

An Interdisciplinary Perspective on the Association Between Chronotype and Well-being

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Individuals with a circadian preference for mental and physical activity later in the day (“Evening types”) are consistently found to fare worse on most facets of well-being than individuals with a circadian preference for mental and physical activity earlier in the day (“Morning types”). Several explanatory hypotheses of this association between chronotype and well-being have been proposed, including shared genetic, biological, developmental, and psychosocial mechanisms. This paper presents a critical summary of these explanatory mechanisms and offers suggestions for their integration in an interdisciplinary biopsychosocial framework.

Sufficient evidence now exists for a robust and highly replicable association between chronotype and well-being. Across a variety of cultures, geographic locations, and age groups, a circadian orientation that favors early waking and activity is associated with better mental and physical well-being, while the opposite is common among those with a circadian orientation that favors later waking and activity [1]. Many potential explanatory hypotheses have been proposed for the association between chronotype and well-being. The aim of this paper is to critically summarize the main theories and suggest strategies for their integration using an interdisciplinary biopsychosocial framework.

CHRONOTYPE

The chronotype construct refers to individual differences in diurnal preference for mental and physical activity. Some people achieve peak mental and physical arousal earlier in the day (Morning Types, or MT) and who thus organize their activities for this part of the day. At the opposite end of the spectrum are those people whose mental and physical arousal peaks later in the day (Evening Types, or ET), approximately 2 hours later according to 24-hour profiles of core body temperature and melatonin synthesis [2], and whose activity preference is thus oriented towards later parts of the day. Approximately 20 percent of the general population may be classified as MT and another 20 percent as ET, with the remaining

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†Abbreviations: MT, Morning type; ET, Evening type; NT, Neither type.

Keywords: chronotype, well-being, circadian, biopsychosocial

Author Contributions: BB conceived the idea and wrote the manuscript.

majority classified as Neither Type (NT) and who thus have no strong diurnal preference for early or late mental and physical activity [3]. Chronotype is a heritable trait, as demonstrated in twin studies [4] with several candidate gene polymorphisms proposed [5]. Non-genetic factors such as family and work schedules also play a significant role in determining chronotype, particularly in middle adulthood [6], as do developmental processes in adolescents [7].

Like any trait construct, diurnal preference exists along a continuum with quantitative high and low endpoints – in the case of chronotype, between the two extremes of *morningness* and *eveningness*. As such, classification of people into “types” is a fundamentally inaccurate conceptualization of the trait [8]. Nevertheless, operationalization of the morningness-eveningness continuum as categorical types has significantly aided our understanding of this trait construct. For example, MT and ET clearly differ in expected ways across many biological indices – in comparison to ET, MT is characterized by earlier sleep/wake times, core body temperature peak/nadir, and melatonin synthesis [2,9]. Cognitive and behavioral performance also differ in expected ways between the two types [10].

CHRONOTYPE AND WELL-BEING

Another way in which MT and ET differ is in their associated well-being outcomes. Subjective well-being is broadly defined as the presence of frequent positive affect and the relative absence of negative affect, in combination with a cognitive evaluation of overall satisfaction with life [11]. Across myriad measures and conceptualizations of well-being, ETs fare worse than their MT counterparts. Knutson and von Schantz [1], for example, recently showed that eveningness was associated with higher incidence of both psychological and physical disorders, and a higher mortality rate in a large population-level study using the UK Biobank data.

The magnitude of the association between chronotype and well-being is small-moderate. Drezno *et al.* [12] reported a partial correlation of $r = .17$ – morningness thus explained less than 3 percent of the variance in life satisfaction after controlling for age and sex of participants. Similarly, small-moderate partial correlations are common in the associated literature [13-16]. Jankowski [17] used a within-subject design to monitor changes in well-being associated with a shift towards Polish summer time among students aged between 19 and 31 years. The move to summer time was used as a naturalistic experimental manipulation that shifted participants towards a morning orientation. Despite a shift to earlier sleep/wake timing as a result of the change in clocktime, no associated changes in mood or life satisfaction were observed.

In association with the small-moderate correlations, these longitudinal findings suggest there is significant and poorly understood complexity in the relationship between chronotype and well-being. Clearly, there is a need for greater clarity around the mechanisms that underpin the association between chronotype and well-being.

THEORIES EXPLAINING THE CHRONOTYPE/WELL-BEING RELATIONSHIP

Explanatory hypotheses of the relationship between chronotype and well-being cover many fields and disciplines. Not surprisingly, given the circadian origins of the chronotype construct [18], biological explanations that reference variations in photoperiod, light exposure, and misalignment between circadian and sleep/wake systems are prominent in the literature. Shared genetic processes may also explain the relationship between chronotype and well-being. Developmental theories reference the longitudinal variations in diurnal preference that occur with advancing age, and psychological models reference the influence of personality traits. These theories are summarized below. A further theory, drawing on what we know about social influences on health and well-being, is also introduced.

