Dynamical Modeling of the Relations Between Leisure Activities and Health Indicators

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In an extension of maladaptive behavior determinism (MBD) theory, which states that ordered behavior patterns over time are suggestive of disease states, we examined the relation between leisure activity and health behavior over time. MBD is derived from complexity or chaos theory. It was hypothesized that, over time, increased activity levels would be related to more randomly occurring health behaviors. For 68 participants, daily self-monitoring of leisure activities and four health indicators (healthy eating, feeling hassled, positive mood, and drinking alcohol) were assessed for five weeks and modeled using multiple time series methods. Results showed some support for the hypothesis, particularly with respect to the health indicator feeling hassled. The findings extend support for MBD, and also suggest that physically very active leisure time might have health benefits that are dynamical and not necessarily immediately apparent.

KEYWORDS: Leisure activity, health indicator, dynamical modeling, chaos, complexity.

Introduction

The increased appreciation of the benefits of leisure activity and active living (Di Bona, 2000) are well known and reflected in an increase in exercise participation and a positive response to public health promotion efforts (Frankish, Milligan, & Reid, 1998). The benefits of leisure activity include alleviation of anxiety (Kaufmann, 1988), increased well-being (Coleman & Iso-Ahola, 1993), identity development (Kleiber & Rickards, 1985), improved physical and mental health (Caldwell, Smith, & Weissinger, 1992; Winefield, Tiggemann, & Winefield, 1992), and stress-coping benefits (Shaw, Caldwell, & Kleiber, 1996). Prior research often does not distinguish type of leisure activity. However, physically active leisure activities (versus sedentary ones)

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have been shown to be preventive factors for cardiovascular and other major diseases (Folsom et al., 1997; Mensink, Deketh, Mul, Schuit, & Hofmeister, 1996; Schlicht, 2002; Wenger, 1996). Therefore, inspection of the effect of different types of leisure activities upon health appears to be warranted.

In addition to exploring the effect of type of leisure activity, an issue that has yet to be addressed is the dynamical relation between leisure activity and health. (Frankish et al., 1998; Kleiber, Hutchinson, & Williams, 2002; Mahoney & Stattin, 2000; Mota & Esculas, 2002; Zeijl, te Poel, du Pois-Reymond, Ravesloot, & Meulman, 2000). Dynamical modeling represents how a system changes or "behaves" as time passes and requires repeated measures of variables, such as by daily self-monitoring. This is in contrast to static modeling, which only examines variables at a single point in time. Prior research has relied almost exclusively on static modeling using retrospective self-reports of leisure activity. Given that some health indicators are unstable, such as mood (Hill & Hill, 1991; Thayer, 1996), it is important to inspect their relation to leisure activities over time.

For purposes of this study, we define *health* in the broadest sense to include not only absence of disease, but also overall well-being (e.g., happiness and quality of life). We define *health indicators* to include not only physical behaviors related to (or indicators of) health, but mood states as well. Our primary objective was to examine the dynamical influences (i.e., over time) of physical leisure activity on health indicators. This was possible by incorporating daily self-monitoring in a prospective manner for the assessment of all variables (leisure activity and health indicators). Additionally, an open-ended format was incorporated for assessing types of leisure activity, avoiding the problem of pre-determined (and possibly insufficient) categories.

This approach allowed for the testing of an important health theory that has been emerging in recent years: *maladaptive behavior determinism* (MBD), which is based on complexity or chaos theory. This theory originated through studies of behavior involving laboratory-based biological and psychophysiological assessment over time, such as electrocardiograms (Goldberger & West, 1987). Evidence has suggested that adaptive conditions exhibit a high degree of randomness, whereas maladaptive conditions exhibit more deterministic, and possibly chaotic, characteristics (Babloyantz & Destexhe, 1986; Ehlers, Havstad, Garfinkel, & Kupfer, 1991; Goldberger et al., 1987). However, in studies of behavior requiring self-report outside of the laboratory, comparable evidence has been developing only very gradually (Barton, 1994; Melancon, Joanette, & Belair, 2000).

