A COMPARISON OF THE DISTRIBUTION OF CHRONOTYPES IN TWO GEOGRAPHICAL LOCATIONS

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INTRODUCTION

Chronotype is a term used to categorize people by their preferred sleep/wake and activity times; those favoring early times are called morning-types and those favoring late times are called evening-types.[1] Chronotype, or morningness/eveningness, has been experimentally shown to have a neurobiological basis. Specifically, morningness/eveningness has a basis in inter-individual differences in the phase of the circadian pacemaker.[2] The involvement of the circadian pacemaker implies a potential role for light exposure patterns, as light is a dominant Zeitgeber (circadian time synchronizer) in humans.[3]

The effect of light on the phase of the circadian pacemaker varies as a function of the timing, duration and intensity of the light exposure.[4,5] A mathematical function called a phase response curve (PRC) describes the relationship between the timing of light and its effect on circadian phase.[4] It shows that light exposure in the morning leads to a phase advance (placing the circadian rhythm earlier in time), whereas light exposure in the evening leads to a phase delay (placing the circadian rhythm later in time).

Sleep/wake timing preferences may influence light exposure patterns, and vice versa. Evening-types have been found by some investigators to sleep relatively early in their endogenous circadian cycle compared to morning-types.[6,7] They should therefore be exposed to (day)light across a greater part of the phase *advance* portion of their PRC for light.[7] Paradoxically, this would be expected to advance the preferred timing of sleep, which seems inconsistent with being an evening-type person.

If light exposure patterns are nonetheless causally involved in determining morningness/eveningness, then it is reasonable to assume that geographical locations with different daylight patterns may differentially influence the morningness/eveningness distribution of the population. Indeed, questionnaire-based research has revealed variation in the distribution of morning- and evening-types as a function of location.[8] It has been theorized that this reflects uncoupling of circadian phase from entrainment to natural daylight ("sun time") in larger cities, leading to dominance of behavioral cycles over environmental light-dark cycles and resulting in a wider morningness/eveningness distribution with more delayed chronotypes.[8,9]

In the context of this idea, we employed a morningness/eveningness questionnaire to compare chronotype distributions between two geographical locations in the U.S.A.: Philadelphia, Pennsylvania and Spokane, Washington. Although these cities are both located on the eastern edge of their respective time zones, they differ in latitude, daily daylight exposure, and population density. In summer, Philadelphia has up to 58 minutes less sunlight per day, with the sun rising up to 40 minutes later than in Spokane. In winter, Spokane has up to 55 minutes less sunlight per day, with the sun rising up to 16 minutes later than in Philadelphia. Philadelphia's population is roughly seven times greater than that of Spokane, with approximately 3.4 times as many people per km^2. See Table 1.

METHODS

Data were taken from 543 telephone-screened, healthy, non-smoking subjects with regular sleep schedules, who had not engaged in shift work for at least three months and had not traveled across time zones in the month prior to screening. Subjects were between the ages of 18 and 40 (M=28.3, SD=5.9) and 62.7% of the sample was male. The data set included 150 subjects from Philadelphia and 393 subjects from Spokane.

In order to assess chronotype, subjects completed the Composite Scale of Morningness (CSM)[10] as part of an on-site screening process to determine eligibility for various laboratory studies.

The means of the CSM scores were compared between locations, using an independent t-test. The variances of the CSM scores were also compared between locations, using Levene's test for equality of variance. Both tests employed a type I error threshold of 0.05.

Table 1. Population and sunlight by location.

	Philadelphia, PA	*Spokane, WA*
Geographical Location	40°00'N, 75°09'W	47°40'N, 117°25'W
Population Density	4,405/km^2	1,308/km^2
Total Population	~1.5 million	~200,000
Summer Sunrise Time	05:32	04:52
Winter Sunrise Time	07:19	07:36
Summer Daily Sunlight	15h 1min	15h 59min
Winter Daily Sunlight	9h 20min	8h 25min

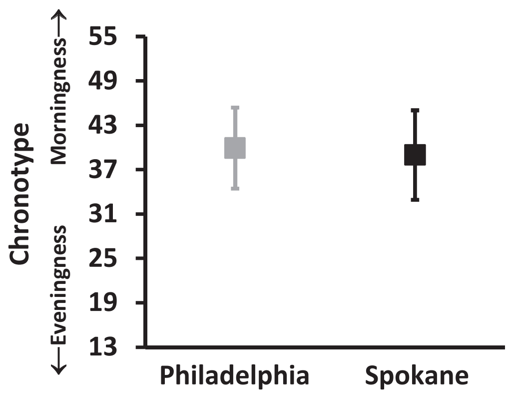

Figure 1. Means ± SD for CSM scores by location.

RESULTS AND DISCUSSION

CSM scores in Philadelphia (M=39.9, SD=5.5) were not significantly different from those in Spokane (M=38.9, SD=6.1), although there was a trend for slightly more eveningness in Spokane (t_{541}=1.67, P=0.096). The variance in CSM scores did not differ significantly between the two locations ($F_{1, 541}$=2.2, P=0.139). See Figure 1.

Our results showed no significant differences in chronotype distribution between Philadelphia and Spokane, despite differences in daylight patterns and population size and density. Notably, our results did not conform to the idea of greater uncoupling of circadian phase from

entrainment to natural daylight in larger cities resulting in a wider morningness/eveningness distribution with more delayed chronotypes.
The dose of light required to substantively affect circadian phase has long been debated.[11] Recent studies have shown that even common indoor lighting has the potential to entrain circadian rhythms[5,12,13] (and possibly offset seasonal change as well[13–15]). Furthermore, mathematical modeling research has shown remarkable robustness of the circadian pacemaker to variable day-to-day light exposure patterns.[16] These findings suggest that light exposure patterns are only part of the story, if causally relevant here at all. Other factors such as genetic make-up[17] and social desirability and constraints[18–21] may also determine sleep/wake timing preference and thus chronotype.

CONCLUSIONS

Our findings are not in line with the theory of greater uncoupling of circadian phase from entrainment to natural daylight in larger cities.[8] This theory is based in analyses of a wider range of geographical locations and thus cannot be dismissed on the basis of a single location pair. That said, the purported effects of population density, through altered sunlight exposure, on circadian entrainment may be significantly moderated by exposure to artificial light and/or social Zeitgebers. This may actually be advantageous in research on circadian rhythms and sleep, in that it would lessen concerns about systematic circadian confounds when combining samples from multi-site investigations.

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