EVAL 6970: Meta-Analysis
Subgroup Analysis

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Agenda

- Subgroup analyses
  - In-class activity

Subgroup Analyses

- Three methods
  - Method 1: Z-test
  - Method 2: Q-test based on ANOVA
  - Method 3: Q-test for heterogeneity
- All three methods are used to assess differences in subgroup effects relative to the precision of the difference
- All three are mathematically equivalent

Subgroup Analyses

- The computations for each of the three methods vary slightly depending on how subgroups are analyzed
  - Fixed-effect model within subgroups
  - Random-effects model with separate estimates of τ^2
  - Random-effects model with pooled estimate of τ^2

Subgroup Analyses

Model	Method 1	Method 2	Method 3
Fixed-effect	1	2	3
Random-effects with separate estimates of τ^2	4	5	6
Random-effects with pooled estimate of τ^2	7	8	9

Fixed-Effect Model within Subgroups: Method 1

- Method 1: Z-test (similar to t-test in primary studies)
- Used when there are only two subgroups
  - In the fixed-effect model θ_A and θ_B are the true effects underlying groups and M_A and M_B are the estimated effects with variance V_A and V_B

Fixed-Effect Model within Subgroups: Method 1

- The difference between the two effects is

$$Diff = M_B - M_A$$

- Which is tested as

$$Z_{Diff} = \frac{Diff}{SE_{Diff}}$$

- Where

$$SE_{Diff} = \sqrt{V_{M_A} + V_{M_B}}$$

Fixed-Effect Model within Subgroups: Method 1

- Where

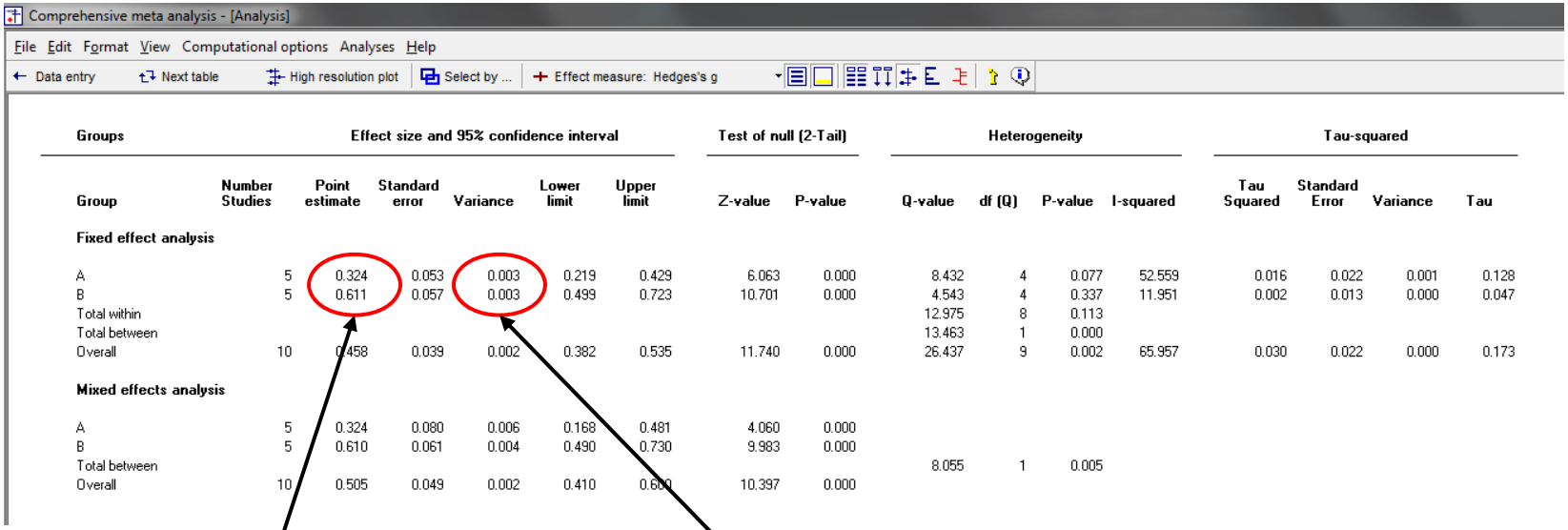
$$H_0 : \theta_A = \theta_B$$

- For a two-tailed test

$$p = 2\left[1 - \left(\Phi(|Z|)\right)\right] M_B - M_A$$

=(1-(NORMDIST(ABS(Z))))*2

Fixed-Effect Model within Subgroups: Method 1



Groups		Effect size and 95% confidence interval					Test of null (2-Tail)		Heterogeneity				Tau-squared			
