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SEASONAL COGNITIVE RHYTHMS WITHIN THE ARCTIC CIRCLE: AN INDIVIDUAL DIFFERENCES APPROACH

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Abstract

At 69°N the annual swings in the physical environment are considerable. For instance, for two months in winter there is no direct sunlight and for two months in summer the sun does not set. Brennen *et al.* (1999) tested the cognitive performance of 100 participants living at 69°N in summer and in winter. Overall there were very few seasonal effects, and most of these were, contrary to expectation, winter advantages. In order to determine whether particular subgroups of the sample may have shown winter deficits, in this paper Brennen *et al.*'s database is analysed to investigate whether the age, gender or the proportion of life spent in northern Norway predicts the difference between performance in summer and winter on each test. The multiple regressions showed that age was a significant predictor on five tasks, gender on one task, and the proportion of life lived in northern Norway on none. Overall this analysis is in line with Brennen *et al.*'s conclusion: there are only very modest seasonal effects in cognition.

In this paper an individual differences approach is used to investigate whether the extreme annual variation in the physical environment of polar regions influences cognitive peformance. Studies of mood variations over the annual cycle report a sizeable minority of people who have impaired social and affective functioning in winter compared to summer, the syndrome referred to as Seasonal Affective Disorder, or SAD (see for example Rosenthal *et al.* 1984). On the other hand, until recently there have been almost no studies of cognitive performance over the annual cycle.

There are several reasons for which it is timely to investigate possible cognitive rhythms over the annual cycle in a nonclinical population living at a very high latitude. Firstly, it is widely claimed that there is a cognitive component in SAD and the cognitive performance of SAD patients has recently begun to be investigated, e.g. Drake *et al.* (1997), Hodges and Marks (1999). Secondly, currently available studies of the psychological correlates of the seasonal rhythm have largely used self-report techniques, in contrast to objective measures of performance. Thirdly, there are intuitive and theoretical reasons for expecting psychological seasonal swings to increase with latitude. It seems obvious that places with big differences in amount of daily light over a year should have strong psychological effects compared to places on the equator where length of night and day vary minimally. Furthermore, current accounts of the aetiology of SAD claim that the reduction in amount of daylight triggers the mood disorder. Thus this hypothesis predicts that people at high latitude should be particularly vulnerable to the manifestations of SAD.

Since the golden age of polar exploration the effects of 'wintering-over' on Antarctica have been documented. In 1898–9 the crew of the Belgica became the first people to winter over in Antarctica. Their boat became trapped in the ice for 13 months during a scientific expedition, and the doctor reported that homesickness and mental disturbances were widespread symptoms amongst the crew. In the century since, many more expeditions have wintered over on the Antarctic continent, and the symptoms of depression, irritability, insomnia and cognitive impairment have been frequently reported (Edholm & Gundersen, 1973). Palinkas, Houseal and Rosenthal (1996) reported that while the rate of clinical depression and SAD amongst 'winter-over' staff are low, subsyndromal symptoms of SAD increase across the winter.

Taylor and Duncum (1987) investigated how performance of a mental imagery task varied in people on Antarctica, and reported no objective differences over the year, despite the participants' own intuitions that they were performing worse in winter. Palinkas and Houseal (2000) tested 'winter-over' staff monthly throughout the winter at three Antarctic research stations, using a questionnaire that measured anxiety, depression, anger, confusion, fatigue and vigor. The scores got better up to and beyond the winter solstice, before getting worse in the spring, and this effect was larger overall for participants at the South Pole.

The present paper reports the extension and reanalysis of a database collected by Brennen *et al.* (1999). In the initial study the cognitive performance of a population living in Tromsø, northern Norway was tested. The city of Tromsø is at 69°N, 300 km north of the Arctic Circle. At this latitude, the sun remains below the horizon between mid-November and mid-January and doesn't set between mid-May and mid-July.

Tromsø provides a useful natural laboratory for the study of circannual rhythms because, despite its very northerly location, it is a lively city, in contrast to the impoverished social environment and restricted daily routine of polar research stations, for instance. Tromsø's population is 60,000 which, while small by international standards, puts it among Norway's ten biggest cities. Figures 1 and 2 show the university campus in summer and winter.