Nevertheless, the above-cited findings provide support for MBD, which states that adaptive behavior is characterized by a dominant random component because it adjusts to exogenous factors in the environment that occur independently of time (Skarda & Freeman, 1987). Maladaptive behavior is characterized by greater determinism because it responds relatively more to endogenous factors, which do occur as a function of time and perseverate even in the presence of environmental change. So, according to MBD, when an individual is healthy, measures of behavior (indicators) are characterized by unstructured (i.e., random) fluctuations over time. When the individual is unhealthy, these same measures exhibit structured (i.e., cyclic or periodic) patterns over time (Goldberger et al., 1987; Heiby, Pagano, Blaine, Nelson, & Heath, 2003; Skarda et al., 1987). A *cycle* is simply a pattern of change that repeats itself over time. For example, the rise and fall of the tides follows a cyclic pattern.

The theory of MBD is still in its infancy, and much more research is needed to demonstrate its applicability. If MBD is true, its most important implication is in terms of assessing and ultimately improving health. One possible way in which MBD could be applied is in an area that current research suggests is an important health factor: physical activity (Blair & Connelly, 1996; Frankish et al., 1998; Salmon, Owen, Crawford, Baumann, & Sallis, 2003; Schlicht, 2002). Given that physical activity is important to health, it is almost certain to be relevant in the context of MBD. Specifically, assuming that engaging in physically very active leisure activity is conducive to health, from MBD it follows that the greater the amounts of time spent being very active, the less structured one's health indicators will be. Similarly, assuming that engaging in not very active leisure activity is not conducive to health, then the greater the amounts of time spent being not very active, the more structured one's health indicators are. Empirical tests of these hypotheses are important to the development of a complete MBD theory.

Four health indicators that have been shown to be associated with active living are healthy eating (Field et al., 2002), feeling less hassled, positive mood (Shaw et al., 1996), and drinking alcohol moderately (Vicary, Smith, Caldwell, & Swisher, 1998). The dynamical relation between activity level and these four health indicators was the focus of this study. Additionally, we investigated possible differences between males and females, and differences between study locations (Honolulu, Hawaii USA and Stuttgart, Germany).

With regard to gender differences, research has shown that men tend to be more active on a regular basis and rate regular activity as important to their health more often than do women (Frankish et al., 1998). With regard to location, research supports the existence of ethnic differences in leisure time activity (Philipp, 1998). Hawaii and Germany differ with respect to several variables including ethnic diversity (Hawaii is a multi-ethnic society whereas Germany is primarily mono-ethnic), geographic location, and climate (temperate versus subtropical). These differences could have an impact on the opportunities to engage in leisure activity, and are therefore examined here for exploratory purposes.

The goal of this study was to assess the effect of physically very active (PVA) versus physically not very active (PNVA) leisure activity on four health indicators. It was not our goal in this study to examine leisure that could be considered non-physically very active (e.g., solving mental puzzles). We had four specific hypotheses in this regard. Our first hypothesis was that PVA leisure activity is associated with more positive health indicators. Specifically, we hypothesized that the number of hours spent engaged in PVA leisure

activity is positively correlated with health indicators. In contrast, hours spent engaged in PNVA leisure activity has zero or negative correlation with health indicators. This prediction is based on current research (Blair et al., 1996; Frankish et al., 1998; Salmon et al., 2003; Schlicht, 2002), and we seek further empirical support.

The remaining three hypotheses were based on the theory of MBD. Our second hypothesis was that the number of hours spent engaged in PVA leisure activity is negatively correlated with the strength of cyclic patterns in measures of health indicators. Conversely, hours spent engaged in PNVA leisure activity have a positive correlation with the strength of these cyclic patterns. This hypothesis was generated from the assumption that PVA leisure activity is conducive to health, and that health is reflected in a lack of cyclic patterns (according to MBD). Hence, poor health would imply greater cyclic patterns.

