Assignment 4

Bayesian Network for Diagnosis of Alzheimer's Disease

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1 Introduction

The purpose of this project is to design a Bayesian network for diagnosis of Alzheimer's Disease based on CAD (Center for Alzheimer's Disease and related disorders) of Federal University of Rio de Janeiro patient's cases set. There are nine variables: Education, IQCode score, Lawton scale, Depression, Age, Gender, Diagnosis of Alzheimer's Disease, Berg balance scale and Stroop color word test. Short descriptions of some variables are as follows:

IQCode score: The Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE) uses collateral information to assess changes in everyday cognitive functions over the previous 10-year period. If the patient's score is higher than 3.55, it is more likely to be diagnosed with Alzheimer's Disease.

Lawton scale: The Lawton Instrumental Activities of Daily Living (IADL) Scale assesses a person's ability to perform tasks such as using a telephone, doing laundry, and handling finances. The higher the score, the greater the person's abilities.

Berg balance scale: The Berg balance scale is used to objectively determine a patient's ability (or inability) to safely balance during a series of predetermined tasks. A score of < 45 indicates individuals may be at greater risk of falling.

Berg Balance Score for Community-Dwelling Adults:					
Age	Gender	N	Mean	SD	95% CI
60-69	Male	15	55	1	55-56
	Female	22	55	2	54-56
70-79	Male	14	54	3	52-56
	Female	22	53	4	52-55
80-89	Male	8	53	2	51-54
	Female	15	50	3	49-52

Stroop color word test: The Stroop Color and Word Test is based on the observation that individuals can read words much faster than they can identify and name colors. The cognitive dimension tapped by the Stroop is associated with cognitive flexibility, resistance to interference from outside stimuli, creativity, and psychopathology.

Table A1

Normative data for the Stroop-Word stratified by age and education levels for ARGENTINA

						Age (Years)					
	Percentile	18– 22	23– 27	28– 32	33– 37	38– 42	43– 47	48– 52	53– 57	58– 62	63– 67
	95	128.2	127.0	125.9	124.7	123.5	122.3	121.2	120.0	118.8	11'
	90	123.0	121.9	120.7	119.5	118.3	117.2	116.0	114.8	113.6	11:
	85	119.6	118.4	117.3	116.1	114.9	113.7	112.5	111.4	110.2	10!
	80	116.7	115.6	114.4	113.2	112.0	110.9	109.7	108.5	107.3	10(
	70	112.1	111.0	109.8	108.6	107.4	106.3	105.1	103.9	102.7	10:
> 12 years of education	60	108.3	107.1	105.9	104.7	103.6	102.4	101.2	100.0	98.9	97.
	50	104.7	103.5	102.3	101.2	100.0	98.8	97.6	96.5	95.3	94.
	40	101.1	99.9	98.7	97.6	96.4	95.2	94.0	92.9	91.7	90.
	30	97.2	96.1	94.9	93.7	92.5	91.3	90.2	89.0	87.8	86.
	20	92.6	91.5	90.3	89.1	87.9	86.8	85.6	84.4	83.2	82.
	15	89.8	88.6	87.4	86.2	85.1	83.9	82.7	81.5	80.4	79.
	10	86.3	85.2	84.0	82.8	81.6	80.4	79.3	78.1	76.9	75.
	5	81.2	80.0	78.8	77.6	76.5	75.3	74.1	72.9	71.8	70.
	95	122.3	121.1	120.0	118.8	117.6	116.4	115.2	114.1	112.9	11:
	90	117.1	116.0	114.8	113.6	112.4	111.3	110.1	108.9	107.7	10(
	85	113.7	112.5	111.3	110.2	109.0	107.8	106.6	105.5	104.3	10:
	80	110.8	109.7	108.5	107.3	106.1	104.9	103.8	102.6	101.4	10(
	70	106.2	105.1	103.9	102.7	101.5	100.4	99.2	98.0	96.8	95.
1 to 12 years of education	60	102.4	101.2	100.0	98.8	97.7	96.5	95.3	94.1	93.0	91.
	50	98.8	97.6	96.4	95.3	94.1	92.9	91.7	90.5	89.4	88.
	40	95.2	94.0	92.8	91.7	90.5	89.3	88.1	87.0	85.8	84.
	30	91.3	90.1	89.0	87.8	86.6	85.4	84.3	83.1	81.9	80.
	20	86.7	85.6	84.4	83.2	82.0	80.8	79.7	78.5	77.3	76.
	15	83.9	82.7	81.5	80.3	79.2	78.0	76.8	75.6	74.5	73.
	10	80.4	79.2	78.1	76.9	75.7	74.5	73.4	72.2	71.0	69.
	5	75.3	74.1	72.9	71.7	70.6	69.4	68.2	67.0	65.8	64.

2 Implementation

2.1 Observations

The following observations are specified as follows:

1. The higher a person's IQCode score is, the more likely the person has the Alzheimer's Disease.
2. The longer years of education a person has and the younger a person is, the more likely it is for person to have a high Stroop color word test score.
3. The gender of "Male" a person has and the Alzheimer's Disease a person does not have, the more likely it is for person to have a high Berg balance scale.
4. The older a person is, the more likely the person is to have higher IQCode score.
5. The higher the person's IQCode score, the more likely to the person has lower Lawton scale.
6. The gender of "Female" a person has and the lower the person's Lawton scale, the more likely it is for person to have a Depression.