Each subject in the original study was tested twice, once in winter and once in summer and about half of the subjects was tested first in winter while the rest were tested first in summer. Brennen *et al.* (1999) used the classic experimental analysis, collapsing data across subjects and running a two-way analysis of variance with the factors of season and order of testing, separately for each test. On a battery of tests including explicit and implicit memory for words, verbal fluency, face recognition, and short-term digit memory, the predicted global winter deficit did not emerge. On the contrary, of the five significant results, four indicated summer deficits.

FIGURE 1 The University of Tromsø campus in summer.

FIGURE 2 The University of Tromsø campus in winter.

In this paper an individual differences approach is taken to determine whether some subgroups of subjects do in fact show the expected winter disadvantage. This reanalysis thus provides another opportunity for seasonal cognitive rhythms to be detected. Another possibility is that even if the independent variables do not reveal a subset of the sample with winter deficits, they will demonstrate how the summer deficits vary.

The independent variables to be used in the regressions are gender, age and the proportion of one's life lived in northern Norway. Several epidemiological studies have shown that women are more susceptible than men to SAD, (e.g. Thompson & Isaacs, 1988; Kasper *et al.*, 1989, though see Kane & Lowis, 1999 for a contrary view). It might be argued that since Brennen *et al.*'s study included over 40 women it was well placed to detect any seasonal cognitive effects even if they should only be observed for women.

In addition, Brennen *et al.*, (1999) argued that with a mean age of 31 years old (S.D. = 10) the sample should be highly sensitive to seasonal changes, as determined by the typical age range of SAD patients. So, on the one hand, Brennen *et al.*'s sample was of appropriate age and gender to pick up any seasonal effects, but on the other hand, it is possible that any seasonal effect in particularly seasonal subgroups were swamped by null effects in the rest of the sample. The present reanalysis will check for this possibility.

The proportion of one's life lived in northern Norway was included as an independent variable because the prevailing economic conditions make the Norwegian population potentially highly mobile, and it might reasonably be expected that people experiencing uncomfortably large seasonal swings would move south to avoid such extreme annual changes in the physical environment. Just over half of our sample had only ever lived in northern Norway, whereas the remainder had lived there for a mean of nine years, and a quarter of the sample had lived there for four years or less. The length of time in northern Norway may correlate negatively with seasonality because only people recently arrived in the far north might be expected to show severe effects of season, before either adapting or moving south.

Method

Participants

The participants were recruited via posters hung up around Tromsø, for instance in coffee rooms of places of work, and taxi and ferry waiting rooms. The posters asked for volunteers for a longitudinal research project on memory and attention. No mention was made of seasons, in order to avoid recruiting a sample biased in some way with regard to seasonality. In May 1997, 110 people volunteered and were tested within four weeks of the summer solstice. They were informed that they would be contacted in November to be retested. It was possible to make appointments with the vast majority of these people at the second time of testing, but due to failures to turn up in the end sixty two were retested in winter. These formed the summer–winter group, reflecting the order of testing.

In December 1997, 70 new volunteers were recruited through similar methods and sources. Of these 38 completed testing the following summer, forming the winter–summer group. In both seasons, all subjects were tested within at least a month of the solstice. Table 1 presents summary data for the participants.

TABLE 1
Characteristics Of The Sample Of Participants

Mean age	30·6 years
S.D.	11
Age range	16–63
Gender	45 women, 55 men
Northern Norway	
Mean number of years	9·3
S.D.	10
Range	0–56 years
Mean proportion of life	·43
S.D.	·35
Range	·003–1

Tasks

The tests can be divided into latency tasks, attention tasks and memory tasks, and each task is described below.

Latency

Speed. Participants had to respond by pressing a button as quickly as possible to a yellow circle presented in the middle of the screen, where the background colour was grey. This was thus a simple latency task. The temporal characteristics of this test were as follows: There was a four-second gap between the participant's key press to clear the instructions and the presentation of the first stimulus. Thereafter the length of the interval between a participant's response and the presentation of the next stimulus was determined by an exponentially decreasing random process, with a maximum of 7500 ms. There were 40 trials.