Group	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau Squared	Standard Error	Variance	Tau
Fixed effect analysis																
A	5	0.324	0.053	0.003	0.219	0.429	6.063	0.000	8.432	4	0.077	52.559	0.016	0.022	0.001	0.128
B	5	0.611	0.057	0.003	0.499	0.723	10.701	0.000	4.543	4	0.337	11.951	0.002	0.013	0.000	0.047
Total within									12.975	8	0.113					
Total between									13.463	1	0.000					
Overall	10	0.458	0.039	0.002	0.382	0.535	11.740	0.000	26.437	9	0.002	65.957	0.030	0.022	0.000	0.173
Mixed effects analysis																
A	5	0.324	0.080	0.006	0.168	0.481	4.060	0.000								
B	5	0.610	0.061	0.004	0.490	0.730	9.983	0.000								
Total between									8.055	1	0.005					
Overall	10	0.505	0.049	0.002	0.410	0.600	10.397	0.000								

M_A and M_B

V_A and V_B

Fixed-Effect Model within Subgroups: Method 2

- Method 2: Q-test based on ANOVA
  - For comparisons between more than two subgroups
  - An analogy to ANOVA in primary studies
  - Used to partition the total variance into variance within groups and variance between groups

Fixed-Effect Model within Subgroups: Method 2

- The following quantities are required
  - Q_p, the weighted *SS* of all studies about the mean for all *p* subgroups (separately; e.g., Q_A, Q_B)
  - Q_{within}, the sum of all Q_p subgroups (e.g., $Q_A + Q_B$)
  - Q_{bet}, the weighted *SS* of the subgroup means about the grand mean ($Q_{bet} = Q - Q_{within}$
  - Q, the weighted *SS* of all effects about the grand mean

Fixed-Effect Model within Subgroups: Method 2

- Each source of variance (Q statistic) is evaluated with respect to the corresponding degrees of freedom

$$=\text{CHIDIST}(Q, df)$$

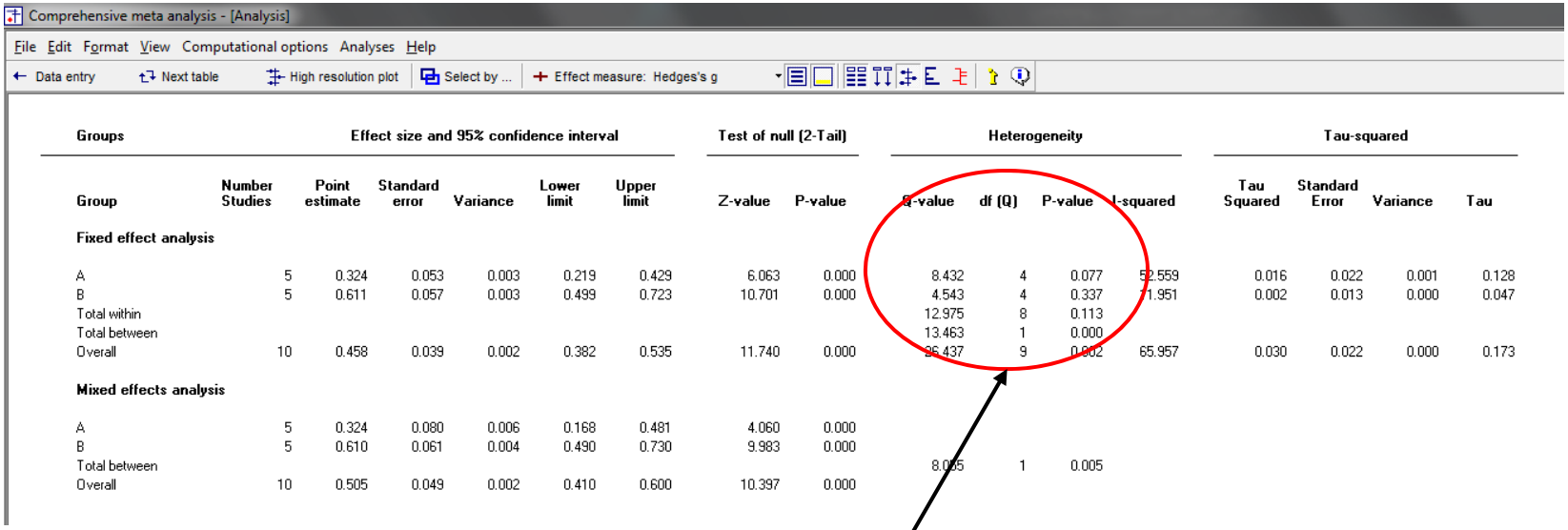
- Which returns the exact p-value associated with each source of variance

