Using the triangle of human ecology for understanding self-rated depression: A quantitative study based on the HUNT 3 cohort

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Abstract

Aims: To test the triangle of human ecology by examining associations between unipolar depression and different measures of biological factors, health behavior, and the physical environment.

Methods: Data originate from the third wave of the Nord-Trøndelag Health Study (2006-2008). The survey was based on a random sample of 50,000 Norwegians (response rate: 54 %). Logistic regression was preformed, using unipolar depression, measured with the HADS-score, as outcome variable and 38 explanatory variables.

Results: Biological factors including older age and male gender were associated with higher odds of depression as were behavioral factors like including drinking behavior and neurotic personality. Reduced odds were associated with units of alcohol consumed, extrovert personality and physical activity. Social networks were an environmental factor with reduced odds at both personal and neighborhood levels, as was warmer outdoor temperatures.

Conclusion: Using the triangle of human ecology to study mental health provides a holistic insight into how behavior, biology and the environment influence mental health.

Keywords: *Unipolar depression, mental health, HADS, cross-sectional study, surveys and questionnaires, HUNT, triangle of human ecology*

Wordcount: 3054

Background

Unipolar depression is a mental disorder characterized by episodes of all-encompassing low mood, low self-esteem, and loss of interest in normally enjoyable activities [1]. The World Health Organisation has predicted that unipolar depression will be the leading cause of disease worldwide by 2030 [2]. Depressed individuals have a shorter life expectancy than others, in part because they are at elevated risk of suicide [3]. However, they also have a higher risk of mortality from other causes such as heart disease [4].

Risk factors that may influence the onset of depression include biological factors like gender [5], behavioural elements such as alcohol consumption [6], and environmental drivers like social networks [7]. Biological aspects cannot be changed easily, but environmental and behavioural factors can be influenced by political and social measures. It is therefore important that they are identified to operate an effective prevention system. Most previous studies on mental health and depression have tested the potential influence of a restricted number of risk factors. Whilst this brings some methodological benefits, depression is a complex phenomenon. As recognised by the WHO [1] mental health is a result of a complex interaction of biological, psychological, social, and environmental factors, and this makes it important to consider a holistically broad range research of factors.

We suggest that Meade & Earicsons Triangle of Human Ecology [8] helps conceptualise and explore the risk factors for health states that are likely to be based on multiple explanations, and thus it provides a useful framework by which to elucidate the relative importance of a range of risk factors. The model is intended to help understand states of health based on three dimensions: population, environment, and behaviour [8]. It explains a state of health based on three components: population factors (biological aspects), environmental factors (built, natural and social contexts) and behavioural factors (habits, technology etc.).
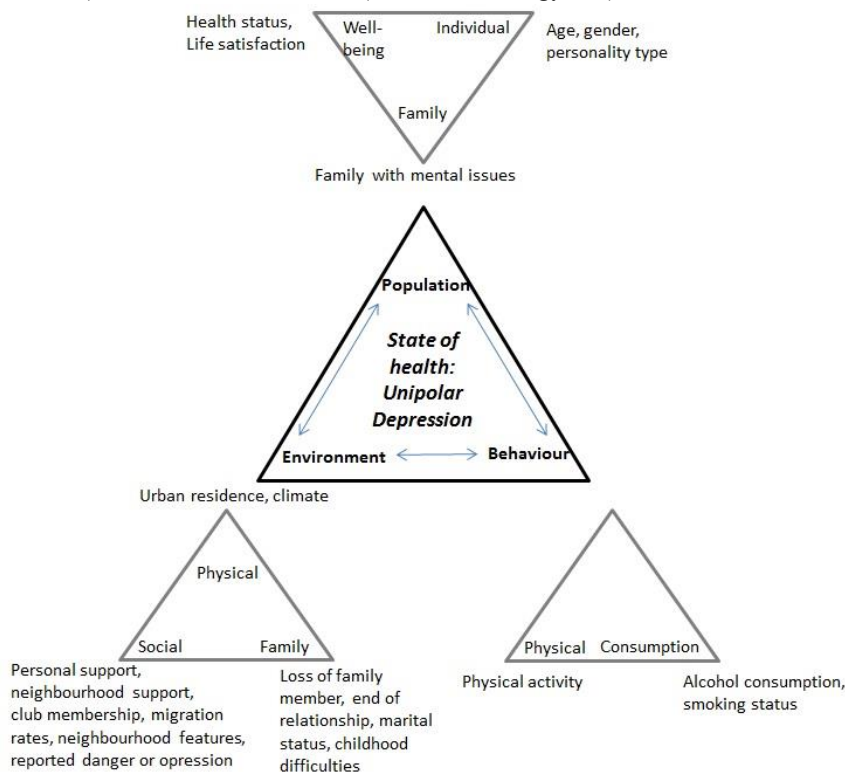