Third, we hypothesized that the number of hours spent engaged in PVA leisure activity on a given day was not predictive of health indicators on the same day or on a future day. For PNVA leisure activity, however, we did hypothesize predictability. Again, this prediction was formed from the assumption that PVA leisure activity is conducive to health, and that health is reflected in a randomness of behavior patterns (according to MBD). Hence, PVA leisure activity is hypothesized to generate random health indicator patterns, and therefore it cannot be predictive of these indicator patterns. However, PNVA leisure activity is hypothesized to generate cyclic indicator patterns, and is therefore predictive.

Fourth, we hypothesized that cyclic patterns present in PNVA leisure activity also exist in measures of health indicators (a mathematical measure of this is called *coherence*), but that this is not the case for PVA leisure activity. As with the third hypothesis, the assumption is that PVA leisure activity is conducive to health, and health is reflected in a randomness of health indicator patterns (according to MBD). This implies that PVA leisure activity cannot correlate with any health indicator patterns. Hence, there can be no consistency in the cyclic patterns of these measures.

Method

Participants

As part of a larger study on health indicators, a total of 81 participants were recruited. All were students at either the University of Hawaii at Manoa or the University of Stuttgart. The following criteria were used to determine eligibility: (1) volunteering to perform five weeks of daily self-monitoring of leisure activities and four health indicators, (2) completing at least four of the five weeks of daily self-monitoring (in order to reduce the biasing effect of missing values), (3) having a raw score lower than 10 on the MMPI-Lie scale (in order to reduce measurement error of self-reports) (Dahlstrom, Welsh, & Dahlstrom, 1972), and (4) at least 18 years of age. The MMPI-Lie scale cutoff score was used because it is an indicator of a response style of denying minor weaknesses and faults and not answering honestly on some self-report measures. Hawaiian participants received bonus class credit for their participation while German participants were given a stipend of 10 Euro (bonus class credit was not appropriate within their education system). Individuals not wishing to take part in the study were able to receive the class credit or 10 Euro by reading and summarizing two articles on health psychology, and submitting them to one of the researchers.

Of the 81 students recruited, 13 did not meet the inclusion criteria, leaving an effective sample of 68 participants. Of these 68 participants, 48 (71%) were living in Hawaii and 20 (29%) were living in Germany; 19 (28%) were male, and 49 (72%) were female. Ages ranged from 19 to 29 years with a mean of 22.2 and standard deviation of 2.7.

Measures

For this study we created two page English and German language versions of a self-monitoring form in order to obtain daily measures of leisure activities and four health indicators. The first page of the form was an openended question instructing the subject to list all leisure activities and time spent on each activity. Participants were instructed that leisure time includes all the time that they did not spend working at a job or attending a class. The second page of the daily self-monitoring form instructed subjects to rate three items measuring degree of healthy eating, feeling hassled, and positive mood on a six-point Likert-scale. A fourth health indicator, drinking alcohol, was measured on the second page of the self-monitoring form by an item instructing the participant to indicate the number of alcoholic drinks consumed each day. Participants completed the daily self-monitoring form for five weeks.

Scoring of the open-ended question concerning leisure activity was conducted as follows. The second author and research assistants reviewed all daily self-monitoring logs in order to create a list of reported leisure activities. Twenty different activities were identified, with different kinds of sport activities combined under the heading "sports." Seven judges agreed that among the 20 different activities, two were PVA: working out and sports (including different kind of sports such as surfing, swimming, hiking, and walking). The remaining 18 (e.g., watching TV, eating, reading, playing video games, cooking, etc.) were PNVA. The judges included four faculty members in sport science, one faculty member in psychology, and two graduate students in psychology. The judges classified the activities independently with 100% agreement. For every study participant, both PVA and PNVA leisure activity time (measured in hours) were calculated each day. Summing total hours engaged in the activities categorized as PVA and PNVA yielded two leisure scores per subject.