2.2 Variable Description

Variable	Random Variable	Values	Description
Education	E	$Val(E) = \{e^0, e^1\}$	$e^0 -\ 0 - 13\ years$ $e^1 -\ > 13\ years$
IQCode score	IQ	$Val(IQ) = \{iq^0, iq^1\}$	$iq^0 -\ 0 - 3.55\ score$ $iq^1 -\ > 3.55\ score$
Lawton scale	L	$Val(L) = \{l^0, l^1\}$	$l^0 -\ 0 - 9\ score$ $l^1 -\ > 9\ score$
Depression	D	$Val(D) = \{d^0, d^1\}$	$d^0 -\ Absence$ $d^1 -\ Presence$
Age	A	$Val(A) = \{a^0, a^1\}$	$a^0 -\ 0 - 72\ years\ old$ $a^1 -\ > 72\ years\ old$
Gender	G	$Val(G) = \{g^0, g^1\}$	$g^0 -\ Male$ $g^1 -\ Female$
Diagnosis of Alzheimer's Disease	AD	$Val(AD) = \{ad^0, ad^1\}$	$ad^0 -\ Negative$ $ad^1 -\ Positive$
Berg balance scale	B	$Val(B) = \{b^0, b^1\}$	$b^0 -\ 0 - 51\ score$ $b^1 -\ > 51\ score$
Stroop color word test	S	$Val(S) = \{s^0, s^1\}$	$s^0 -\ 0 - 15\ score$ $s^1 -\ > 15\ score$

Table 1: A description of the variables and their corresponding random variables

2.3 Network Construction

Based on the observations stated in Section…, we can infer the following:

- From observation 4, IQCode score depends on Age.

- From observation 5, Lawton scale depends on IQCode score.

- From observation 6, Depression depends on Gender and Lawton scale.

- From observation 1, Diagnosis of Alzheimer's Disease depends on IQCode score.

- From observation 3, Berg balance scale depends on Gender and Diagnosis of Alzheimer's Disease.

- From observation 2, Stroop color word test depends on Age and Education.