Figure 1: Triangle of human ecology - State of Health: Unipolar Depression – Hypothesised variables tested for association with depression

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Figure 1 shows the hypothesised list of factors based on previous literature using the human ecology triangle. Population factors are most concerned about the biological factors of sex, age, genetics. For example, previous studies have found that women report more mental health problems than men [5], and that there is a higher prevalence of depression in the oldest and young adult age-groups [15]. Personality factors can also influence mental health; people with a high degree of nervousness have been found to have more depression than others[16]. In terms of social environmental factors, difficult life events may increase the risks of developing depression especially shortly after the occurrence [16, 18]. Negative events in childhood such as neglect, trauma, abuse, and lack of love increase the risk of later developing depression [16], and there is also evidence of increased risk of developing depression amongst those losing a parent during childhood [19]. Social networks are associated with depression at both individual [7, 20] and neighbourhood levels [21] and participation in social activities is one dimension of loneliness [18],

In relation to family structure, there is evidence that single people have a lower quality of life and poorer mental health than married or cohabiting individuals [15, 22], A further area of interest is whether animals can have any impact on the mental health, although the evidence for this is somewhat equivocal [23], contextual characteristics of the place the individual lives may also be important. For example, an unstable population could reflect social disintegration, which in turn could lead to a general impact on the depression prevalence of an area [24].

In terms of the physical environment most studies show a tendency towards a higher incidence of depression in urban rather than rural areas, although research findings are again equivocal [25]. Further, some studies have shown an association between climate and mental health [26]. For behavioural factors physical activity is known to improve mental health, and has a particular impact on depression [15]. Tobacco habits have a major impact on mental health [27, 1], whilst alcohol consumption has also been strongly linked to depression [27, 22],

There are models presenting the complexity of mental health [1] but we are not aware of previous studies that have applied the triangle of human ecology, and hence we test is utility as a framework in the context. Based on the model, this study examines the strength of association between depression and a much wider range of potential risk factors than is typically tested.

Methods

This study is a secondary analysis of the Nord-Trøndelag Health Study (HUNT). HUNT is one of the largest health surveys in the world [9]. It comprises a cohort study in which all citizens over the age of 20 of Nord-Trøndelag county in mid-Norway are eligible for inclusion. Several sampling methods have been used in HUNT, but this study concerns mainly the variables collected through questionnaires and interviews. Full descriptions of methods can be found online (http://www.ntnu.edu/hunt).

Our analysis utilises cross-sectional data collected during HUNT 3, which was undertaken between 2006 and 2008. 50 807 individuals completed at least one questionnaire, and they formed the basis of this sample. Using the Triangle of Human Ecology, the data was reviewed by members of the research team and those measures that were hypothesised to be potentially associated with mental health were identified. The number of candidate variables was very large, and prefiltering of the variables was based on consideration of their importance in earlier studies.

The primary measure of depression, and hence outcome in this study, was based on the responses of each participant

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to questions forming the Hospital Anxiety and Depression Scale (HADS). HADS consists of 14 questions of which 7 cover anxiety symptoms and 7 cover symptoms of depression [10]. Each of the 14 questions was answered on a four-point Likert scale (0-3), with a final score of 0-21 being achieved on the HADS-D (depression) and 0-21 on HADS-A (anxiety) domains. Although the appropriateness of separating the two domains of HADS has received discussion, Mykletun et al. [11] recommend doing so based on their analysis of HADS scores in HUNT 1, so we chose to follow the two-factor structure here. Cronbach's alpha was found to be above 0.60 in a review of studies using HADS [12], where the average values were as high as 0.8 [13]. Although HADS scores can be modelled as a continuous measure, Bjelland et al. [12] found that a binary measure based on scores of 8 or more (depressed) versus below this value (not depressed) was optimal for identifying anxiety and depression based on ICD-9 codes. Hence, we also chose this cut-off point, although this is clinically relatively low, as 8-10 points is categorised as a mild depression [10]. What makes the HADS measurement distinct from other measures is that physical symptoms of depression which could also be related to somatic illness are excluded [12]. To separate out emotions such as grief from depression, the HADS-questions are centred on anhedonia, one of the main symptoms of major depressive illness [14].