Procedures

An announcement was made by the second author at the start of each sampled class, inviting students to participate in a research study of health indicators for bonus class credit to be added to their final course grade (Hawaii) or for a payment of 10 Euro upon completion of the five-week study (Germany). The logs and the procedure regarding the five weeks of daily self-monitoring of leisure activities and the four health indicators were briefly explained during recruitment. In both locations the procedures followed the same guidelines. The participants were instructed to begin the self-monitoring that day and to complete the form each day before going to bed for the duration of five weeks. Self-monitoring logs could be dropped off at the start of class each week in a designated box.

The second author prompted each participant by email once a week to complete the daily self-monitoring logs. He also went to the start of the selected classes each week to collect self-monitoring logs and distribute new logs for the next week. The designated box was also checked and emptied several times per day, and additional logs were made available at that location. Two of the authors were available in person or via email for any questions regarding the study or self-monitoring logs. Near the end of the five weeks, prompts were sent to the participants with missing logs to remind them to drop them off at the designated box as soon as possible.

Data Analysis

The data analyses consisted of four modeling procedures, with each developed to test one of the hypotheses of the study. The first procedure assessed the relationship of total hours spent engaged in PVA and PNVA leisure activities (over a five week period) with each of the four outcome measures (healthy eating, feeling hassled, positive mood, and drinking alcohol), which were measured every day for five weeks. A multilevel modeling approach (Goldstein, 1995; Hox, 2002; Raudenbush & Bryk, 2002) was employed in which observations across time (level 1) were nested within individuals (level 2). The SAS MIXED procedure (SAS Institute Inc., 1999) was used to perform the necessary computations.

Four models were computed, one for each of the outcome health indicator measures. The predictors in each of the models were the total number of hours spent engaged in PVA leisure activity, the total number of hours spent engaged in PNVA leisure activity, the day (ranging from 1 to 35), the location (Hawaii or Germany), and the participants' sex. Day was included to assess if any linear trends over time were present. Location and sex were included because of potential differences that might exist on these variables (Frankish et al., 1998; Philipp, 1998). Note that within the context of multilevel modeling, day is a level 1 variable, but all the other variables are level 2. It was hypothesized that more hours spent engaged in PVA leisure activity would be predictive of better health indicators (i.e., higher scores on healthy eating and positive mood, and lower scores on feeling hassled and drinking alcohol).

In the second modeling procedure, the time series structure (i.e., its periodicity or cyclic pattern) for each of the outcome measures was assessed

as a function of total hours spent engaged in PVA leisure activity. Mathematica 4.2 with the Time Series add-on package (He, 1995) was used to perform the calculations. The time series structure was determined through spectral analyses (Shumway & Stoffer, 2000). For each outcome, the power spectrum for each individual's time series was computed. Correlation coefficients (across individuals) were then calculated between total hours spent engaged in PVA leisure activity and the power at a given frequency. Therefore, one correlation coefficient was calculated for each frequency. Plots of correlation versus frequency, with statistical control lines ($\alpha = .001$), were produced to visually assess statistically significant effects. Subsequent analyses were conducted separately for Hawaiian versus German and male versus female participants.

A statistically significant positive correlation for a given frequency would imply that increased hours spent engaged in PVA leisure activity is related to more periodic (less random) fluctuations in the given outcome. Similarly, a statistically significant negative correlation would imply that increased hours spent engaged in PVA leisure activity is related to less periodic (more random) fluctuations in the given outcome. It was hypothesized that periodic structure (at any frequency) would be suggestive of maladaptive leisure activity. If supported, the greater the number of hours spent engaged in PVA leisure activity, the less periodic structure would exist in the outcome measures (negative correlation).

The same approach was used to assess the effect of hours spent engaged in PNVA leisure activity. Here it was hypothesized that increased hours would be predictive of more periodic structure in the outcome measures (positive correlation). Additionally, separate analyses were run to assess possible differences between Hawaiian versus German and male versus female participants.