$$P(E, IQ, L, D, A, G, AD, B, S) = P(E)P(IQ|A)P(L|IQ)P(D|G, L)P(A)P(G)P(AD|IQ)P(B|G, AD)P(S|A, E)$$

2.4 SAMIAM Network
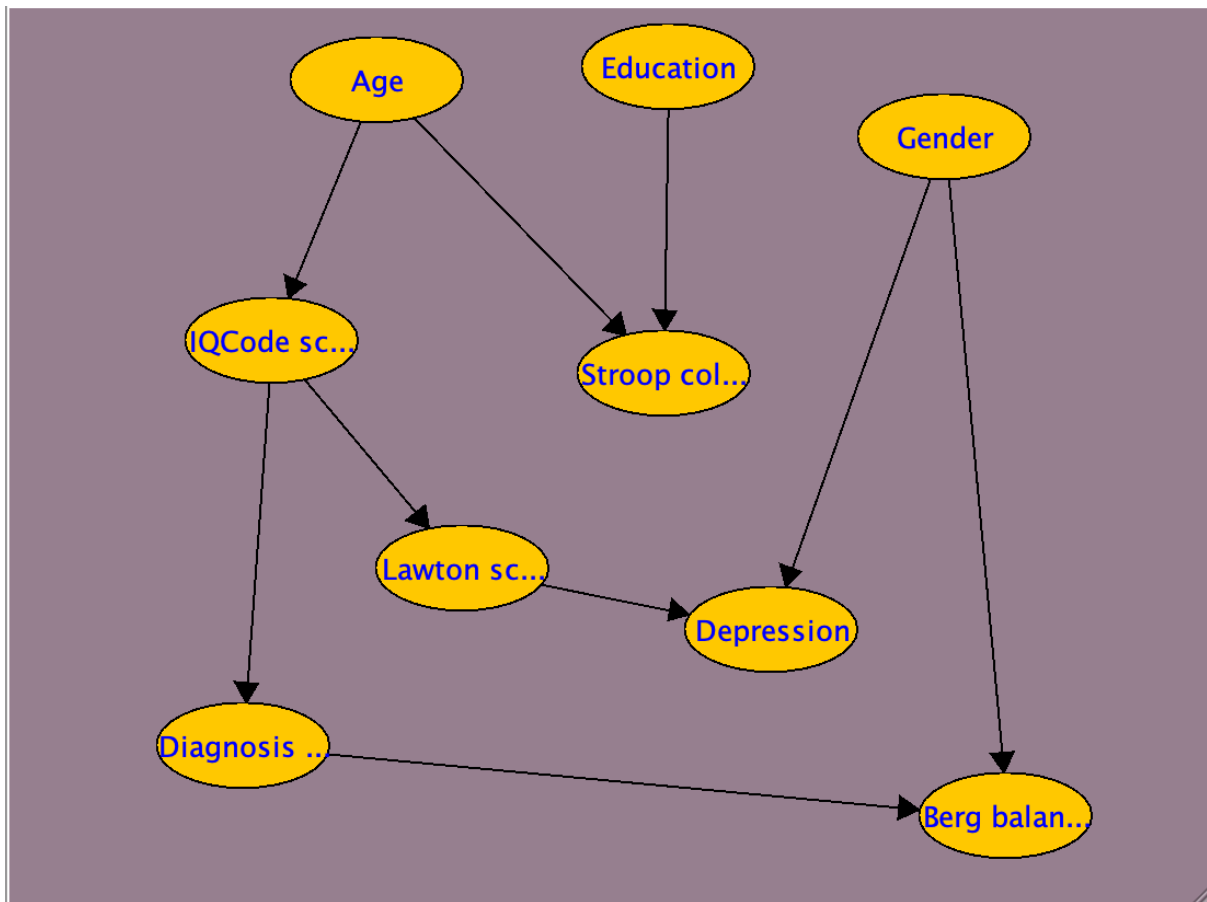
2.5 CPT Tables

Education	
$P(E = e^0)$	0.96
$P(E = e^1)$	0.04

Gender	
$P(G = g^0)$	0.23
$P(G = g^1)$	0.77

Age	
$P(A = a^0)$	0.34
$P(A = a^1)$	0.66

IQCode score	
$P(IQ = iq^0/A = a^0)$	0.75
$P(IQ = iq^1/A = a^0)$	0.25
$P(IQ = iq^0/A = a^1)$	0.20
$P(IQ = iq^1/A = a^1)$	0.80

Lawton scale	
$P(L = l^0/IQ = iq^0)$	0.18
$P(L = l^1/IQ = iq^0)$	0.82
$P(L = l^0/IQ = iq^1)$	0.90
$P(L = l^1/IQ = iq^1)$	0.10

Depression	
$P(D = d^0/G = g^0, L = l^0)$	0.25
$P(D = d^1/G = g^0, L = l^0)$	0.75
$P(D = d^0/G = g^0, L = l^1)$	0.97
$P(D = d^1/G = g^0, L = l^1)$	0.03
$P(D = d^0/G = g^1, L = l^0)$	0.05
$P(D = d^1/G = g^1, L = l^0)$	0.95
$P(D = d^0/G = g^1, L = l^1)$	0.45
$P(D = d^1/G = g^1, L = l^1)$	0.55

Diagnosis of Alzheimer's Disease	
$P(AD = ad^0/IQ = iq^0)$	0.85
$P(AD = ad^1/IQ = iq^0)$	0.15
$P(AD = ad^0/IQ = iq^1)$	0.05
$P(AD = ad^1/IQ = iq^1)$	0.95

Berg balance scale	
$P(B = b^0/G = g^0, AD = ad^0)$	0.05
$P(B = b^1/G = g^0, AD = ad^0)$	0.95
$P(B = b^0/G = g^0, AD = ad^1)$	0.55
$P(B = b^1/G = g^0, AD = ad^1)$	0.45
$P(B = b^0/G = g^1, AD = ad^0)$	0.40
$P(B = b^1/G = g^1, AD = ad^0)$	0.60
$P(B = b^0/G = g^1, AD = ad^1)$	0.92
$P(B = b^1/G = g^1, AD = ad^1)$	0.08

Stroop color word test score	
$P(S = s^0/A = a^0, E = e^0)$	0.45
$P(S = s^1/A = a^0, E = e^0)$	0.55
$P(S = s^0/A = a^0, E = e^1)$	0.10
$P(S = s^1/A = a^0, E = e^1)$	0.90
$P(S = s^0/A = a^1, E = e^0)$	0.90
$P(S = s^1/A = a^1, E = e^0)$	0.10
$P(S = s^0/A = a^1, E = e^1)$	0.45
$P(S = s^1/A = a^1, E = e^1)$	0.55

3 Test Cases

In order to verify whether the network is consistent with the desired behaviour, we check that it satisfies a set of conditions based on the observations.
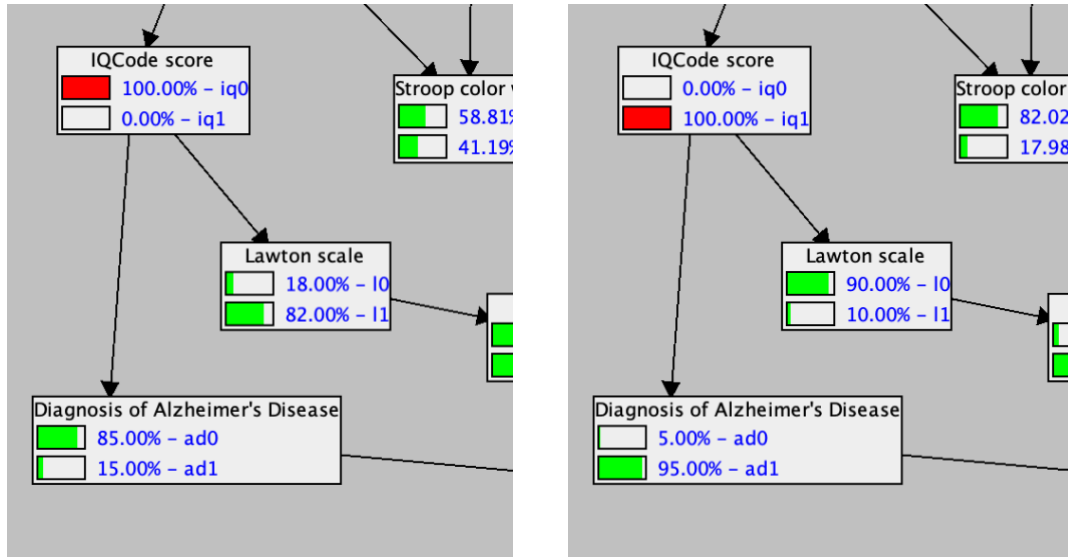
Observation 1:

The higher a person's IQCode score is, the more likely the person has the Alzheimer's Disease.