The following explanatory variables where tested (table 1). With all measures based on individual data in HUNT except for urban residence, climate, migration, and education which were area based.

Table 1 Operationalization of explanatory variables

Explanatory variable	Measurement
Age	Continuous variable and divided into groups of 20-29, 30-49, 50-69 and 70+ for adjusted
Sex	Male/Female
Genetics	Reporting a family member with mental health issues
Marital status	Unmarried, married, widower, divorced and separated. Original categories of surviving partner, registered partner and divorced partner were merged together with widower, married and divorced.
Personality (extroversion and neuroticism)	EPQ, Eyesenck Personality Questionnaire. 6 questions on extroversion and neuroticism. Total score is calculated giving a score between 0-6 on each and treated as a continuous variable.
Difficult life events	Death of a family member, having been in imminent mortal danger or having gone through a relationship breakup during the previous 12 months
Difficult childhood	Likert scale ranging from "very good" to "very difficult", Parental loss before the age of 7 and between the ages 7-18
Social network, individual level	Emotional network: "do you have friends you can speak to confidentially?"; tangible networks: "do you have friends who can give you help when you need them?"
Social network, participation	Participation in sports, outdoor activity, dance, parish work, theatre/music, club meetings. Dichotomous indicator, last 6 months
Social network, living arrangement	Alone, with parents, with partner, with people over 18, with people under 18.
Social network, neighbourhood level	Sense of community, lack of social capital/distrust, and social cohesion in their neighbourhood using three 5 category Likert-items

Pet ownership	Dog, cat, ferrets/bird, none
Oppression	"Has anyone at any time in your life tried to oppress, degrade or humiliate you over an extended period of time?"
Tobacco consumption	Frequency of smoking, type of cigarettes smoked, and if they currently or previously used snuff
Alcohol consumption	Weekly alcohol consumption (units), both overall and by type of alcohol
Alcohol behaviour	CAGE score (4 questions related to alcohol behaviour)
Physical activity	Weekly frequency of physical activity, which was aggregated into three categories: never, less than once a week and more than once a week
Sedentary lifestyle	Daily hours of sitting
Education	Percentage of people with high education in a municipality. These numbers are collected from SSBs statistical database from 2010
Migration	Migration rates were modelled as a positive or negative net number of immigrants per 1000 residents of each municipality.
Climate	Precipitation and temperature at municipality level, normals for the period 1961 - 1990, which were collected from the Norwegian Meteorological Institute eKlima system
Urban residence	Residents in Levanger, Steinkjær, Namsos, Stjørdal and Verdal municipalities were coded as 'urban'.

For the Eyesenck Personality Questionnaire (EPQ) [17] the total score was calculated for each variable, giving a score between 0 (low) and 6 (high) on each of the measurements. CAGE score is an instrument comprising four questions related to problematic drinking behaviour [28]. We examined responses to the individual questions as well as a binary measure of a 'yes' response to at least two questions, which is a commonly used identifier of individuals with a very high likelihood of alcohol addiction [22]. Approximately 15% of HUNT participants did not respond to this question, so to prevent loss of these individuals from the study, non-response to CAGE was modelled as a separate category.

The Norwegian Regional Ethics Committee (REK) approved this study 06.09.11 (2011/1270), and it was reapproved 2018 as the former approvement was expired. All participants in HUNT provide written consent for the data to be used for research purposes.

