

**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 human 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 performed, 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 including drinking behavior and having a 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 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*

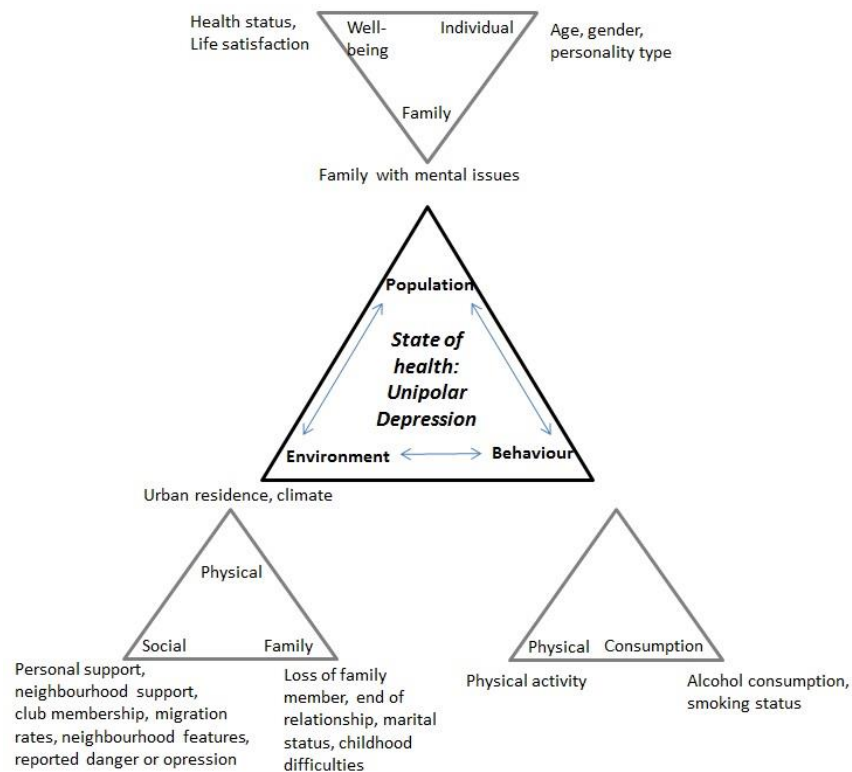
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## **Background**

Unipolar depression is a mental health 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 (WHO) has predicted that the condition will be the leading cause of disease and death worldwide by 2030 [2]. In addition to the debilitating impact of depression on day-to-day living, depressed individuals have a shorter life expectancy than others. In part this is because they are at elevated risk of suicide [3], yet they also have a higher risk of mortality from other causes such as heart disease [4].

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 holistically consider a broad range of risk factors. Those that may influence the onset of depression include biological characteristics like gender [5], behavioural drivers such as alcohol consumption [6], and environmental factors such as the existence and extent of social networks [7]. Biological aspects of depression are not amenable to modification by public health practitioners, but environmental and behavioural factors can be influenced by political and social interventions. 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 putative influence of a restricted number of risk factors as drivers of the condition. Whilst this brings some methodological benefits, depression is a complex phenomenon and hence the evidence remains lacking.

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; 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**

Figure 1 shows the hypothesised list of risk factors for depression based on previous literature using the Triangle. Population factors are typically concerned with the biological factors of sex, age, and genetics. For example, previous studies have reported 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 as people with a high degree of nervousness have been found to be more likely to be depressed compared to 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 have been found to increase the risk of later developing depression [16], and there is also evidence of increased risk of depression amongst those losing a parent during childhood [19]. Social networks have been associated with depression risk at both the individual [7, 20] and neighbourhood levels [21] whilst participation in social activities is a well understood 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 degree to which animals impact mental health [23], whilst 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 adverse impact on the mental health of residents of an area [24]. In terms of the physical environment, most studies show a tendency towards a higher prevalence of depression in urban compared to rural areas, although research findings are somewhat equivocal [25]. Further, some studies have shown an association between climate and mental health, with poorer weather conditions associated with increased symptom reporting [26]. For behavioural factors, physical

activity is known to improve mental health, and has a particular protective impact on depression [15], whilst tobacco use and excessive alcohol consumption are both well understood risk factors for poorer mental health [22, 27].

Whilst there exist models presenting the complexity of mental health [1], we are not aware of previous studies that have applied the triangle of human ecology, and hence we test its utility as a framework in the context. Based on the Triangle, this study examines the strength of association between self-reported 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 20yrs of Nord-Trøndelag county in mid-Norway are eligible for inclusion. Several data collection methods have been used in HUNT, but this study largely concerns 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 available variables were 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 therefore 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 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 are clinically categorised as 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 were tested (Table 1). All measures were based on individual data in HUNT except for urban residence, climate, migration, and education, which were area based.