Biological Theories

Biological hypotheses for reduced well-being in ETs fall broadly into two classes. Firstly, inadequate exposure and/or non-optimal timing of light affect the stability of the circadian system, causing chronodisruption and an impaired circadian system [19]. ETs, by virtue of later sleep/wake times, are exposed to less natural daylight than MTs and more artificial light at night when the circadian system should be initiating sleep [20]. Light at the short wavelength (blue) end of the visible spectrum, such as those employed in LED devices, appears to have the greatest disruptive effect on the circadian system [21]. The 24-hour light/dark cycle is an important entraining influence on the suprachiasmatic nuclei (SCN), the so-called “conductor(s) of the circadian orchestra” [22, p. 110]. The SCN strongly influence not only physiological arousal, but also mood and emotion regulation [23], all of which are important drivers of well-being. A second biological hypothesis for the apparent reduction in well-being among ETs is the lack of adequate sleep that occurs as a result of misalignment between the internal circadian clock and social time. Lack of adequate sleep has multiple negative consequences for health and well-being [24]. ETs, despite waking at a later clocktime than MTs, wake at an earlier relative circadian phase position due to the delayed timing of their circadian system and the need to

get up early in the morning, largely for work and social reasons [25,26]. The resulting misalignment has been termed social jetlag due to its apparent similarities with transmeridian jetlag [16]. The latter of course is temporary and only sporadically experienced by most people, whereas social jetlag is more persistent and widespread, and thus has longer-term consequences for well-being.

Genetic Theories

Shared genes between chronotype and aspects of well-being also explain how these processes are mechanistically related. Lane *et al.* [27], for example, reported analyses linking gene sets associated with chronotype and those underlying nervous system activity using data from the large UK Biobank study. In particular, shared genetic processes underlying chronotype, mental illness, the fear response, and the behavioral defense response were found using a genome wide association strategy. Shared genetic mechanisms underlying chronotype and other characteristics of well-being, including mood [28] and metabolic disorders [29] have also been reported. Alternatively, a study of the association between chronotype and environmental predictors of well-being (*e.g.*, general health, drug and alcohol use) among young adult monozygotic twin pairs found complex gene-environment interactions explained most of the variance in these relationships [30]. So, while biological and genetic explanations are fundamental to our understanding of the association between chronotype and well-being, they offer only a partial explanation and complementary mechanistic explanations are necessary for a comprehensive understanding of this important association.

Developmental Theories

Shared developmental processes also contribute to the association between chronotype and well-being. The lifetime trajectory for chronotype tends to follow a consistent pattern of a morningness preference in childhood, followed by a shift towards eveningness during adolescence, and a return to morningness in early adulthood that gets more pronounced with age [7,31]. It is unclear whether the tendency towards a morning preference with advancing age is biologically driven (*e.g.*, shortening circadian period) or socially mediated via family and work schedules. The shift towards eveningness during adolescence appears to be largely driven by pubertal processes at this critical stage of physiological maturation [32,33]. The significant hormonal changes occurring at this stage of development are also associated with neurobiological changes that affect social and emotional well-being [34]. The associated shift towards eveningness at this stage of development further compounds negative well-being outcomes in adolescents [35]. The confluence of devel-

opmental circadian and neurobiological processes in the transition to adulthood appears therefore to be an important driver of the association between chronotype and well-being.

Psychological Theories

Personality is a strong predictor of well-being and reliable associations exist between specific personality traits and chronotype. Personality traits that are characterized by facets of discipline, persistence, and dutifulness – *e.g.*, conscientiousness, constraint, control – are most reliably associated with morningness [3,36]. These traits are also positively associated with well-being [37]. Neuroticism is associated with poorer long-term mood outcomes and overall well-being [38]. Emotion dysregulation, a core component of neuroticism and associated traits, may be associated with eveningness and depression [39], potentially via shared neural mechanisms [40]. Extraversion contributes positively to well-being [37] but interacts with eveningness in interesting ways to affect well-being outcomes. Drezno *et al.* [12] recently showed that extraversion moderated the association between chronotype and life satisfaction such that the positive effects of extraversion on life satisfaction increased with greater levels of eveningness. Being an evening-oriented introvert on the other hand, resulted in significantly reduced well-being. The authors suggest that the “unstructured nature” of social activities at night (p. 9) and the larger social networks of extraverts may explain this difference in well-being outcomes between introverted and extraverted ETs. Drezno *et al.* also showed that the traits of conscientiousness and emotional stability partially mediated the positive relationship between morningness and life satisfaction, suggesting a prominent role for these personality traits in linking chronotype and well-being. They suggest that early manifestations of eveningness in children influence the developing personality via the negative effects of social jetlag on conscientiousness and emotional stability. Shared maturational processes [*e.g.*, changes in emotion regulation and sleep; 41] and common biological substrates [*e.g.*, serotonergic pathways; 42] between chronotype and personality are further suggested as explanatory mechanisms, although further research is required.