Statistical analysis
Unadjusted associations with the dichotomous primary outcome (HADS below 8 vs 8 or above) were examined using descriptive statistics and cross tabulations. Significance testing was undertaken using chi-squared tests for categorical predictors and t-tests for continuous. To determine which hypothesised factors were associated with depression after adjustment, a logistic regression model was fitted with binary outcome. Fitting was undertaken via stepwise backward procedure, starting the model with all variables, then removing them sequentially starting with the least significant. Backward stepwise selection was selected because we did not have any a-priori assumptions about which of the variables we analysed would be associated with HADS-scores, and it therefore provided an assumption free approach.

As the effects of each variable may be influenced by the variables already entered into the model, significance testing was also performed by checking that the removal of each variable from the final model resulted in a statistically significant drop in model fit, as determined by the log-likelihood ratio. All statistical analysis was undertaken using IMB SPSS Statistics 19. The explanatory variables used in the unadjusted regression are described in Table 2. Statistically significant variables in the unadjusted regression model were considered for inclusion in the adjusted model; because of the large number of predictors, the variables were first divided into groupings, then stepwise regression was performed on each group before the statistically significant variables were considered in the final model, Table 3. Observations with missing data were excluded from the analysis for most variables except where the respondent has ticked other boxes for the same question in which case the response was coded as 'no'. All variables had missing less than 10 % prevalence of missing values except sitting hours a day (13.3%), occupational status (15.9%) and CAGE-score

Results

In total, a response to at least one of the questions studied were provided by 50,807 (54.1 %) HUNT 3 participants. There was a higher response rate among women compared to men (58.4% vs 49.3%). 10, 341 people were excluded from this study due to a non-response to the HADS-D questions or not replying to both questionnaires. Hence the analysis utilised a final sample of 40,466 HUNT 3 participants.

Table 2 presents characteristics of the sample. 9.6 % (3 892) had a HADS-score over 8, indicating depression. Participants were more likely to be women (56 % vs. 44 %) and to live in an urban location (64 % vs 36 %). Participants were more likely to be married (61 %) than being in one of the other categories of marital status, which is also reflected in living situation where 78 % were living with a spouse.

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Table 2 Baseline characteristics of the HUNT 3 sample for those with valid data on HADS-score and both questionnaires

Sample Characteristics		N (percentages) (N = 40 466)
Mean age (SD)		54.4 (15.6)
Gender	Male	17 787 (44.0)
	Female	22 679 (56.0)
Occupational status	Working	25 318 (74.4)
	Students	1 291 (3.8)
Marital status	Unmarried	8 281 (20.5)
	Married	24 637 (61.0)
	Widow(er)	3 487 (8.6)
	Divorced	3 536 (8.7)
	Separated	475 (1.2)
Living situation	Living alone	6 443 (16.0)
	Living with parents	678 (1.7)
	Living with spouse/partner	31 484 (78.0)
	Living with other persons over 18	4 151 (10.3)
	Living with other persons under 18	9 212 (22.8)
Urban rural status	Urban	25 550 (64.0)
	Rural	14 400 (36.0)
HADS-D over 8	Depression	3 892 (9.6)
	No depression	36 574 (90.4)

Table 3 shows the unadjusted associations between HADS-D and potential explanatory variables. Amongst the population factors, there was a significant association between gender and depression, where men were 23 % more likely to have depression. There was also a statistically significant association with age, whereby older participants are more likely to have a HADS-D score of above 8. Reporting a family member with mental problems also increases the odds of being depressed.

For behavioural factors, having a CAGE score over 2 was significantly associated with depression. Surprisingly an association in the opposite direction is found with reported alcohol consumption, whereby those who were not depressed reported drinking significantly more. Individuals reporting having never smoked or taken snuff or only occasionally smoking cigarettes are less likely than heavier smokers to be depressed based on HADS-D scores.

There is evidence that personality is strongly associated with depression in the sample. Participants with responses that classified them as neurotic were almost 13 times more likely to be depressed than others, whilst those classified as extroverted had an odds of depression of just 0.14 (around a tenth as likely as others). Respondents who were more physically active were also less likely to be depressed and, more generally, the number of life events reported, both recently and those which had occurred sometime in the past, were significantly associated with the odds of depression. The odds ratio for childhood difficulties shows that those reporting a score above the mean were over twice as likely to be depressed. Social networks on both personal and neighbourhood levels were associated with a lower odds of depression, but pet ownership was not. There was evidence for the importance of networks whether they were measured by living arrangements, marital status, and participation in community events.
Analysis of the physical environment variables showed that respondents living in urban areas were significantly less depressed than their rural counterparts. Climatic factors were also associated with depression, whereby there was higher odds of depression in rainy areas and a lower odds in warmer areas. Depression was also associated with migration whereby there was a significantly higher positive net migration in those with HADS scores below 8. Of the general health questions, life satisfaction was significantly negatively associated with depression.

