shifts in the day-night cycle (such as during shift work) or exposure to light during the night (such as by using laptops and smartphones, and watching TV) or dim light during the day (when spending time in an office) have been shown to lead to elevated weight gain; problems with sleep and insomnia; changes in metabolism; as well as and risk of cardiovascular disease and increased all-cause mortality.

The effects of circadian disruption are pronounced and are likely to exist in most of us, given the fact that we live in the modern world, which is characterised by bright nights and dim days. The effects of circadian disruption – increased weight gain, hormonal problems, and changes in sleep patterns – however, may be moderated by improved strength of the circadian rhythm. It is believed that exercise might be another environmental cue which, if light is not available, can be used by the biological clock to synchronise the bodily processes and improve the circadian rhythm.

What am I interested in?

I was interested to see what effect exposure to dim light at night would have on mice, and whether these can be influenced by the presence or absence of a running wheel, which they could use to exercise. Most rodents will voluntarily use running wheels if they are placed in their cages, which makes running wheels an easy and effective way of tracking mouse activity. If exercise does indeed improve synchronisation of the biological clock, it may suggest that exercise might alleviate some of the adverse side effects of a disrupted light-dark cycle – in this case, I could test if disrupted mice with a running wheel to aid in synchronisation would gain different amounts of weight than those without.

What did I do?

To investigate the effect of exercise as a synchroniser on the circadian clock, I used four groups of mice. Half of the mice were housed in a normal LD cycle, while the other half were exposed to dim light at night. Dim light at night was illuminated as 25 lux (the SI unit of illuminance). For comparison, lux outside in the sun would measure approximately 100K lux, while even a cloudy day outside would be about 1500 lux.

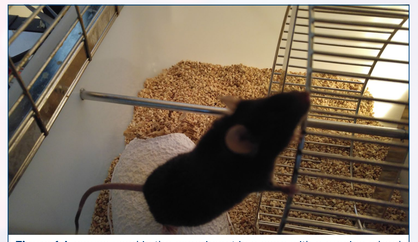

Figure 1 A mouse used in the experiment in a cage with a running wheel.

In addition, half of each group were housed in cages which were equipped with a running wheel, which they could use at all times (see Figure 1). The other half were housed in normal flat-bottom cages and did not have access to a running wheel.

The experiment lasted for 30 days and I measured the activity of the mice (their movements inside the cage) via special infrared scanners, as well as their weight at the beginning, at two points during and at the end of the experiment.

What did I find?

At the end of the experiment, I found that the mice kept in dim light at night without the running wheel gained considerably more weight than the other three groups. The mice that were held under a normal LD cycle (who I would expect had strongly synchronised biological clocks linked strongly to the environment) with a running wheel showed little change in weight, while those held under dim light at night with an exercise wheel lost weight, but not a significant amount. The mice kept under normal LD cycle without a wheel gained weight, but not a significant amount, and not nearly as much as the mice kept in dim light at night without the running wheel (see Figures 2 and 3).

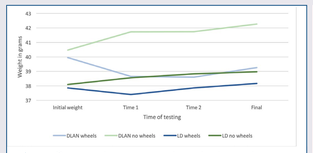

Figure 2 shows the changes in weight over the course of the experiment of the mice kept in dim light at night (DLAN), normal light-dark cycle (LD), with and without an exercise wheel.

Figure 3 the total weight change per group at the end of the experiment of the mice kept in dim light at night (DLAN), normal light-dark cycle (LD), with and without an exercise wheel.

This difference in weight gain could not be attributed to a change in overall activity as there was no significant difference in overall activity levels between the groups (see Figure 4). Given work by others has demonstrated consistently, via activity patterns and gene expression, that animals housed in dim light at night are less well synchronised and have a weaker circadian rhythm, and there was not significantly more activity among the mice with the wheels, I attribute the protection against weight gain seen in the dim light with wheel group to an improvement in the strength of the circadian rhythm in these mice.

Given this, I might have expected to see a significant difference in the percentage of daily activity consolidated during the night (which is the active phase in nocturnal rodents) across the four groups. I would have predicted that activity would have been more distributed around the 24 hour day in the dim light condition; however, there was no significant difference in the distribution of activity between those animals that had a wheel and those that did not under the dim light at night condition. Therefore, I suggest that additional measures of the circadian rhythm, including the interdaily variability (indicates fragmentation of an individual's rhythm), intradaily stability (provides an indication of the strength of the linkage of the circadian rhythm to light dark cycle) and amplitude (strength of rhythm), are tested in a sufficiently powered prospective investigation.

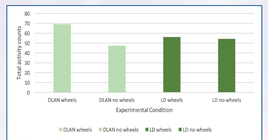

Figure 4 shows the activity of the four groups of mice kept in dim light at night (DLAN), normal light-dark cycle (LD), with and without an exercise wheel.

What does it mean?

This work is important as the circadian system is very well conserved across species. Thus, experiments on rodents often have significant implications for humans who share a similar response to light and dark. If exercise is able to overcome some of the negative health effects of LD disruption this could be a useful for people struggling with insomnia or sleep issues due to circadian disruption, or help shift workers improve the functioning of their internal biological clocks, and it is important to elucidate the mechanism of action.

Who am I?

I am a fourth-year undergraduate Psychology student at the University of Glasgow. My Vacation Scholarship project and my final year dissertation, the work of both of which are presented here, are both supervised by Professor Stephany Biello and look at the circadian clock in mice. Upon completion of my undergraduate degree, I would like to continue with a postgraduate programme in Psychology and Neuroscience and look further into the biological substrates of circadian rhythms and potentially their relevance to mental disorders.

Dimana was supervised during her Vacation Scholarship project, *"The Effects of Exercise on Measures of Circadian Rhythm Disruption in Mice"*, by Professor Stephany Biello.