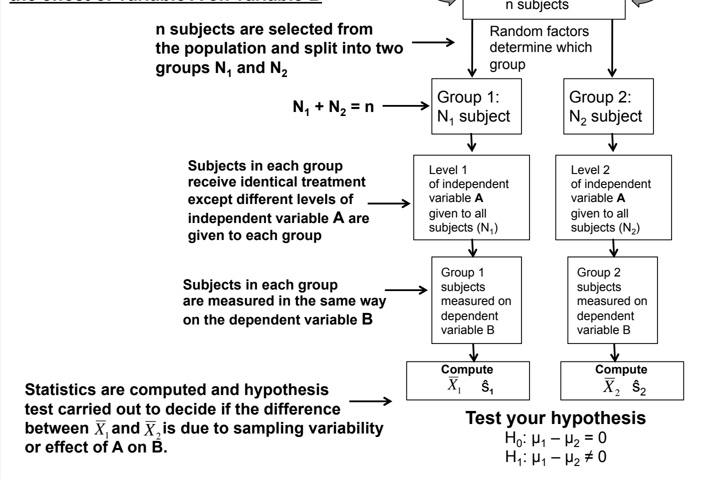
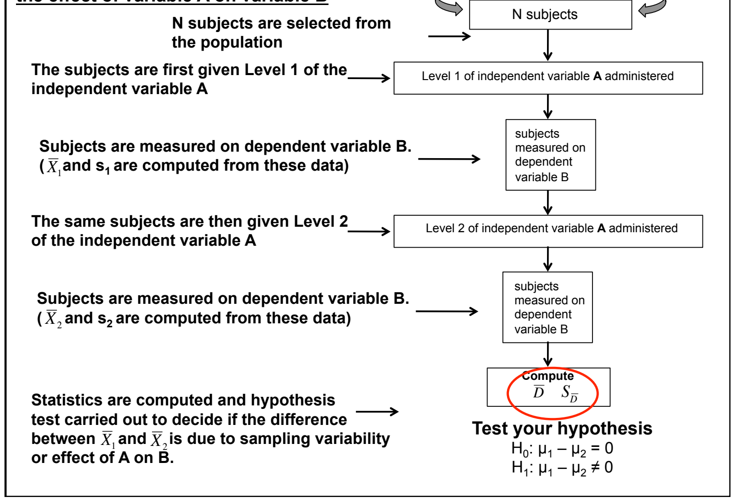
Two types of *t*-tests:

Independent Measures (last week)
& Repeated Measures

Independent Samples experiment. To examine the effect of variable A on variable B



Repeated measures experiment. To examine the effect of variable A on variable B



Both types of *t*-test have one ***independent*** ***variable***, with two ***levels*** (the two different conditions of our experiment).

There is one ***dependent*** ***variable*** (the thing we actually measure).

Example 1: ***Effects of personality type on a memory test.***
-Independent Variable is “personality type”;
Two levels - introversion and extraversion.
-Dependent Variable is memory test score.

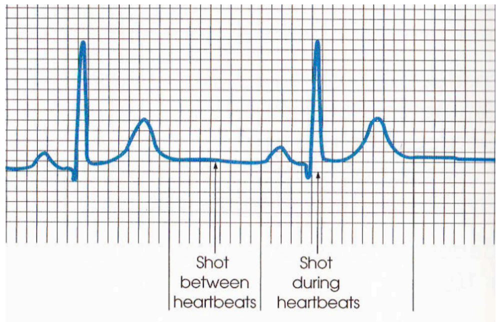
Use an independent-measures *t*-test: measure each subject's memory score once, then compare introverts and extraverts.

Example 2: ***Effects of alcohol on reaction-time (RT) performance.***
-Independent Variable is “alcohol consumption”;
Two levels - drunk and sober.
-Dependent Variable is RT.

Use a repeated-measures *t*-test: measure each subject's RT twice, once while drunk and once while sober.