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Table 3 Distribution of Hospital Anxiety and Depression Scale (HADS-D) by population, behavioural and environmental factors (n=40 466)

		HADS-D < 8[1]	HADS-D ≥ 8[2]	P-value	Unadjusted Odds ratio	Frequencies	Total
Population factors							
Male		43.5	48.6	<0.001	1.23	17787	40466
Age		53.9 (years)	58.7 (years)	<0.001	2.20	-	40466
Family member with mental problem		19.0	29.2	<0.001	1.76	7721	38710
Health status	Poor	0.9	6.1	<0.001	1	542	39307
	Not so good	22.2	50.7		0.32	9807	39307
	Good	59.8	40.4		0.10	22764	39307
	Very good	17.1	2.8		0.02	6194	39307
Life satisfaction (7-item Likert)		5.74 (value)	4.64 (value)	<0.001	0.15	-	39997
Personality							
Neurotic	Worry about terrible things	16.1	37.9	<0.001	3.18	7087	38960
	Felt indifferent	19.3	58.8	<0.001	5.97	8918	38736
	Nervous problem	13.3	47.5	<0.001	5.87	6441	38861
	Lose interest	34.3	73.4	<0.001	5.26	14710	38699
	Easily hurt	40.4	64.1	<0.001	2.63	16491	38680
	Worried	25.2	63.6	<0.001	5.20	11224	38930
	Total score (0-6)	1.47 (value)	3.45 (value)	<0.001	12.83	-	-
Extroverted	Takes first step to make new friends	44.1	24.7	<0.001	0.42	16296	38582
	Lively person	71.9	46.0	<0.001	0.33	26918	38752
	Likes life and excitement around you	54.9	32.7	<0.001	0.40	20360	38592
	Like meeting new people	90.5	72.3	<0.001	0.27	34593	38942
	Mostly quiet and reserved	33.9	59.4	<0.001	2.85	14141	38873
	Life of the party person	53.1	29.9	<0.001	0.38	19385	38079
	Total score (0-6)	3.81 (value)	2.46 (value)	<0.001	0.14	-	-

[1] All numbers are percentages unless otherwise is stated I brackets. See table 1 for operationalization of each variable.
[2] All numbers are percentages unless otherwise is stated I brackets. See table 1 for operationalization of each variable.

Behavioural factors
Alcohol
CAGE-score

Felt to reducing alcohol intake		10.2	18.6	<0.001	2.02	3754	34353
Criticised about use of alcohol		7.0	13.7	<0.001	2.09	2606	34161
Felt guilty drinking		12.9	21.4	<0.001	1.83	4667	34096
Have had a pick me up drink in the morning		2.0	5.4	<0.001	2.72	799	34187
CAGE over 2		7.2	13.5	<0.001	2.29	3170	33997
CAGE missing		15.2	23.1	<0.001	1.86	6469	40466
Consumption							
Glasses of beer a week		0.8 (glass)	0.8 (glass)	0.848	0.85	-	37330
Glasses of wine a week		1.1 (glass)	0.8 (glass)	<0.001	0.58	-	37330
Glasses of spirits a week		0.4 (glass)	0.4 (glass)	<0.01	1.00	-	37330
Total amount a week		2.3(glass)	2.1 (glass)	<0.001	0.61	-	37330
Tobacco							
Never smoked		46.2	39.8	<0.001	0.77	17971	39443
Quit smoking		31.8	34.1	<0.01	1.11	12615	39443
Occasionally cigarettes		9.0	8.5	0.294	0.94	3524	39443
Occasionally cigars		1.6	2.7	<0.001	1.66	685	39443
Cigarettes Daily		17.1	23.8	<0.001	1.51	7015	39443
Cigars Daily		1.2	2.5	<0.001	2.11	534	39443
Used snuff	Never	86.4	85.2	<0.05	1	33654	39007
	Quit	4.5	5.4		1.30	1787	39007
	Occasionally	2.9	3.2		1.12	1139	39007
	Daily	6.2	6.2		1.01	2427	39007