Dot numerosity judgements. In this task the screen was divided by a vertical line down the middle. On each trial participants had to decide on which side there were more dots, pressing the left or right button accordingly. On half of the trials there were more dots on the left side and on the other half there were more on the right. On each trial, one side had 20 dots in a random pattern. The other side had the same 20-dot pattern plus from one to five extra dots. All dots were presented simultaneously. The visual stimulus remained on screen until the participant's response or 3000 ms were up, whichever came first. The dots were yellow on a grey background and there were forty trials in total. On each trial, after the participant had responded, feedback was given by showing the location of the key extra dots in blue.

Attention tasks

Stroop. This Stroop task used manual responses on a four-button response pad. The four colours were red, yellow, green and blue, and the words were the equivalent Norwegian colour words: rød, gul, grønn and blå. Participants were instructed to respond to the colour of the stimulus and not the word. There were sixty trials of which 24 were consistent (e.g. 'blå' written in blue) and 36 were inconsistent (e.g. 'blå' written in yellow). Feedback was provided on the screen on each trial as to whether the participant's response was correct or not.

Mapping. On each trial either an X or an O was presented, either left or right of centre. The participants' task was to press the lefthand button when an O was presented and the righthand button when an X was presented. This is thus a task where confusion arises due to response mapping conflict: a stimulus is presented on the lefthand side and the correct response is to press the righthand button. There were 40 trials. The visual angle subtended by the X and the O was 2°, and the eccentricity was 7°.

Time estimation. Participants were given the task of estimating time intervals. Participants initiated each trial by a key press which triggered a tone that indicated the beginning of the time period. The participant pressed the button when s/he reckoned the time period was up. There were three trials, carried out in the following order: 60 seconds, 30 s, 15 s. Throughout each trial the target number of seconds was on screen.

Memory tasks

Sternberg. This task required scanning of short-term memory, and was based on Sternberg's (1966) task. On each trial to-be-remembered yellow digits were presented one at a time, for 1000 milliseconds. All 10 digits had an equal chance of being selected, and no repetition within trials was allowed. Then a dash was presented for 3000 ms, followed by a single white digit. The participants' task was to decide whether the white digit was a member of the previously presented set. Forty trials were presented in total, half of which with three digits to remember and half with five. For half of each of these set sizes, the white digit did in fact come from the set (target present), and for half it did not (target absent).

Face recognition. On each trial a face was presented in the middle of the screen. The participant's task was to decide whether or not it was a famous face. Of the 42 faces in the experiment, 25 were famous and 17 were not. Each face was presented twice during the task, giving a total of 84 trials for each participant on each test session. There were two sets of faces, and about half the participants saw Set A in their first test session and Set B on their second, whereas the other participants saw Set B and then Set A.

Word memory. Words were presented for 3000 ms, one at a time in the middle of the screen. The participant triggered the presentation of the following word by pressing the space bar. Participants were told that their memory for these words would be tested later. In every test session, 61 words were presented. The first six and the last five words were held constant in order to reduce any effects of primacy and recency, and memory for these items was not tested. This gave 50 target words for which memory was tested.

Memory for these items was tested approximately 10 min after this presentation phase, the time it took to perform the mapping and Sternberg tasks. The technique employed was that used by Jacoby, Toth and Yonelinas (1993) for separating conscious and unconscious influences on memory. This consists of a stem completion task where the instructions varied according to the colour of the stem: When the stem was written in green, the participant had to complete it with a word from the previously seen list. If the participant did not remember a word from the list, any other word could be written. When the stem was written in red, the participant had to complete it with a word not from the previously seen list. These instructions are known as the inclusion and the exclusion tests, respectively. Each participant saw 25 stems in the inclusion condition and 25 in the exclusion condition. In conjunction these two types of test provide estimates of the contributions of recollection and automatic influences on memory performance.