Accuracy of Olympic marksmen/markswomen

Shots fired between heartbeats versus during a heartbeat (repeated measures design)



Rationale behind repeated measures the t-test:

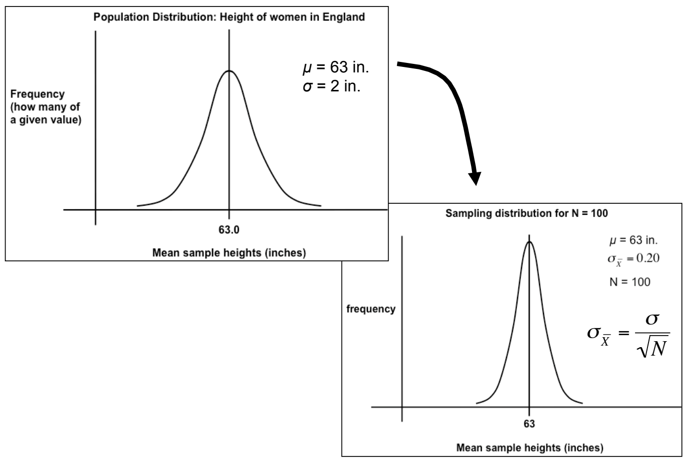
EXAMPLE: Experiment on the effect of alcohol on task performance (time in seconds).

Measure time taken to perform the task for subjects when drunk, and when (same subjects are) sober.

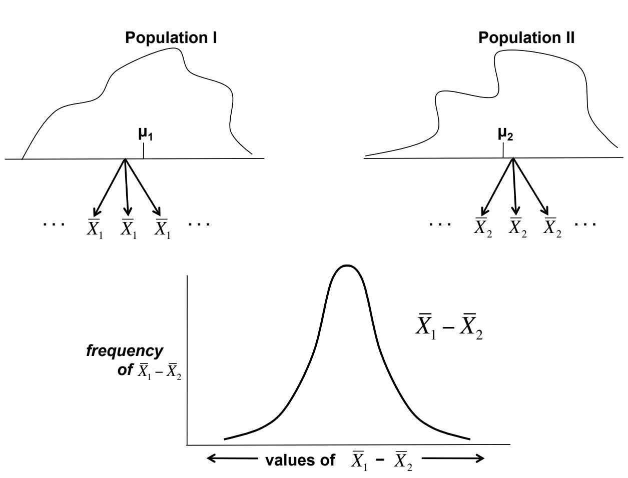
Null hypothesis: alcohol has *no* effect on time taken: variation between the drunk sample mean and the sober sample mean is due to *sampling variation*.

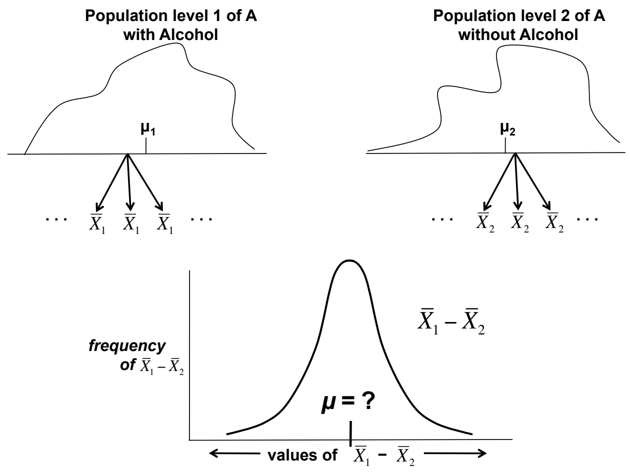
i.e. The drunk and sober performance times are samples from the same population.

From the lecture on sampling distribution:



Sampling distribution of differences between means





EXAMPLE

Time (in seconds) participants take to complete a motor coordination task

	Condition A Level 1	Condition A Level 2			
Participant	**With Alcohol**	**Without Alcohol**			
1	12.4	10.0			
2	15.5	14.2			
3	17.9	18.0			
4	9.7	10.1			
5	19.6	14.2			
6	16.5	12.1			
7	15.1	15.1			
8	16.3	12.4			
9	13.3	12.7			
10	11.6	13.1			

$$t(observed) = \frac{\bar{D} - \mu_D(hypothesized)}{S_{\bar{D}}}$$

the *mean* difference between scores in our two samples (should be close to zero if there is no difference between the two conditions)

the *predicted* average difference between scores in our two samples (usually zero, since we assume the two samples don't differ)

estimated standard error of the mean difference (a measure of how much the mean difference might vary from one occasion to the next).