For the third modeling procedure, multivariate time series analyses (He, 1995; Shumway et al., 2000) were conducted using Mathematica 4.2 to assess the relation between the daily activity time series and the four outcome measure time series. In the previous modeling procedures, total hours (summed across the five week period) for PVA and PNVA leisure activities were used for analysis. In this modeling procedure (and the next one), however, daily time series for hours engaged in PVA and PNVA leisure activities were used. For each participant, cross-correlation functions were computed between the PVA (and PNVA) series, and each of the four outcome measure series (for a total of eight cross-correlation functions). The resulting cross-correlation functions were then averaged across all participants. Statistical significance (p < .001) for cross-correlation values was assessed by single sample twotailed t-tests, testing for values statistically different from the expected value, zero. Plots of the mean (across participants) cross-correlation functions, along with lines indicating statistical significance for p = .001, were provided. It was hypothesized that statistically significant cross-correlations would exist between hours spent engaged in PNVA leisure activity on a given day and health indicators on a future day (and the same day). Subsequent analyses were performed separately for Hawaiian versus German and male versus female participants.

For the fourth and final modeling procedure, spectral analyses were performed to assess the coherence between the leisure activities series (PVA and PNVA) and the four outcome series. Coherence provides information regarding the degree of similarity between two series in terms of the underlying structure (periodicity) at a given frequency. If two time series have the same frequency, they will have high coherence.

As with the cross-correlations in the third modeling procedure, a coherence function was calculated for each subject, and the results were then averaged across all subjects. Mathematica 4.2 with the time-series add-on package was again used. Statistical significance (p < .001) for coherence values was assessed by single sample two-tailed t-tests, testing for values statistically different from the expected value. The expected values were determined using simulations with random time series data, which had the same means and standard deviations as the actual data. These expected values were consistently equal to approximately 0.2. Plots of the mean (across participants) coherence functions, along with statistical control lines for p =.001, were provided. It was hypothesized that for the PVA series, no statistically significant coherence would be present but for the PNVA series, there would be.

Results

In each of the outcome time series, missing values were replaced with the mean of the values immediately preceding and immediately following. For example, if a value were missing on day 5, the mean of the values for day 4 and day 6 would be imputed. The numbers of missing values that needed to be imputed in this way were 32, 32, 33, and 30 for the healthy eating, feeling hassled, positive mood, and drinking alcohol variables, respectively. This represented 1.3%, 1.3%, 1.4%, and 1.3% of the total number of values (2380 - 68 participants with 35 daily observations) for each outcome variable. When participants did not record any leisure activities (be it PVA or PNVA), this was coded as zero. Hence, there were no missing values in either of the leisure activity time series.

Before testing the hypotheses, preliminary descriptive statistics were calculated. The mean (across participants) total hours spent engaged in PVA and PNVA leisure activities (over the five week period) was 17.3 and 243.7, respectively. Thus, participants spent, on average, 30 minutes a day engaged in PVA leisure activity, and seven hours a day engaged in PNVA leisure activity. (Recall that only leisure time hours were recorded.) Standard deviations were 22.7 and 70.0 for PVA and PNVA, respectively. The correlation between the two variables was -.15 (p = .23). Means and standard deviations by location and sex are shown in Table 1.