There were two counterbalancing factors: Firstly, there were two lists of 50 words and half the participants saw List 1 in their first test session and List 2 in their second, while the other half had the reverse order. Secondly, each wordlist was divided into two, so that across each test session equal numbers of participants in the inclusion and the exclusion conditions saw any particular word.

The last task in each test session was a surprise free recall test for the words in the original list. And although we expected this test to be less of a surprise at the end of the second session, the number, variety and intensity of tests meant that the participants were surprised the second time too.

Fluency. This was a verbal fluency test. Participants were given a letter from the alphabet and told to generate as many words as possible in one minute. Proper names and foreign words were not allowed, and words with the same stem as a previously generated word, e.g. plurals, did not count. The letters used were F and S. About half the participants generated words from the letter F in the first test session and S in the second, while the others generated in the reverse order.

Order of tasks

The order of tests was identical for all participants in all test sessions:

1. Dot numerosity judgements; 2. Fluency; 3. Word Memory—Presentation Phase; 4. Sternberg; 5. Mapping; 6. Word Memory-stem Completion; 7. Time Estimation; 8. Speed; Break; 9. Face Recognition; 10. Stroop; 11. Word Memory—Free Recall.

The purpose of the present analysis was to determine which of the participant variables were associated with differences between performance in summer and winter on each task. Some tasks had more than one dependent variable, e.g. number of errors and mean response times (RT), and each dependent variable from each cognitive task was analysed separately, by means of a multiple regression. Each dependent variable was the difference between the summer score and the winter score on that particular task. Worse performance, i.e. a longer RT, a higher number of errors or a lower number of words recalled, will be referred to as a deficit. For each subject, each season's score was obtained by collapsing data across conditions (e.g. disregarding the difference in latencies to familiar and unfamiliar faces on the face recognition task), giving the mean correct latency on a trial over the whole task, or the mean number of errors over the whole task.

For the attentional tasks that had inbuilt measures of confusability, the difference between the seasons' confusability scores for each participant was used as a dependent variable in separate multiple regressions. The dependent variable for the time estimation task was the absolute proportion deviation from the target time period, because this measure ensured that over- and underestimates did not cancel each other out, and meant that the amount of deviation in the 60 s condition did not swamp the amount of deviation in the other conditions. In Table 2, the direction, mean and standard deviation of the summer–winter difference for the whole sample are given for each dependent variable.

Results

Using Minitab version 11.11, each dependent variable was plotted separately against each independent variable to determine whether the assumption of linearity in multiple regression analysis was respected. In cases of plots of a quadratic form the independent variable was squared and entered separately into the regression. In cases of cubic plots, the square and the cube terms of the independent variable were also entered separately into the regression. The requirement of homogeneity of variance was checked by using the residual plots.

The independent variables included were: age, gender, and the proportion of life lived in northern Norway. The term 'northern Norway' (nord-Norge, in Norwegian) is popularly understood to be the three northernmost counties of Norway, corresponding, to a first approximation, to the area above the Arctic Circle.

The alpha level for the regressions was ·05. In Table 3, the significant predictors that emerged from the multiple regressions are presented. The following statistics are given for each: the coefficient and standard error, the *t*-value of the regressor, the *F* value of the overall regression, and the r^2 value of the regression model.

On no dependent variable did the proportion of a participant's life lived in northern Norway significantly predict performance, while gender was associated only with RT on the face recognition task, where male participants had a mean 43 ms summer deficit and female participants had a mean 5 ms winter deficit.

On five dependent variables, independent variables derived from participants' age were significant predictors. In no case did the inclusion of other independent variables improve the model. The only dependent variable for which age alone (rather than age raised to a power) was a predictor was the summer–winter difference in Stroop confusability as measured in milliseconds: at the lower age range of the sample there was essentially no difference in confusability in summer and winter, but a winter deficit in confusability increased with age, to about 50 ms at 50 years old (see Figure 3). All figures are lowess plots, which are locally weighted smoothed lines that limit the influence of outliers.