For the network to be consistent with observation 1, the following condition should be satisfied:

$$P(AD = ad^1/IQ = iq^1) > P(AD = ad^1/IQ = iq^0)$$

As shown in the figure, we get

$$P(AD = ad^1/IQ = iq^1) = 0.95 > P(AD = ad^1/IQ = iq^0) = 0.15$$
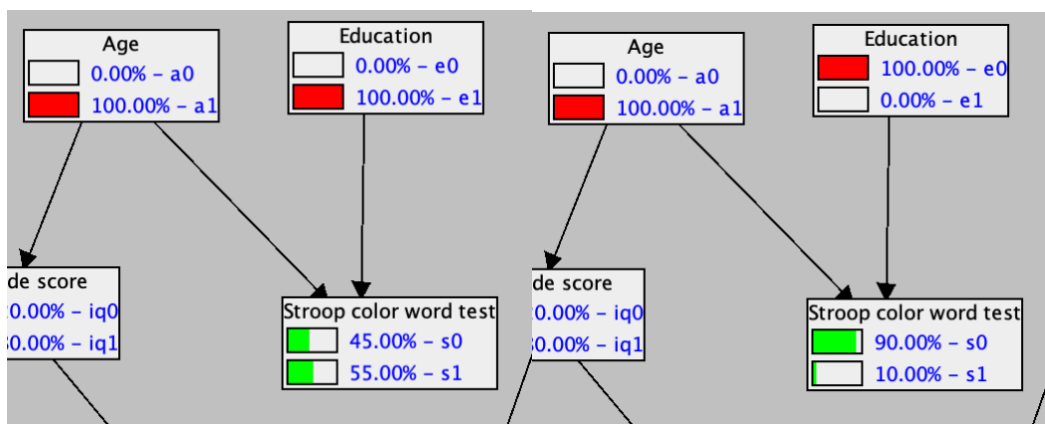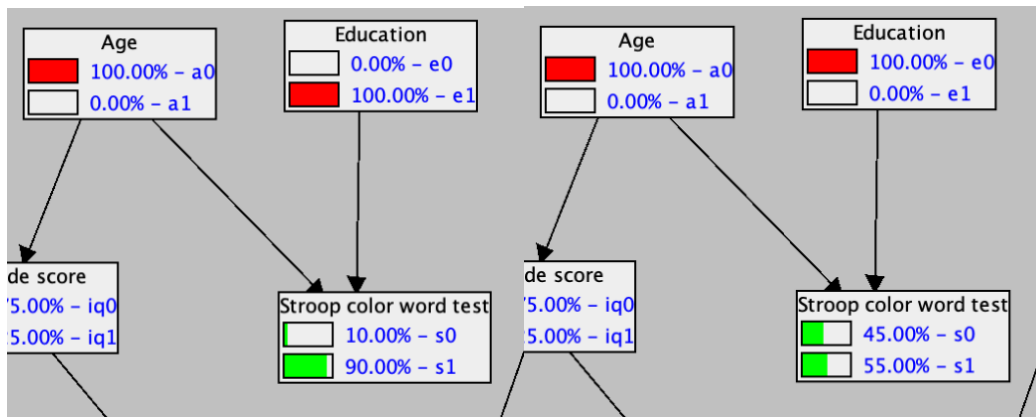
Thus, the condition is satisfied.

Observation 2:

The longer years of education a person has and the younger a person is, the more likely it is for person to have a high Stroop color word test score.

For the network to be consistent with observation 2, the following condition should be satisfied:

$$P(S = s^1/A = a^0, E = e^1) > P(S = s^1/A = a^0, E = e^0)$$
$$P(S = s^1/A = a^1, E = e^1) > P(S = s^1/A = a^1, E = e^0)$$
$$P(S = s^1/A = a^0, E = e^1) > P(S = s^1/A = a^1, E = e^1)$$
$$P(S = s^1/A = a^0, E = e^0) > P(S = s^1/A = a^1, E = e^0)$$