**Table 1 Operationalization of the explanatory variables**

Explanatory variable	Measurement
Age	Continuous variable and divided into groups of 20-29, 30-49, 50-69 and 70+yrs
Sex	Male/Female

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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 with widower, married and divorced.
Personality (extroversion and neuroticism)	EPQ, Eyesenck Personality Questionnaire. Six questions on extroversion and neuroticism. Total score was calculated giving a value 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, five 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 were collected from SSBs statistical database from 2010
Migration	Migration rates modelled as a positive or negative net number of immigrants per 1000 residents of each municipality.
Climate	Precipitation and temperature at the municipality level, normals for the period 1961 - 1990, collected from the Norwegian Meteorological Institute eKlima system
Urban residence	Residents in Levanger, Steinkjær, Namsos, Stjørdal and

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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 (Cut, Annoyed, Guilty, and Eye) 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 approval 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 a stepwise backward procedure, starting the model with all variables, then removing them sequentially starting with the least statistically 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 in 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 IBM 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 in most cases except where the respondent 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 the CAGE-score.

## **Results**

In total, a response to at least one of the questions studied were provided by 50,807 (54.1 %) of the HUNT 3 participants. There was a higher response rate among women compared to men (58.4% vs 49.3%). Some 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 %) rather than being in one of the other categories of marital status, which is also reflected in the measure of living situation where 78 % reported living with a spouse.



**Table 2 Baseline characteristics of the HUNT 3 sample for those with valid data for analysis**

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 statistically significant association between gender and depression, whereby men were 23 % more likely to have depression than women. 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 statistically significantly associated with depression. Surprisingly an association in the opposite direction to that expected was found for 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 were less likely than heavier smokers to be depressed based on HADS-D scores.

There was strong evidence that personality was 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, representing 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. We found that social networks on both personal and neighbourhood levels were associated with a lower odds of depression, but pet ownership was not. For social networks, there was evidence of network importance 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 statistically 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 area migration, whereby there was a significantly higher positive net migration in the localities of HUNT participants reporting HADS scores below 8. Finally, of the general health questions, life satisfaction was significantly negatively associated with depression.

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

		HADS-D < 8	HADS-D ≥ 8	P-value	Unadjusted Odds ratio	Frequencies	Total
<b>Population factors</b>							
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
<b>Personality</b>							
<i>Neurotic</i>	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	-	-
	<i>Extroverted</i>	Takes first step to make new friends	44.1	24.7	<0.001	0.42	16296
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	-	-
<b>Behavioural factors</b>							
Alcohol							

<i>CAGE-score</i>							
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
<i>Consumption</i>							
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
<i>Tobacco</i>							
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
<i>Physical activity</i>							
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
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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
<b>Area factors</b>							
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	-	-

Note: all numbers are percentages unless otherwise is stated in brackets. See Table 1 for the operationalization of each variable.

The adjusted associations between depression and the range of explanatory variables selected from the Triangle are presented in Table 4. Sex and age were still statistically significantly associated with depression, with men having a 58 % higher odds of the condition than women and older individuals having increased odds of a higher HADS-D score; this was 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, with a 50% elevated risk in the group with the higher CAGE score. Furthermore, there was an independent negative relationship between higher alcohol consumption and the odds of depression. Our results suggest a 5-20 % reduced odds of depression amongst those reporting having a job or participating in music and outdoor activity. It is noteworthy that all variables measuring social networks on a personal level retained a statistically significant association with depression after full adjustment, with 15-30 % reduced odds of depression between the measures. This highlights the importance of quality social networks in the maintenance of good mental health. Finally, recalling childhood difficulties (8,5 %), having a neurotic personality (58 %) and reporting being in imminent mortal danger the last 12 months (33,7%) remained positively associated with a higher 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.

**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
<b>Population factors</b>					
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
<b>Behavioural factors</b>					
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
<b>Environmental factors (social and physical)</b>					
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



	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
<b>Area factors</b>				
Mean temperature		0.919	0.88-0.97	0.001

## Discussion

We found that 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 unambiguously linked to only to one of the three components. For example, 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, albeit one that provides a useful tool for straightforward communication of the primary drivers of health.