Physical activity

Sitting hours a day		5.8(hours)	6.1(hours)	<0.001	1.24	-	35074
Exercise	Never	4.3	9.5	<0.001	1	1926	39810
	Less than 1/w	15.2	21.2		0.64	6273	39810
	Once a week	21.3	21.1		0.46	8461	39810
	2-3 times/w	40.4	31.5		0.36	15740	39810
	Nearly every day	18.8	16.7		0.41	7410	39810

Environmental factors (social and physical)

Life events

Last 12 months

Family member died		10.1	13.9	<0.001	1.45	4139	39698
Imminent mortal danger		2.8	5.8	<0.001	2.10	1241	39768
Relationship ended		9.5	12.9	<0.001	1.42	3903	39708
Parental loss	No	92.5	90.9	<0.01	1	36844	39911
	Before 7 years	2.4	2.7	<0.01	1.15	954	39911
	7-18 years	5.2	6.4	<0.01	1.26	2113	39911
Childhood difficulties (5-item Likert)		1.7 (value)	2.1 (value)	<0.001	2.44	-	40099

Social network

Personal level	Emotional support	92.8	75.9	<0.001	0.25	38096	40106
	Tangible support	96.2	84.0	<0.001	0.21	36579	40125
Neighbourhood level	Sense of community	4.0 (value)	3.6 (value)	<0.001	0.46	-	40067
	Distrust (Lack of social capital)	2.2 (value)	2.7 (value)	<0.001	2.55	-	39714
	Like living here (Social cohesion and social capital)	4.6 (value)	4.2 (value)	<0.001	0.39	-	40136
Occupational status	Have a job	75.7	60.6	<0.001	0.49	25318	34038
	Student	3.9	2.9	<0.01	0.74	1291	34038
	Housewife/husband	2.5	3.9	<0.001	1.56	903	34038

Pet ownership	Pet ownership	64.9	64.8	0.884	1.00	14191	40466
	Dog ownership	17.9	18.0	0.971	1.04	7259	40466
	Cat ownership	20. 1	20.7	0.343	1.00	8156	40466
	Other pet ownership	2.7	3.1	0.124	1.16	1094	40466
Living arrangement	Live alone	15.2	23.5	<0.001	1.72	6443	40375
	Parents	1.7	1.6	0.881	0.98	678	40375
	Spouse/partner	78.	70.3	<0.001	0.64	31484	40375
	Other over 18	10.4	9.3	<0.05	0.89	4151	40375
	Other under 18	23.4	17.2	<0.001	0.68	9212	40375
Marital Status	Unmarried	20.6	19.7	<0.001	1	8281	40416
	Married/reg. Partner	61.5	55.5		0.94	24637	40416
	Widower/ surv. Partner	8.3	11.9		1.51	3487	40416
	Divorced/ div. Partner	8.5	11.1		1.37	3536	40416
	Separated	1.1	1.7		1.61	475	40416
Been oppressed for a long time period		18.1	33.9	<0.001	2.31	7332	37399
Participated in	Club meeting	42.2	29.6	<0.001	0.58	15921	38832
	Music, singing, theatre	19.9	13.1	<0.001	0.61	7554	39153
	Parish work	5.5	4.5	<0.01	0.80	2127	39203
	Outdoor activity	80.1	65.5	<0.001	0.47	30477	38704
	Dance	36.6	22.8	<0.001	0.51	13822	39135
	Sports	60.6	43.7	<0.001	0.51	22904	38848
Area factors							
Urban		64.5	58.8	<0.001	0.79	25550	39950
Precipitation (mm)		1042.85 (mm)	1056.42 (mm)	<0.001	1.18	-	39950
Temperature (°C)		4.38 (°C)	4.30 (°C)	<0.001	0.92	-	39950

Moving rates (net number immigrants pr. 1000 inhabitant)	1.14	0.43	<0.001	0.78	-	39950
Highly educated	22.2	21.6	<0.001	0.72	-	-