As shown in the figure, we get
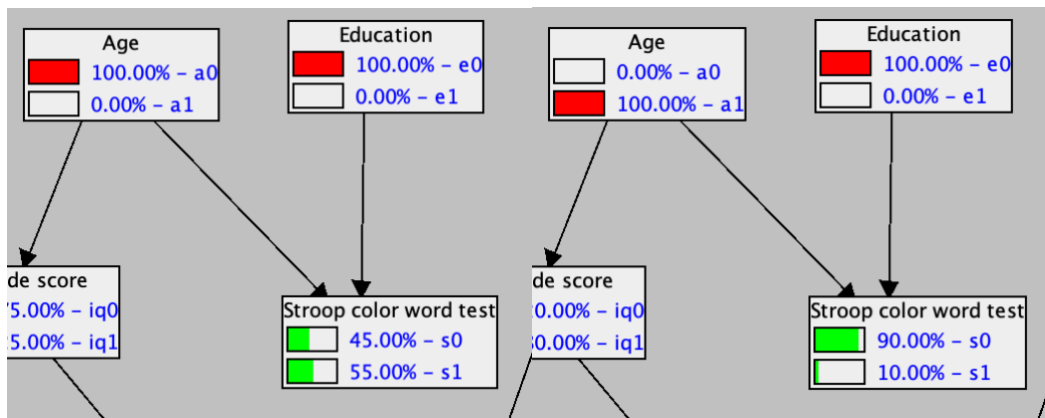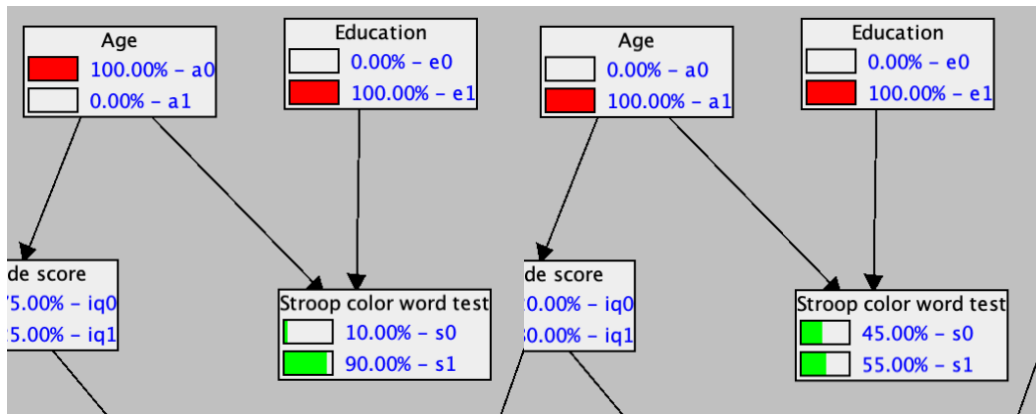
$$P(S = s^1/A = a^0, E = e^1) = 0.90 > P(S = s^1/A = a^0, E = e^0) = 0.55$$
$$P(S = s^1/A = a^1, E = e^1) = 0.55 > P(S = s^1/A = a^1, E = e^0) = 0.10$$
$$P(S = s^1/A = a^0, E = e^1) = 0.90 > P(S = s^1/A = a^1, E = e^1) = 0.55$$
$$P(S = s^1/A = a^0, E = e^0) = 0.55 > P(S = s^1/A = a^1, E = e^0) = 0.10$$
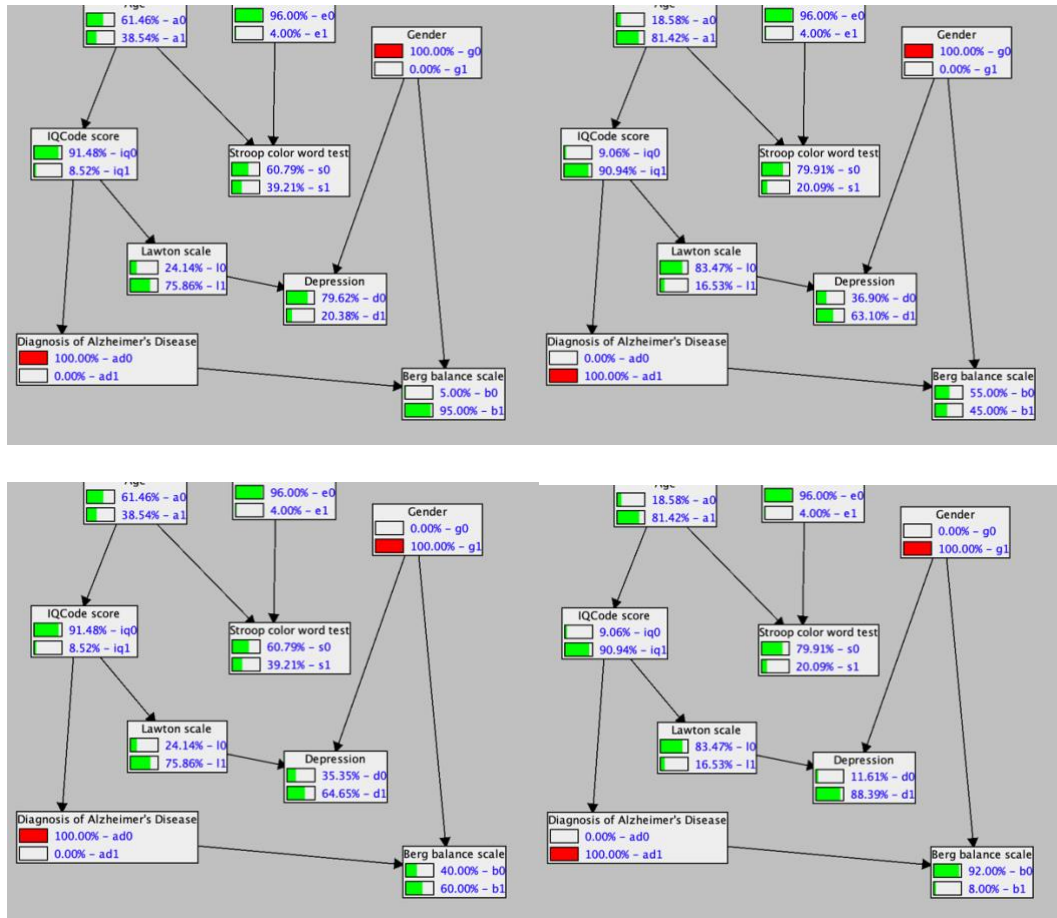
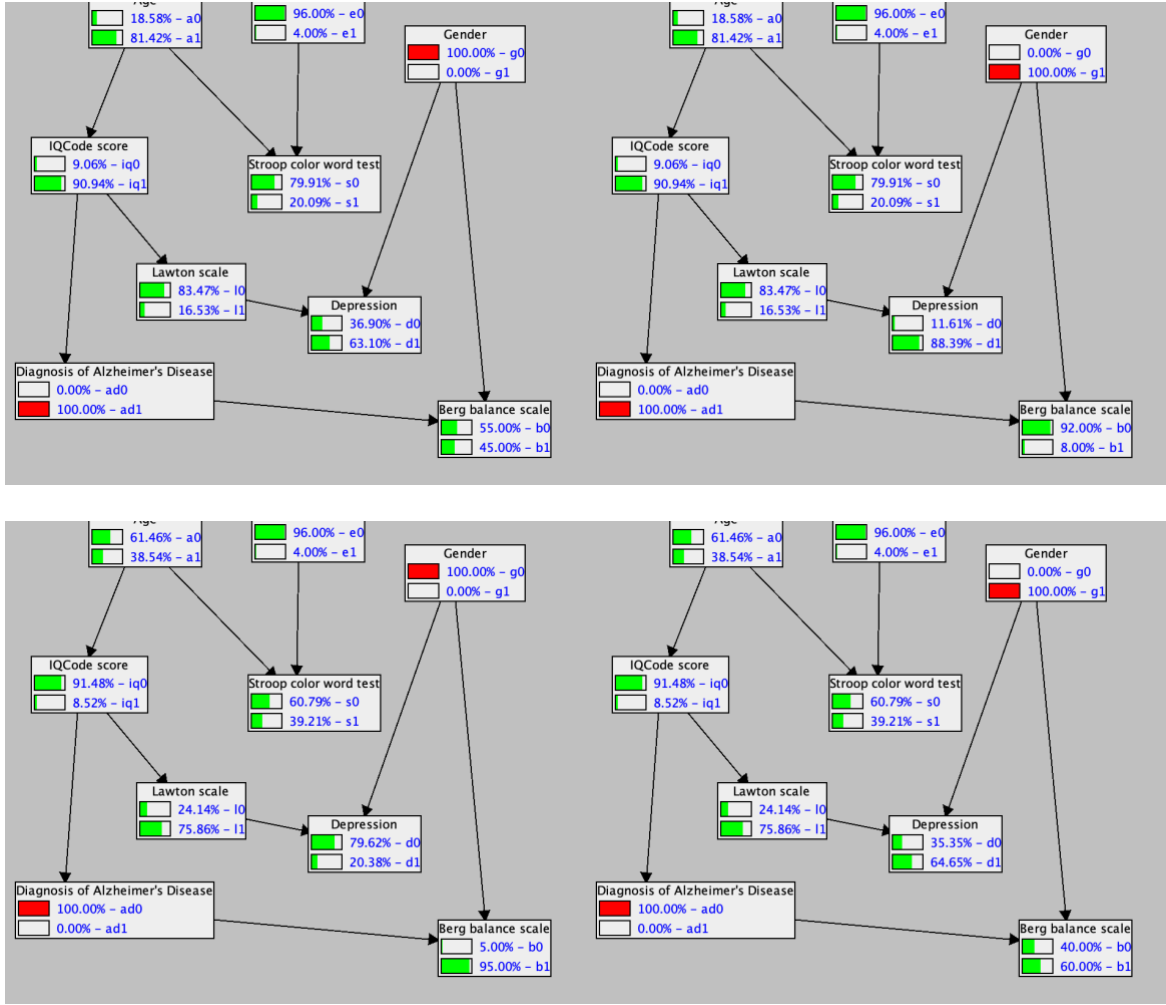Thus, the condition is satisfied.