The other four dependent variables where age was a significant predictor were reaction time on the speed task, RTs on the mapping task, absolute proportion deviation on the time estimation task and number of words generated on the verbal fluency task. For the speed and mapping tasks the cubic

TABLE 2
A summary of the descriptive statistics for the difference between summer and winter performance for each task. (RT is response time)

Tasks	Dependent variable	Direction of Deficit	Mean Deficit	S.D.
Speed	RT	Summer	11 ms	42
Dots	RT	Summer	110 ms	494
	Errors	Summer	0·29	4·0
Stroop	RT	Summer	46 ms	225
	Errors	Winter	0.08	1·6
	Confusability RT	Summer	7 ms	85
	Confusability Errors	Summer	0·02 Errors	1·1
Mapping	RT	Summer	16 ms	70
	Errors	Summer	0·1 Errors	0·9
	Confusability RT	Summer	8 ms	32
	Confusability Errors	Summer	0·07 Errors	1·1
Time Estimation	Absolute Proportion Deviation	Summer	0·018	0·20
Word Memory	Automatic Component	Winter	·002	0·09
	Recollection Component	Winter	0·03	0·2
	Surprise free Recall	Summer	2·4	7
Face Recognition	RT	Summer	20 ms	114
	Errors	Winter	0·05	6
Verbal Fluency	Number of words	Winter	0·7	6
Sternberg	RT	Summer	30 ms	183
	Errors	Summer	0·27 Errors	2

components were significant and the patterns were very similar, as shown in Figures 4 and 5. At the lower end of the age range there was a slight winter deficit that crossed over into an equivalent summer deficit by the age of around 28. The trend reversed down towards seasonal equality by the age of around 40, when it turned upwards towards a summer deficit again.

Time estimation, with a significant quadratic component, also had a winter deficit at low ages, crossing into a summer deficit at about 26 years old, reaching a peak summer deficit at about 35 years old before descending back into a winter deficit at about the age of 50 (see Figure 6).

Verbal fluency, the only dependent variable in the original analysis on which there was an overall winter deficit, showed a more complex pattern (see Figure 7, and note that the dependent measure is winter minus summer, rather than summer minus winter, in order that a summer deficit is positive on the y axis and a winter deficit negative, as in all the other figures). The trough between the ages of 28 and 45 with a local minimum at about 38 years old may reflect increased seasonality in that age range.

Discussion

The present analysis provides evidence that the seasonality of cognitive performance is reliably related to age on five tasks, but only minimal evidence for the influence of gender and the proportion of one's life lived in northern Norway.

One telling aspect of the analyses is that of the five measures that age predicted, four were derived from attentional and pure speed tasks. Overall, this

Table 3

The multiple regressions for the difference between summer and winter performance for each dependent variable, listing dependent variables with significant predictors only. (RT Is response time)

Tasks	Dependent variable	Predictors	Coefficients ±s.e.	*t*	F	R^2 (%)
Speed	RT	Constant	−204±113·8	1·8	$\mathrm{F}_{(3\cdot89)} = 1\cdot9$,	5·9
		Age	19·5 ±9·7	2·0	p = ·14	
		Age^2	−0·5±0·3	2·1		
		Age^3	0·005±0·002	2·2		
Stroop	Confusability	Constant	46·1±25·6	1·8	$\mathrm{F}_{(1\cdot93)} = 4\cdot8$,	4·9
	RT	Age	−1·7±0·8	2·2	$p < \cdot05$	
Mapping	RT	Constant	−557±192	2·9	$\mathrm{F}_{(3\cdot98)} = 7\cdot3$,	18·7
		Age	52·7±16·7	3·1	$p < \cdot0001$	
		Age^2	−1·5±0·45	3·4		
		Age^3	0·01±0·003	3·6		
Time Estimation	Absolute proportion deviation	Constant	−0·4±0·2	2·5	$\mathrm{F}_{(2\cdot96)} = 3\cdot9$,	7·6
		Age	0·03±0·01	2·4	$p < \cdot05$	
		Age^2	−0·0003±0·0001	2·2		
Face Recognition	RT	Constant	90·2±35·3	2·6	$\mathrm{F}_{(1\cdot96)} = 4\cdot4$,	4·4
		Gender	47·6±22·7	2·1	$p < \cdot05$	
Verbal Fluency	Number of words	Constant	−22·1±15·8	1·4	$\mathrm{F}_{(3\cdot93)} = 4\cdot2$,	12·0
		Age	2·3±1·3	1·7	$p < \cdot01$	
		Age^2	−0·07±0·04	2·1		
		Age^3	−0·0007±0·0003	2·4		