The main strength of this work 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 with suitable heterogeneity in key exposures to adequately depict the Triangle. In this case the data came from a rather homogenous environment of Nord-Trøndelag with lack of highly urbanized or segregated areas, limiting generalization, particularly to more urbanised settings [9]. This is pertinent given 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 more heterogeneous or highly urbanised localities. For example, in our area of study the similarity of the rural physical environment provides broadly equal exposure across study participants which makes it difficult to capture the role of the physical environment as a determinant of factors such as physical activity. In addition to the physical environment, we were also limited in our ability to capture some drivers of heterogeneity of the social environment. For example, Nord-Trøndelag has very few immigrants and less than 3% of the population is non-Caucasian [9], making generalization to other ethnic groups problematic.

In terms of our analysis, a limitation that remained was the issue 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 is the fact that we chose a stepwise best-fitting procedure which meant that the final model we produced contained variables that were similar in terms of statistical significance to others that were excluded. Whilst the stepwise approach meant that we were free of a-priori assumptions around which variables to include, an implication 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 infer causality. Although a validated measure was used, our outcome was based on self-report at a single time point rather than clinical diagnosis. The availability of data at only one time point meant it was not possible to consider lags or latencies; most of our measures were based on present status and did not consider the history of behaviour or spending time in different environments.

Whilst it was already understood that mental health and depression are related to physical and social environmental as well as biological factors (see Figure 2), within a broad framework, the Triangle of Human Ecology indicates interactions between these 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 as indirectly by 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 be especially sensitive to such isolation factors. Temperature can also be a more influential factor in rural and sparsely populated areas where residents will experience longer walking distances to informal meeting places and social

networking opportunities. Variables like gender, degree of depression, and 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.

As our findings show, depression is not just related to individual factors. The identification of environmental and behavioural factors indicates the need to more strongly consider the condition outside of the health sector where the individual and biological measures are also strongly linked to contextual interactions. Working towards strengthening social networks at neighbourhood levels, and involving people in both workplaces and domestic settings will call for action from diverse agencies including planners, social workers, and public authorities.

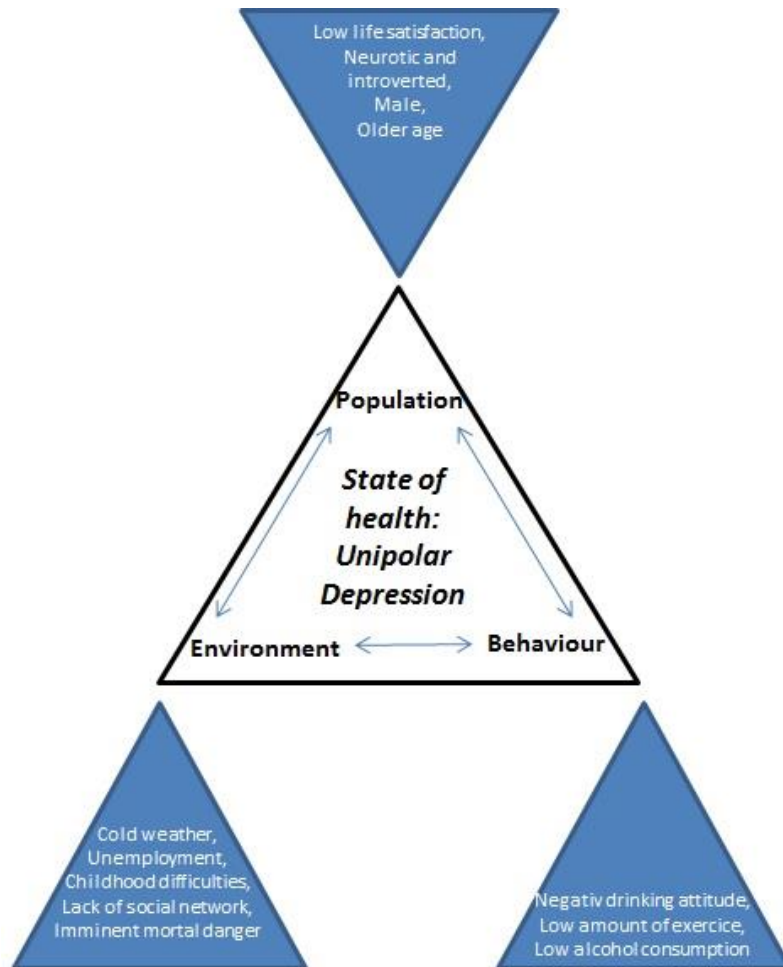


Figure 2: Triangle of Human Ecology: State of Health: Unipolar Depression - Results

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### **Declaration of Conflicting Interests**

The Authors declares that there is no conflict of interest.

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