	Condition A Level 1	Condition A Level 2			
Participant	**With Alcohol**	**Without Alcohol**	**Diff. (D)**		
1	12.4	10.0	2.4		
2	15.5	14.2	1.3		
3	17.9	18.0	-0.1		
4	9.7	10.1	-0.4		
5	19.6	14.2	5.4		
6	16.5	12.1	4.4		
7	15.1	15.1	0.0		
8	16.3	12.4	3.9		
9	13.3	12.7	0.6		
10	11.6	13.1	-1.5		
			$\sum D = 16.0$		

Step 1. Add up the differences: $\sum D = 16$

Step 2. Find the mean difference:

$$\overline{D} = \frac{\sum D}{N} = \frac{16}{10} = 1.6$$

Step 3. ***Estimate of the population standard deviation*** **(the standard deviation of the differences):**

$$S_D = \sqrt{\frac{\sum (D - \overline{D})^2}{N - 1}}$$

$$S_{\overline{D}} = \frac{S_D}{\sqrt{N}}$$

	Condition A Level 1	Condition A Level 2			
Participant	**With Alcohol**	**Without Alcohol**	**Diff. (D)**	$D - \overline{D}$	$(D - \overline{D})^2$
1	12.4	10.0	2.4	0.8	0.64
2	15.5	14.2	1.3	-0.3	0.09
3	17.9	18.0	-0.1	-1.7	2.89
4	9.7	10.1	-0.4	-2.0	4.0
5	19.6	14.2	5.4	3.8	14.44
6	16.5	12.1	4.4	2.8	7.84
7	15.1	15.1	0.0	-1.6	2.56
8	16.3	12.4	3.9	2.3	5.29
9	13.3	12.7	0.6	-1.0	1.0
10	11.6	13.1	-1.5	-3.1	9.61
			$\sum D = 16.0$	$\sum (D - \overline{D})^2 = 48.36$	

$\overline{D} = \frac{16}{10} = 1.6$

…Step 3. ***Estimate of the population standard deviation*** **(the standard deviation of the differences):**

$$S_D = \sqrt{\frac{\sum (D - \overline{D})^2}{N - 1}}$$

$$= \sqrt{\frac{48.36}{9}} = 2.318$$

Step 4. *Estimate of the population standard error* (the standard error of the differences between two sample means):

$$S_{\overline{D}} = \frac{S_D}{\sqrt{N}}$$

$$= \frac{2.318}{\sqrt{10}} = 0.733$$

Step 5. *Hypothesised difference between the sample means*. Our null hypothesis is usually that there is *no difference* between the two sample means. (In statistical terms, the sample means have come from two identical populations):

μ_D ***(hypothesised)*** **= 0**

Step 6. Work out *t*:

$$t(observed) = \frac{1.6 - 0}{0.733} = 2.183$$

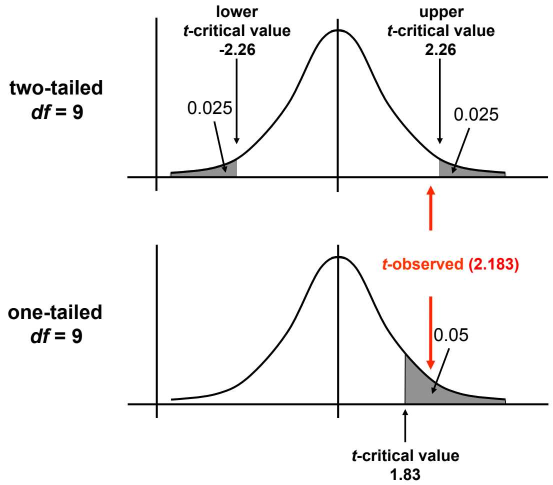
Step 7. "Degrees of freedom" (*df*) are the number of subjects minus one: *df* = N - 1 = 10 - 1 = 9

Step 8. Find *t*-critical value of *t* from a table

(a) "Two-tailed test": if we are predicting *a* difference between Level 1 and 2; find the critical value of t for a "two-tailed" test. With *df* = 9, critical value = 2.26.	**TWO-Tailed: *t*-observed (2.183) is smaller than *t*-critical (2.26)** **"We fail to reject the null hypothesis"** **$t(9) = 2.183$, $p > 0.05$**
(b) "One-tailed test": if we are predicting that Level 1 is *bigger* than 2, (or 1 is *smaller* than 2), find the critical value of *t* for a "one-tailed" test. For *df* = 9, critical value = 1.83.	**ONE-Tailed: *t*-observed (2.183) is larger than *t*-critical (1.83)** **"We reject the null hypothesis"** **$t(9) = 2.183$, $p < 0.05$**