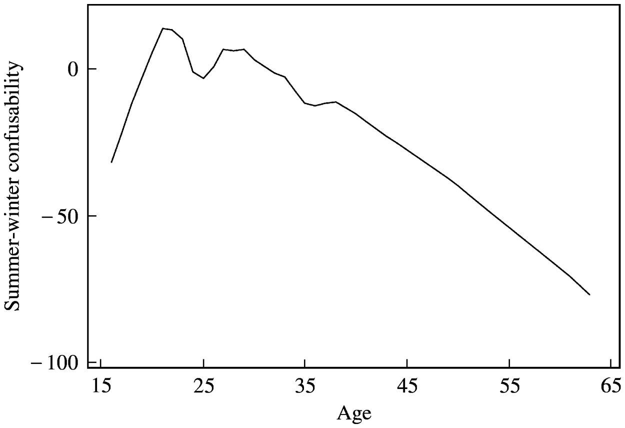

Figure 3 The difference in confusability as measured by the difference in milliseconds per condition in summer and winter on the stroop task, plotted by age.

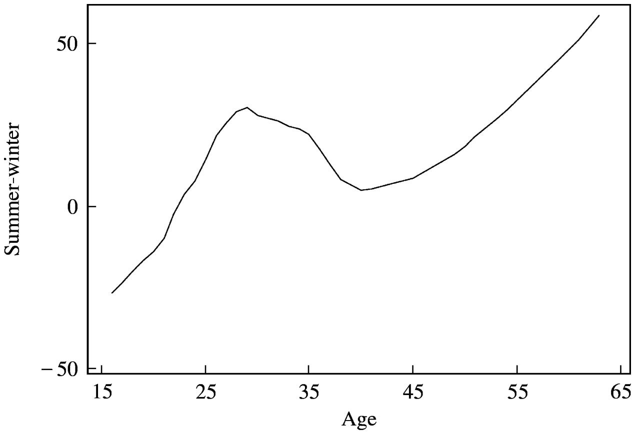

Figure 4 The difference in the mean response times per condition on the mapping task in summer and winter, plotted by age.

suggests that tasks requiring simple and rapid online processing are influenced by seasons, but that tasks requiring access to memories are not. Interestingly, the verbal fluency task, which was the only memory task to show an effect of age on seasonality was also the only task on the whole battery to show a significant winter deficit (Brennen *et al.*, 1999).

It is also striking that, apart from the Stroop confusability measure where the relationship between seasonal differences and age was linear, a change in the direction of the effect of age emerged around

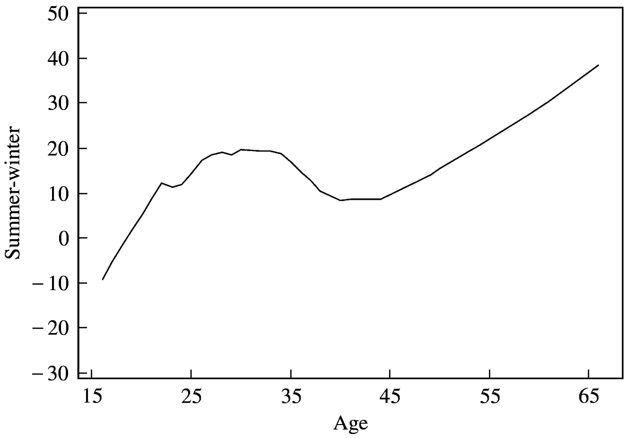

FIGURE 5 The difference in the response times on the speed task in summer and winter plotted by age.