The adjusted associations are presented in Table 4. Sex and age were still associated with depression, with men having a 58 % higher chance of depression then women and older individuals having increased odds of a higher HADS-D score; 3.2 times higher for individuals over 70 years compared to those aged 20-29. Regarding use of alcohol, after adjustment there remained a statistically significant association between a CAGE score over 2 and depression, 1.5 times higher in groups with a CAGE over 2, as well as an independent relationship between higher alcohol consumption and decreased depression odds of around 2 %. There was 15-20 % reduced odds of depression if having a job or participating in music and outdoor activity. Interestingly, all variables measuring social networks on a personal level still showed a statistically significant adjusted association with depression, with a 15-30 % reduced odds of depression, highlighting the importance of quality social networks in the maintenance of good mental health. Childhood difficulties (8,5 %), neurotic personality (58 %) and reporting being in imminent mortal danger the last 12 months (33,7%) remained positively associated with a high HADS-D score, while exercise (- 20-35 %), having extroverted personality (- 21 %), high life satisfaction (-50,9 %) and high mean temperature (- 8,1 %) remained protective in the best fit model.

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Table 4 Results from logistic regression with Hospital Anxiety and Depression (HADS-D) as dependent variable.

N = 28 089

Missing = 12 377

		Odds ratio	95 % CI	P-value
Population factors				
Male		1.56	1.41-1.77	<0.001
Age	20-29 (ref)	1		
	30-49	1.67	1.33-2.10	<0.001
	50-69	2.06	1.65-2.59	<0.001
	70 +	3.23	2.16-4.84	<0.001
Life satisfaction		0.49	0.47-0.52	<0.001
Personality	Extroverted	0.79	0.77-0.81	<0.001
	Neurotic	1.57	1.52-1.62	<0.001
Behavioural factors				
Alcohol				
CAGE	Over 2	1.54	1.32-1.80	<0.001
	Missing	0.99	0.84-1.16	0.868
Alcohol consumption weekly		0.98	0.96-1.00	0.024
Physical activity				
Exercise	Never (ref)	1		
	Once a week or less	0.78	0.63-0.98	0.031
	More than once a week	0.65	0.52-0.81	<0.001
Environmental factors (social and physical)				
Life events				
Imminent mortal danger, last 12. months		1.34	1.04-1.72	0.023
Childhood difficulties		1.09	1.03-1.15	0.004
Social network				
Personal level	Tangible support	0.79	0.65-0.95	0.011

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	Emotional support	0.71	0.61-0.82	<0.001
Neighbourhood level	Distrust	1.105	1.060-1.15	<0.001
	Like living here	0.818	0.77-0.88	<0.001
Occupational status	Have a job	0.838	0.74-0.94	0.003
Participation in	Music/theatre	0.854	0.74-0.98	0.028
	Outdoor activity	0.837	0.74-0.95	0.006

Area factors

Mean temp.		0.919	0.88-0.97	0.001

Discussion

The triangle of human ecology provided to be a suitable framework for studying the complex phenomenon of depression. However, there are some limitations to the model. For example, some variables are not necessarily linked to just only to one of the three components: personality is influenced by the environment as well as genetic components and problematic alcohol consumption is also influenced by the cultural expectations of alcohol consumption, not just units of alcohol. Thus, the triangle represents a somewhat simplistic approach to a complex reality.

The main strength of this study is sample size and the range of variables on individual and area level associated with depression, providing something akin to a systems approach. HUNT is a well characterised cohort, containing validated measures of outcome and relevant exposure variables. The response rate is high compared to other studies, and Nord-Trøndelag is also a county with low migration, making it less problematic to treat current residence as a main exposure. However, it can be difficult to find a sample suitable heterogeneity in all exposures to adequately depict the triangle. In this case the data came from a very homogenous environment with lack of highly urbanized or segregated areas, making generalization limited [9]. Residence in large urban areas has been associated with an increased odds of depression in other populations [25] and it may be that associations would differ in a more heterogeneous setting. The similarity of the physical environment provides equal opportunities across study participants. This makes it difficult to capture the role of the physical environment as a determinant of factors such as physical activity. There were also issues capturing heterogeneity of the social environment; Nord-Trøndelag has very few immigrants and less than 3% of the population is non-Caucasian [9], making generalization to other ethnic groups problematic. The triangle of human ecology therefore is more difficult to apply to less heterogeneous samples. A limitation that remained was the problem of multiple testing; the many statistical tests needed to examine the diverse components of the model leads to the problem of some detected associations most likely being due to chance. Linked to this, the fact that we chose a stepwise best-fitting procedure meant that the final model we produced contained variables that were similar in terms of statistical significance to others thar were excluded. Whilst our stepwise approach meant that we were free of a-priori assumptions around which variables to include, an implication therefore is that our representation of important predictors of mental health could differ with small changes to the data. As such our findings should be treated as an exemplar of the domains of importance rather than a definitive list of key drivers.