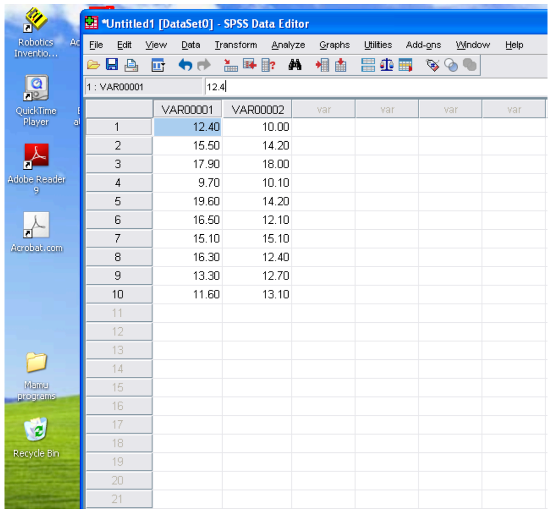
Table of critical values of t:

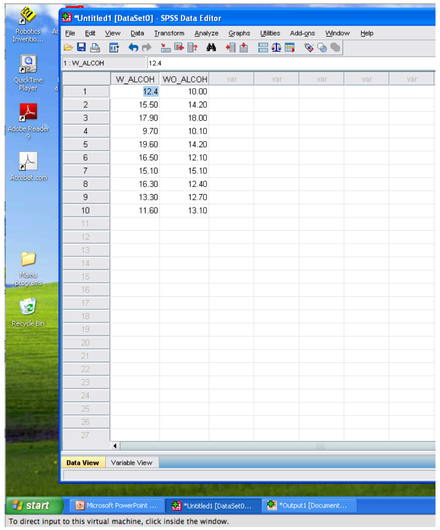
d.f.	0.2	0.1	0.05	0.01	0.005	0.001	0.0005	0.0001
	One Tailed Significance level:							
	0.1	0.05	0.025	0.005	0.0025	0.0005	0.00025	0.00005
	Two Tailed Significance level:							
d.f.	0.2	0.1	0.05	0.01	0.005	0.001	0.0005	0.0001
2	1.89	2.92	4.3	9.92	14.09	31.6	44.7	100.14
3	1.64	2.35	3.18	5.84	7.45	12.92	16.33	28.01
4	1.53	2.13	2.78	4.6	5.6	8.61	10.31	15.53
5	1.48	2.02	2.57	4.03	4.77	6.87	7.98	11.18
6	1.44	1.94	2.45	3.71	4.32	5.96	6.79	9.08
7	1.41	1.89	2.36	3.5	4.03	5.41	6.08	7.89
8	1.4	1.86	2.31	3.36	3.83	5.04	5.62	7.12
9	1.38	1.83	2.26	3.25	3.69	4.78	5.29	6.59
10	1.37	1.81	2.23	3.17	3.58	4.59	5.05	6.21
11	1.36	1.8	2.2	3.11	3.5	4.44	4.86	5.92
12	1.36	1.78	2.18	3.05	3.43	4.32	4.72	5.7
13	1.35	1.77	2.16	3.01	3.37	4.22	4.6	5.51
14	1.35	1.76	2.14	2.98	3.33	4.14	4.5	5.36
15	1.34	1.75	2.13	2.95	3.29	4.07	4.42	5.24
16	1.34	1.75	2.12	2.92	3.25	4.01	4.35	5.13
17	1.33	1.74	2.11	2.9	3.22	3.97	4.29	5.04
18	1.33	1.73	2.1	2.88	3.2	3.92	4.23	4.97
19	1.33	1.73	2.09	2.86	3.17	3.88	4.19	4.9
20	1.33	1.72	2.09	2.85	3.15	3.85	4.15	4.84
21	1.32	1.72	2.08	2.83	3.14	3.82	4.11	4.78
22	1.32	1.72	2.07	2.82	3.12	3.79	4.08	4.74
23	1.32	1.71	2.07	2.81	3.1	3.77	4.05	4.69
24	1.32	1.71	2.06	2.8	3.09	3.75	4.02	4.65
25	1.32	1.71	2.06	2.79	3.08	3.73	4	4.62
26	1.31	1.71	2.06	2.78	3.07	3.71	3.97	4.59
27	1.31	1.7	2.05	2.77	3.06	3.69	3.95	4.56
28	1.31	1.7	2.05	2.76	3.05	3.67	3.93	4.53
29	1.31	1.7	2.05	2.76	3.04	3.66	3.92	4.51
30	1.31	1.7	2.04	2.75	3.03	3.65	3.9	4.48