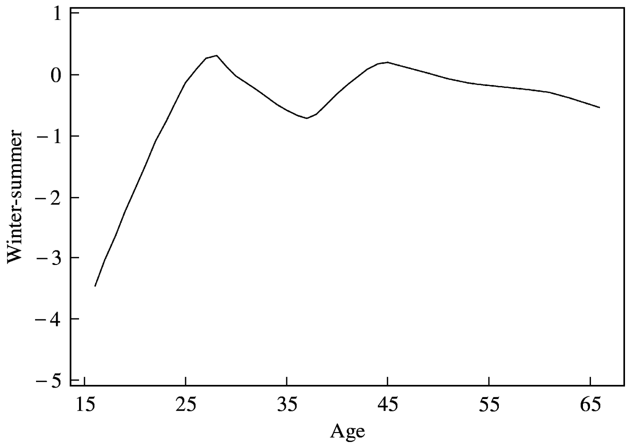

FIGURE 7 The difference in the number of words generated in the verbal fluency task in summer and winter plotted by age.

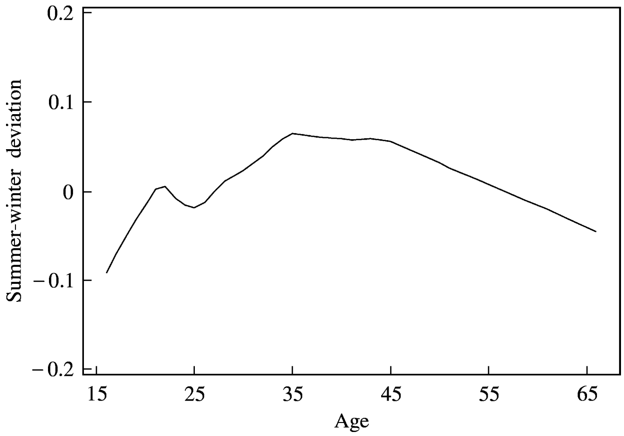

FIGURE 6 The difference in the mean absolute proportion deviation per condition on the time estimation task in summer and winter, plotted by age.

the age of 40. For example, consider the seasonality measures derived from the mapping and speed tasks, which in fact show a remarkably similar pattern (Figures 4 & 5). There appears to be a peak summer deficit of under 30 ms in one's late 20's and early 30's, reducing to summer-winter equivalence at around 40, followed by a summer deficit again from that age on. In sum, on several tasks there appears to be an elevated difference between performance in summer and winter between one's mid-20's to one's early 40's, and this is consistent with the typical age range of SAD patients. However on several tasks the increased seasonality is a tendency for performance to be better in winter.

Gender had a significant effect on only one test and may thus be seen as relatively unimportant. This contrasts with reported preponderance of women as patients diagnosed with SAD.

There were many factors that could have accounted for a correlation between the proportion of one's life lived in northern Norway and cognitive seasonal swings. These include genetic preparedness for the cognitive swings, self-selection of the population due to migration south of people experiencing intolerable swings, and rapid adaptation of newcomers to the physical swings after a number of years in the Arctic. The fact that there were no such correlations may be counted as evidence against the existence of such phenomena.

Brennen *et al.* (1999) reported small or no effects of cognition over the annual cycle. In the present paper, the extent to which age, gender, and the number of years lived in northern Norway were predictors of the difference in cognitive performance in summer and winter was determined. Even with this additional way of analysing the database, there were only a few effects, the most consistent of which were a tendency for age to predict seasonal differences in scores on on-line attentional tasks. Together, this paper and that by Brennen *et al.* (1999) offer empirical evidence that changes in the physical environment have a small and limited effect on humans' mental performance. The absence of impressive seasonal effects in cognition at 69°N strongly suggests that they will not be found at lower latitudes either, because the swings in the amount of daylight over the annual cycle are less extreme. Another take on this view is due to Samuel Johnson:

> "Surely nothing is more reproachful to a being endowed with reason, than to resign its powers to the influence of the air, and live in dependence on

the weather and the wind......to call upon the sun for peace and gaiety, or deprecate the clouds lest sorrow should overwhelm us, is the cowardice of idleness, and the idolatry of folly."

Samuel Johnson (1758)

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Notes

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