Psychosocial Theories

Social factors may also help explain the association between chronotype and well-being. Social connectedness, for example, is a particularly powerful predictor of health and well-being [43]. Recent data suggest that a lack of social connection has a significant impact on mental and physical well-being, with at least as much influence as traditionally cited lifestyle factors such as lack of

exercise and poor diet [44]. As reported above, Drezno *et al.* [12] showed that extraverted ETs report better overall well-being than introverted ETs. From this perspective, it appears that the social advantages of being extraverted protect against the isolation commonly experienced in the evening, while the isolation preferred by introverts is not conducive to social connectedness and the positive well-being outcomes that result from these connections. Regularity of social behaviors may also help entrain the circadian system [45], albeit weakly compared to other prominent *zeitgebers*. A stable lifestyle is not only biologically important for individual health and well-being [19], it is also important for the social, financial, and educational rewards received for such stability [*e.g.*, 46] and the subsequent benefits these factors carry for well-being [47]. Indeed, Velten *et al.* [48] showed that social irregularity was the strongest independent predictor of reduced life satisfaction in a population survey of 7,937 German adults, stronger even than the independent effects of physical activity, mental/cultural activity, smoking, alcohol consumption, and body mass index. Social and lifestyle irregularity are also associated with poorer mood outcomes in vulnerable populations [49]. Unlike biological, developmental, and psychological explanations, social factors are not proposed to share a causal pathway explaining the association between chronotype and well-being. Nevertheless, the powerful moderating effect of social factors on well-being in particular, means they cannot be excluded from discussions on their association.

INTEGRATION AND SUGGESTIONS FOR FUTURE RESEARCH

The foundations of the chronotype construct are evidently biological, and shared biological and genetic substrates explain a substantial proportion of the association between chronotype and well-being. Worth noting however, is the small amount of variance in chronotype explained by markers of circadian function measured under carefully controlled laboratory conditions [*e.g.*, 36], and the implications this has for biological explanations of the association between chronotype and well-being. Other explanatory mechanisms are required for a comprehensive understanding of how chronotype contributes to well-being.

Consideration of the interactions between biological, genetic, developmental, and psychological mechanisms for the association between chronotype and well-being is necessary for a wholistic understanding of this important relationship [30]. Along with the empirically-tested explanations addressed above, it is possible, for example, that childhood temperament precedes the establishment of the circadian phenotype. That is, the brain reward systems underlying early personality development [*e.g.*,

dopaminergic pathway models of approach motivation; 50] determine the most appropriate times of the day to seek reward and avoid non-reward. Learned associations between timing and reward then directly influence the developing circadian phenotype via early morning exposure to light. In such a model, the role of circadian drivers in determining chronotype is diminished, as are biological explanations of the association between chronotype and well-being. Social factors are also important. Loss of social connections may be particularly profound during the transition from adolescence to adulthood, a period of significant social volatility [51]. Individuals that remain evening-oriented during the transition to adulthood may lose these important connections as their social group naturally gravitate with age towards a morning orientation. The loss of established social connections can have a profound effect on well-being, particularly among those with an introverted personality. Clearly these are untested hypotheses that require investigation. Nevertheless, they suggest broad agendas for future research that will assist the field in further delineating the key contributing factors to chronotype development, and how such factors drive the chronotype-well-being relationship.

Future investigations should consider the chronotype-well-being relationship within a multi-level framework of human behavior in the environment. Both well-being and chronotype are inextricably embedded within sociocultural and ecological contexts that modify their expression. Cross-cultural investigations of chronotype and well-being may help delineate these contexts from the mechanistic relationships of interest [*e.g.*, 52]. The biological component of chronotype is also subject to modification via epigenetic phenomena that influence expression of the open circadian system over time [*e.g.*, 53]. Investigation of dynamic brain plasticity processes among circadian clock components in response to significant changes in work hours or geographical latitude may be useful here [*e.g.*, 54]. An interdisciplinary biopsychosocial framework, similar to that described by Lindau *et al.* [55], and which takes into account the genetic and biological antecedents, developmental stage, and psychosocial milieu of the individual, provides a broad prospective strategy for research into the mechanisms driving chronotype effects on well-being. Recent work also suggests that the strength and direction of the relationship between chronotype and mental well-being may vary according to the distribution of chronotypes in the sample [56]. Within the suggested biopsychosocial framework, consideration of chronotype score distributions in individual samples may therefore also be important. The implications of adopting these strategies are not only relevant to future research endeavors in this area, but also the educative health and well-being goals of modern medical practice.

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