Observation 3:

The gender of "Male" a person has and the Alzheimer's Disease a person does not have, the more likely it is for person to have a high Berg balance scale.

For the network to be consistent with observation 3, the following condition should be satisfied:

$$P(B = b^1/G = g^0, AD = ad^0) > P(B = b^1/G = g^0, AD = ad^1)$$
$$P(B = b^1/G = g^1, AD = ad^0) > P(B = b^1/G = g^1, AD = ad^1)$$
$$P(B = b^1/G = g^0, AD = ad^1) > P(B = b^1/G = g^1, AD = ad^1)$$
$$P(B = b^1/G = g^0, AD = ad^0) > P(B = b^1/G = g^1, AD = ad^0)$$

As shown in the figure, we get

$$P(B = b^1/G = g^0, AD = ad^0) = 0.95 > P(B = b^1/G = g^0, AD = ad^1) = 0.45$$
$$P(B = b^1/G = g^1, AD = ad^0) = 0.60 > P(B = b^1/G = g^1, AD = ad^1) = 0.08$$
$$P(B = b^1/G = g^0, AD = ad^1) = 0.45 > P(B = b^1/G = g^1, AD = ad^1) = 0.08$$
$$P(B = b^1/G = g^0, AD = ad^0) = 0.95 > P(B = b^1/G = g^1, AD = ad^0) = 0.60$$