In the assessment of the first hypothesis, results showed that increased hours spent engaged in PVA leisure activity were significantly related to

	Male				Estate Herolo				Total						
	n	PVA		PNVA		<u></u>	PVA		PNVA			PVA		PNVA	
		M	s	М	s	n	M	s	М	s	n	M	s	M	s
Hawaii Germany	13 6	27.2 20.5	29.2 11.6	240.1 215.6	82.1 38.0	35 14	14.2 14.7	23.9 13.3	259.1 220.7	67.8 64.1	48 20	17.7 16.4	25.8 12.8	254.0 219.2	71.6 56.6
Total	19	25.1	24.8	232.4	71.6	49	14.3	21.3	248.1	68.4	68	17.3	22.7	243.7	69.0

TABLE 1 Descriptive Statistics for Leisure Activity Data

Note. Statistics provided are the sample size (n), mean hours over five-week period (M), and standard deviation (s). None of the mean differences was statistically significant. PVA = Physically Very Active; PNVA = Physically Not Very Active.

higher levels of healthy eating, lower levels of feeling hassled, and higher level of positive mood (see Table 2). There was no statistically significant relation with number of alcoholic drinks consumed. Hours spent engaged in PNVA leisure activity were not significantly related to any of the outcomes. No differences were found between Hawaiian and German residents, or between males and females. These results support the first hypothesis.

The results from the tests of our second hypothesis are shown in Figure 1. This figure provides plots of the correlation between the power spectrum and the total hours engaged in leisure activities as a function of period. (Note that the cycle length, or period, is equal to 1/frequency.) A separate plot is provided for each outcome measure for each type of leisure activity (PVA and PNVA). The vertical axis is the correlation (r) and the horizontal axis is the period (T). The gray horizontal lines are the statistical control lines for $\alpha = .001$. When the correlation value exceeds the control lines it suggests that, at the given value of T, there is a statistically significant correlation between the total amount of leisure activity and the strength of the cyclic pattern. Hence, leisure activity is related to the patterns of health indicators as hypothesized according to MBD.

The second hypothesis was supported for the feeling hassled outcome measure. Persons with fewer hours engaged in PVA leisure activity, showed greater periodicity in their time series structure than persons with more hours. The frequency at which this occurred corresponded to a 2.2-day cycle. The other outcome measures were not influenced by total hours engaged in PVA leisure activity. However, in further support of the second hypothesis, there were statistically significant positive correlations between the outcomes healthy eating and positive mood, and time spent engaged in PNVA leisure activity. For healthy eating, these statistically significant results occurred at several frequencies, corresponding to 2.3, 3.2, and 5.0 day cycles. For positive mood, the cycle was 4.0 days. No significant results were found for the drink-

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Outcome	Predictor	Estimate	df	<i>S.E.</i>	t	þ
Healthy Eating	PVA	.0111	63	.0035	3.16	.002
, ,	PNVA	0013	63	.0012	-1.10	.28
	Female	.1086	63	.1752	0.62	.54
	Hawaii	0059	63	.1731	-0.03	.97
	Day	.0089	2311	.0020	4.54	<.0001
Feeling Hassled	PVA	0103	63	.0041	-2.54	.01
-	PNVA	.0011	63	.0014	0.80	.43
	Female	0817	63	.2028	-0.40	.69
	Hawaii	0584	63	.2004	-0.29	.77
	Day	0048	2311	.0024	-1.97	.05
Positive Mood	PVA	.0073	63	.0031	2.37	.02
	PNVA	0005	63	.0010	-0.46	.65
	Female	.0027	63	.1527	0.02	.99
	Hawaii	.1019	63	.1509	0.68	.50
	Day	.0038	2311	.0021	1.78	.07
Drinking Alcohol	PVA	6879	63	.6722	-1.02	.31
-	PNVA	.0753	63	.2230	0.34	.74
	Female	-63.11	63	33.47	-1.89	.06
	Hawaii	20.89	63	33.07	0.63	.53
	Day	0026	2311	.0038	-0.68	.49

TABLE 2Multilevel Regression Model Output

Note. For each of the outcome variables, higher values indicate greater levels. The predictor variable PVA is hours spent engaged in physically very active leisure activity. PNVA is hours spent engaged in physically not very active leisure activity. *Female* is zero if male and one if female. *Hawaii* is zero if the participant resides in Germany and one if the participant resides in Hawaii. Day is the day of observation. *Estimate* is the regression coefficient; *df* is the degrees of freedom; *S.E.* is the standard error of the regression coefficient; *t* is the *t*-value; and *p* is the probability value.

ing alcohol outcome measure, and no significant differences were found between Hawaiian and German residents, or between males and females.