The biggest limitation of the study is that our data was cross-sectional, and therefore it is not possible to say infer causality. Although a validated measure was used, our outcome was based on self-report rather than clinical diagnosis. The availability of data at only a single time point meant it was not possible to consider lags or latencies; most of our measures were based on present status and did not take into account the history of behaviour or spending time in different environments. A further limitation was that some of the variables we tested were closely related and our use of a stepwise best-fit approach meant that small relative differences in statistical significance could have led to some changes in the variables depicted in our final model.

Mental health and depression are related to physical and social environmental factors (see figure 2). Within a broad framework, the triangle of human ecology model indicates interactions between physical and social environmental elements, and their potential effects on (mental) health. For example, temperature may play a role as a transient factor influencing mental health directly through seasonal fluctuations and depression [29] as well indirectly through influencing physical activity levels. Climate and temperature may influence behaviour and the threshold to move out of the house for various activities and for meeting people. Depressed individuals may also be extra sensitive to such isolation factors. Temperature can be a greater factor in typical rural and sparsely populated areas experience longer walking distance to informal meeting places and social networking. Variables like gender, degree of depression, types of daily activity can also mitigate the relationship between environment and mood [30] and require further investigation. We suggest the triangle of human ecology provides a framework to guide researchers in their role.

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As our findings show, depression is not just related to individual factors. The identification of environmental and behavioural factors indicates the need to consider depression outside of the health sector where the individual and biological measures are also strongly linked contextual interactions. Working towards strengthening social networks at neighbourhood levels, and involving people in both workplaces and domestic settings calls for action from diverse agencies including planners, social workers, and public authorities.
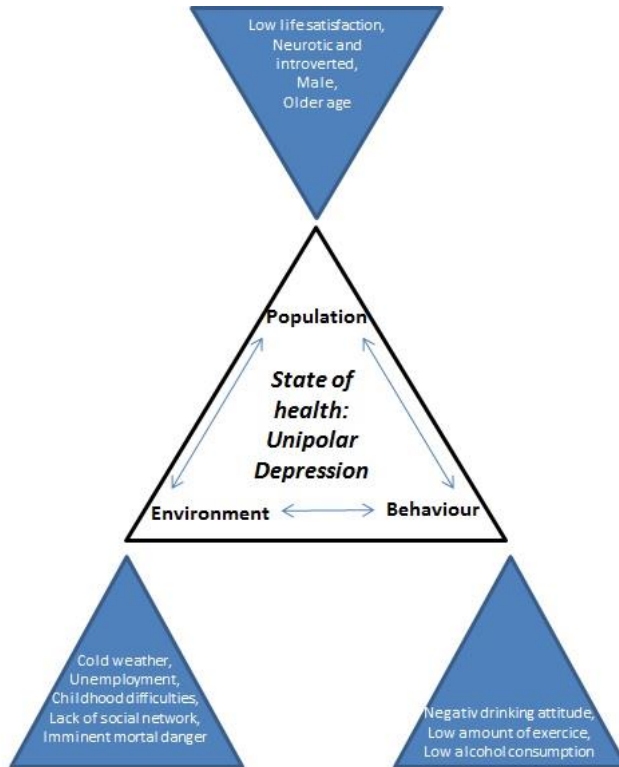
Figure 2: Triangle of Human Ecology: State of Health: Unipolar Depression - Results

Acknowledgment

Funding

Declaration of Conflicting Interests

The Authors declares that there is no conflict of interest.

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