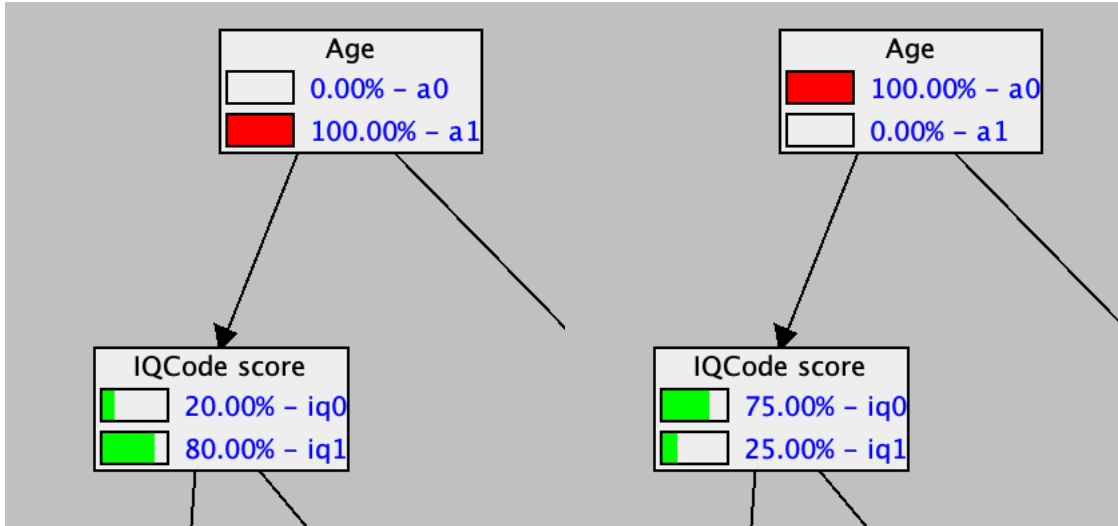Thus, the condition is satisfied.

Observation 4:

The older a person is, the more likely the person is to have higher IQCode score.

For the network to be consistent with observation 4, the following condition should be satisfied:

$$P(IQ = iq^1/A = a^1) > P(IQ = iq^1/A = a^0)$$

As shown in the figure, we get

$$P(IQ = iq^1/A = a^1) = 0.80 > P(IQ = iq^1/A = a^0) = 0.25$$
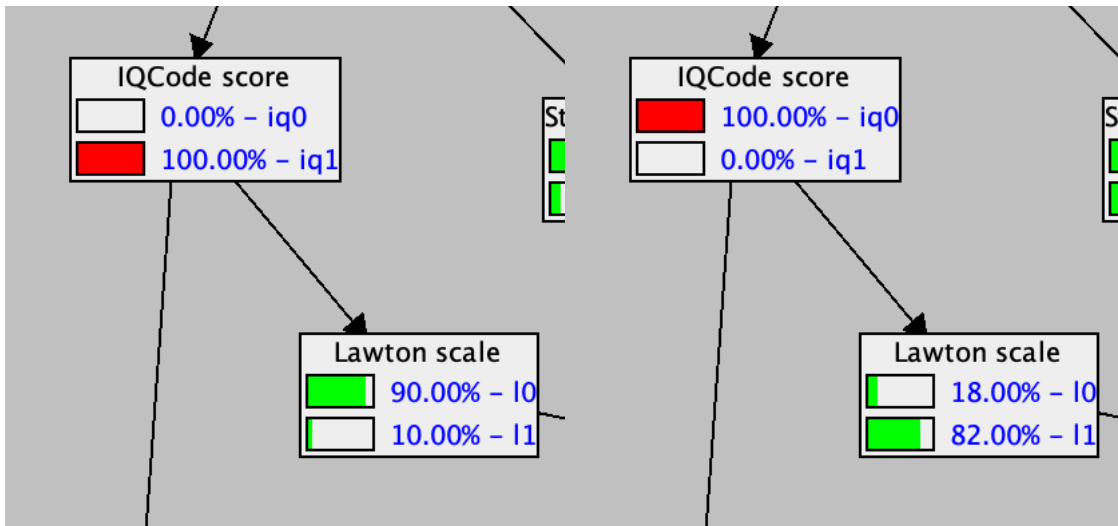
Thus, the condition is satisfied.

Observation 5:

The higher the person's IQCode score, the more likely to the person has lower Lawton scale.

For the network to be consistent with observation 5, the following condition should be satisfied:

$$P(L = l^0/A = iq^1) > P(L = l^0/A = iq^0)$$

As shown in the figure, we get

$$P(L = l^0/A = iq^1) = 0.90 > P(L = l^0/A = iq^0) = 0.18$$
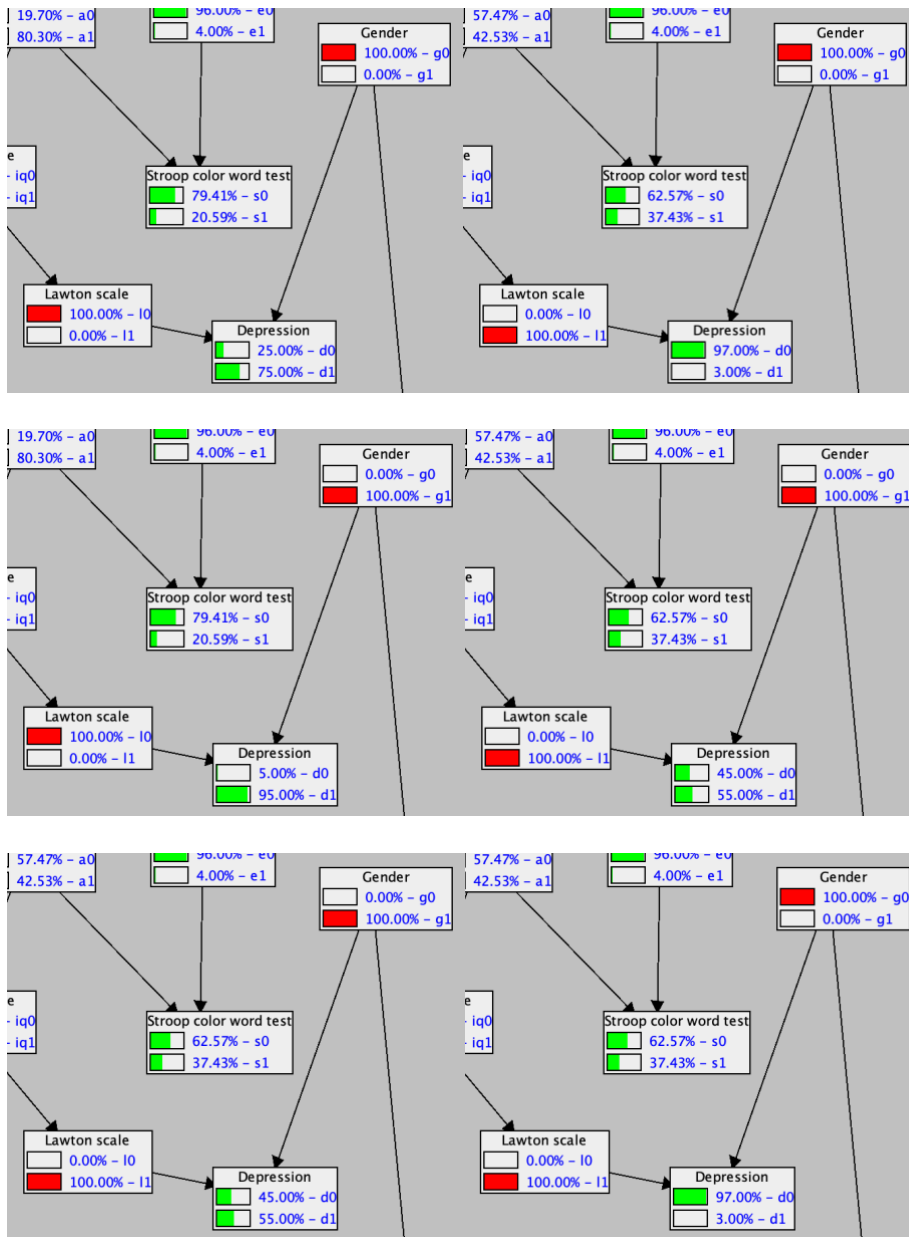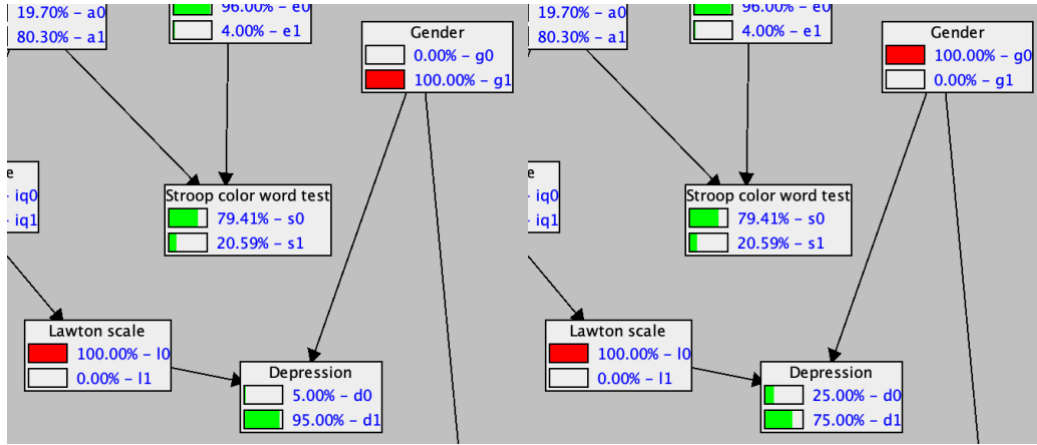
Thus, the condition is satisfied.

Observation 6:

The gender of "Female" a person has and the lower the person's Lawton scale, the more likely it is for person to have a Depression.

For the network to be consistent with observation 6, the following condition should be satisfied:

$$P(D = d^1/G = g^0, L = l^0) > P(D = d^1/G = g^0, L = l^1)$$
$$P(D = d^1/G = g^1, L = l^0) > P(D = d^1/G = g^1, L = l^1)$$
$$P(D = d^1/G = g^1, L = l^1) > P(D = d^1/G = g^0, L = l^1)$$
$$P(D = d^1/G = g^1, L = l^0) > P(D = d^1/G = g^0, L = l^0)$$

As shown in the figure, we get

$P(D = d^1/G = g^0, L = l^0) = 0.75 > P(D = d^1/G = g^0, L = l^1) = 0.03$
$P(D = d^1/G = g^1, L = l^0) = 0.95 > P(D = d^1/G = g^1, L = l^1) = 0.55$
$P(D = d^1/G = g^1, L = l^1) = 0.55 > P(D = d^1/G = g^0, L = l^1) = 0.03$
$P(D = d^1/G = g^1, L = l^0) = 0.95 > P(D = d^1/G = g^0, L = l^0) = 0.75$

Thus, the condition is satisfied.

4 References

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