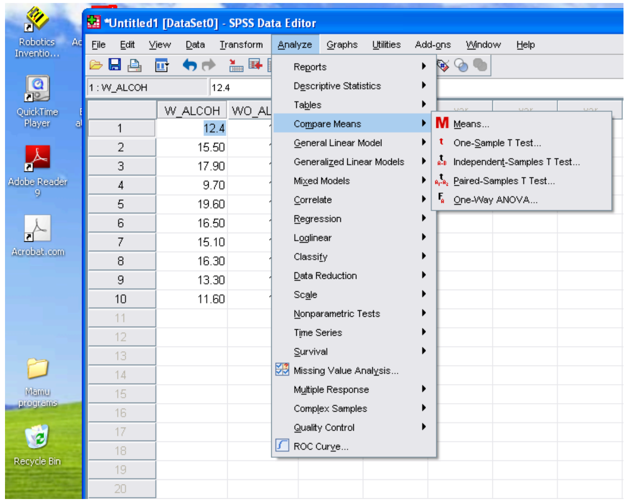
Using SPSS to do a repeated measures *t*-test

Data Entry

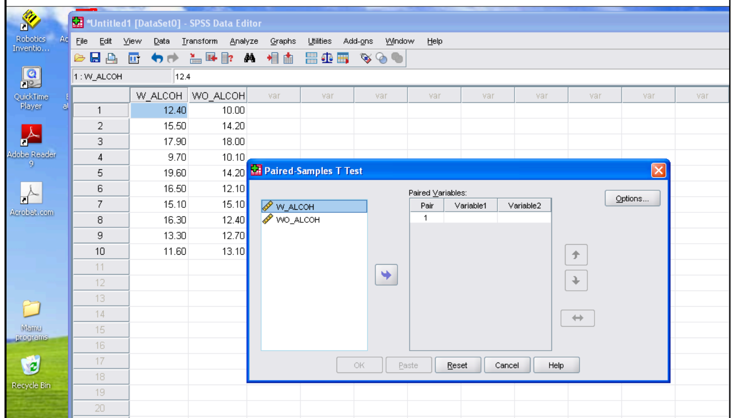




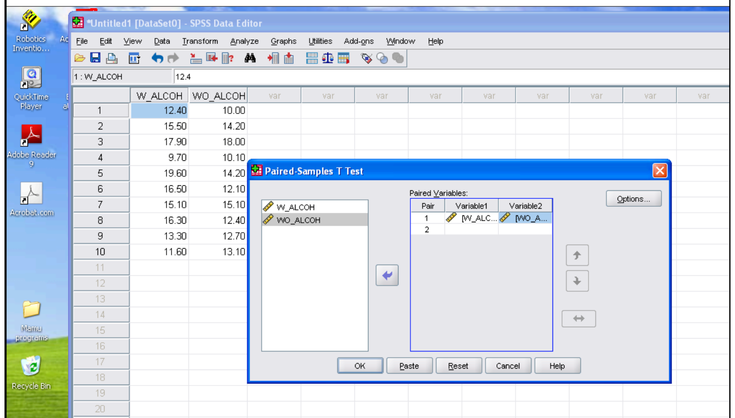
Running SPSS (repeated measures *t*-test)



Running SPSS (repeated measures *t*-test)



Running SPSS (repeated measures *t*-test)



Interpreting SPSS output (repeated measures *t*-test)

*Output1 [Document1] - SPSS Viewer

File Edit View Data Transform Insert Format Analyze Graphs Utilities Add-ons Window Help

Output
- Log
- T-Test
  - Title
  - Notes
  - Active Dataset
  - Paired Samples S
  - Paired Samples C
  - Paired Samples T

```
T-TEST PAIRS=W_ALCOH WITH WO_ALCOH (PAIRED)
  /CRITERIA=CI(.9500)
  /MISSING=ANALYSIS.
```

T-Test

[DataSet0]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	W_ALCOH	14.7900	10	3.03002	.95818
	WO_ALCOH	13.1900	10	2.37133	.74988

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	W_ALCOH & WO_ALCOH	10	.656	.039

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	W_ALCOH - WO_ALCOH	1.60000	2.31805	.73303	-.05823	3.25823	2.183	9	.057