The results from the tests of our third hypothesis are shown in Figure 2. In this figure, plots of the mean (across participants) cross-correlations between the leisure activity time series and the outcome time series are shown. A separate plot is provided for each outcome measure for each type of leisure activity (PVA and PNVA). The vertical axis is the mean cross-correlation (xr) and the horizontal axis is the *Lag*. Negative values for lag imply the cross-correlation of the leisure activity type at a given time predicting the outcome at *lag* number of days in the future. Positive values for lag imply the cross-correlation of the outcome measure at a given time predicting the activity type at *lag* number of days in the future. The gray lines are the statistical control lines for $\alpha = .001$.



Figure 1. Plots of the correlation between the power spectrum and total hours engaged in leisure activities as a function of period (1/frequency) are shown. A separate plot is provided for each outcome measure for each type of leisure activity: physically very active (PVA) and physically not very active (PNVA). The vertical axis is the correlation (r) and the horizontal axis is the period (T). The gray horizontal lines are the statistical control lines for $\alpha = .001$.



Figure 2. Plots of the mean (across participants) cross-correlations between the leisure activity time series and the outcome time series are shown. A separate plot is provided for each outcome measure for each type of leisure activity: physically very active (PVA) and physically not very active (PNVA). The vertical axis is the mean cross-correlation (*xr*) and the horizontal axis is the *Lag*. Negative values for lag imply the cross-correlation of the leisure activity type at a given time predicting the outcome at lag days in the future. Positive values for lag imply the cross-correlation of the predicting the activity type at lag days in the future. The gray lines are the statistical control lines for $\alpha = .001$.

For the third hypothesis, the results were also supportive. All of the cross-correlations between hours spent engaged in PVA leisure activity and each of the outcome measures were not statistically significant. For hours spent engaged in PNVA leisure activity, results indicated statistically significant (p < .001) cross-correlations with feeling hassled, positive mood, and drinking alcohol (see Figure 2). Each of these showed approximately one-week cycles. No significant differences were found between Hawaiian and German residents, or between males and females.

Finally, the results from the tests of our fourth hypothesis are shown in Figure 3. In this figure, plots of the mean (across participants) coherence between the leisure activity time series and the outcome time series are shown. A separate plot is provided for each outcome measure for each type of leisure activity (PVA and PNVA). The vertical axis is the mean coherence (K2) and the horizontal axis is the period (T). The gray lines are the statistical control lines for $\alpha = .001$.

For the fourth hypothesis, results were again supportive (see Figure 3). Statistically significant coherence was found for PNVA leisure activity, but not for PVA leisure. Feeling hassled, positive mood, and drinking alcohol all showed statistically significant coherence with PNVA leisure activity at certain frequencies. For feeling hassled, these frequencies corresponded to cycles of approximately 3.0 and 4.5 days. For positive mood, it was about 5.8 days, and for drinking alcohol, about 4.4 days. Again, no significant differences were found between Hawaiian and German residents, or between males and females.

Discussion

The primary goals of this study were to assess the dynamical relations between leisure activities and health indicators, and to test the theory of maladaptive behavior determinism (MBD) with respect to active living. The results provided some support for all four of the hypotheses of the study, suggesting that engaging in physically very active (PVA) leisure activity is associated with four health indicators (more healthy eating, feeling less hassled, higher positive mood, and drinking less alcohol). In contrast, not very active leisure activities had no significant relation to the four health indicators. This finding was supported by correlation analyses of averaged data as well as modeling of the time series structures of daily leisure and four health indicators over a five-week period.

The first hypothesis was not related to the MBD hypothesis, and simply stated that higher levels of PVA leisure are predictive of health indicators over a five week time period. This was supported for the indicators healthy eating, feeling hassled, and positive mood, but not for drinking alcohol. Excluding the drinking alcohol results, this is consistent with findings from previous research (Frankish et al., 1998). Greater time spent engaged in PVA leisure activity is associated with higher levels of healthy indicators. The amount of time spent engaged in PNVA leisure activity did not appear to have any relationship with the measured health indicators.



Figure 3. Plots of the mean (across participants) coherence between the leisure activity time series and the outcome time series are shown. A separate plot is provided for each outcome measure for each type of leisure activity: physically very active (PVA) and physically not very active (PNVA). The vertical axis is the mean coherence (K2) and the horizontal axis is the period (T). The gray lines are the statistical control lines for $\alpha = .001$.

The second, third, and fourth hypotheses provided tests of MBD with respect to active living. For each hypothesis, a specific aspect of the time series structure of the health indicators was examined in relation to the amount of time spent engaged in both PVA and PNVA leisure activities. The second hypothesis was best supported for the health indicator feeling hassled, with more random patterns in feeling hassled occurring for individuals with higher amounts of PVA leisure time. However, support for this hypothesis was also shown with respect to the amount time spent being PNVA, and the healthy eating and positive mood indicators. Similar to the first hypothesis, no support was found for the drinking alcohol indicator.

The third hypothesis was best supported for the drinking alcohol health indicator, but support was also shown for feeling hassled and positive mood. That is, over time these health indicators can be predicted to some extent by the amount of time spent engaged in PNVA leisure activity. However, these results seem to reflect a simple relation between the day of the week and not necessarily any direct influence of PNVA time on health indicators. The predictive cycles were all approximately one week in duration, suggesting that both PNVA leisure activity and health indicators are influenced by the day of the week. This seems especially likely with respect to alcohol consumption. Most people are off from work and school classes on the weekends and therefore have more leisure time. The added leisure time is likely to add to people's alcohol consumption.

The fourth hypothesis was supported for the feeling hassled, positive mood, and drinking alcohol health indicators. The cyclic patterns in PNVA leisure time have some consistencies with the cyclic patterns in these health indicators. These patterns did not appear to reflect simple day of the week influences, and could suggest that MBD is operating. No consistent patterns were found between PVA leisure activity and the health indicators. Assuming maladaptive indicators exhibit determinism and assuming that PVA time is conducive to health, PVA time may generate randomness in health indicators, preventing the possibility of consistent structural patterns.

Probably the most important advantage of this study is the time series assessment of the data allowing for an examination of the relations among the variables over an extended period of time. While the results did provide support for the study hypotheses, caution is needed when drawing conclusions regarding the implications. First, the self-monitoring form used to measure leisure activities and health indicators was developed for this study and its reliability and validity have not been established. Second, the influence of PVA and PNVA leisure time was not the same across all health indicators, suggesting that the relations between these variables are more complex than what was hypothesized in this study. For example, it seems probable that active living does not affect all health indicators equally. Future research needs to be focused on additional health indicators (e.g., smoking, anxiety, quality of life, etc.) in an attempt to establish the areas that benefit the most from engaging in greater levels of activity. This inquiry could lead to the development of a comprehensive theory of the influences of active living on health.

Additionally, age is a potentially relevant variable in the influence of activity on health. However, this study only included young adults. Therefore, there is no reason to believe that the results obtained here generalize to older populations, and future research is needed in this regard.

This research provides a beginning in the study of active living and how it affects health indicators over time. The evidence here suggests that PVA leisure time might have health benefits that are dynamical and not necessarily immediately apparent. The levels of health indicators might not be the primary factor in determining health, but rather how these levels change over time. A person with consistently low levels on a given health indicator might be healthier than a person with consistently high levels, provided that the changes in the indicator over time are random for the former individual, and cyclic for the latter one. Assuming that PVA leisure time is associated with random fluctuations in health indicators over time, it suggests that it has health benefits that have not been previously studied.

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