Fixed-Effect Model within Subgroups: Method 2

	Q	df	p
A	8.4316	4	0.0770
B	4.5429	4	0.3375
Within	12.9745	8	0.1127
Between	13.4626	1	0.0002
Total	26.4371	9	0.0017

Q-test ANOVA table

Fixed-Effect Model within Subgroups: Method 2



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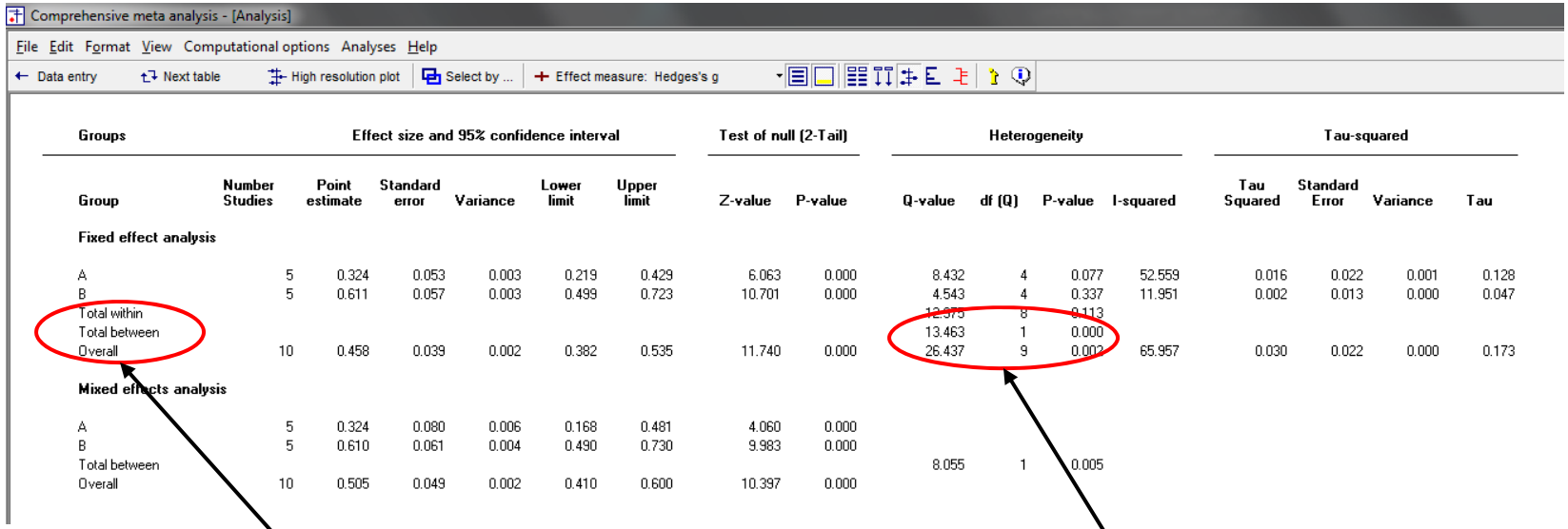
B	5	0.610	0.061	0.004	0.490	0.730	9.983	0.000								
Total between									8.005	1	0.005					
Overall	10	0.505	0.049	0.002	0.410	0.600	10.397	0.000								

Variance components

Fixed-Effect Model within Subgroups: Method 3

- Method 3: Q-test for heterogeneity
  - Each subgroup is the unit of analysis
  - Subgroup summary effects and variances are tested for heterogeneity using the same method for testing the dispersion of single studies about the summary effect

Fixed-Effect Model within Subgroups: Method 3



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Total between									8.055	1	0.005					
Overall	10	0.505	0.049	0.002	0.410	0.600	10.397	0.000								

Q, df, and p

Use Total between

Magnitude of Subgroup Differences

- With

$$Diff = M_B - M_A$$

- The 95% confidence interval is

$$Diff \pm 1.96 \times SE_{Diff}$$

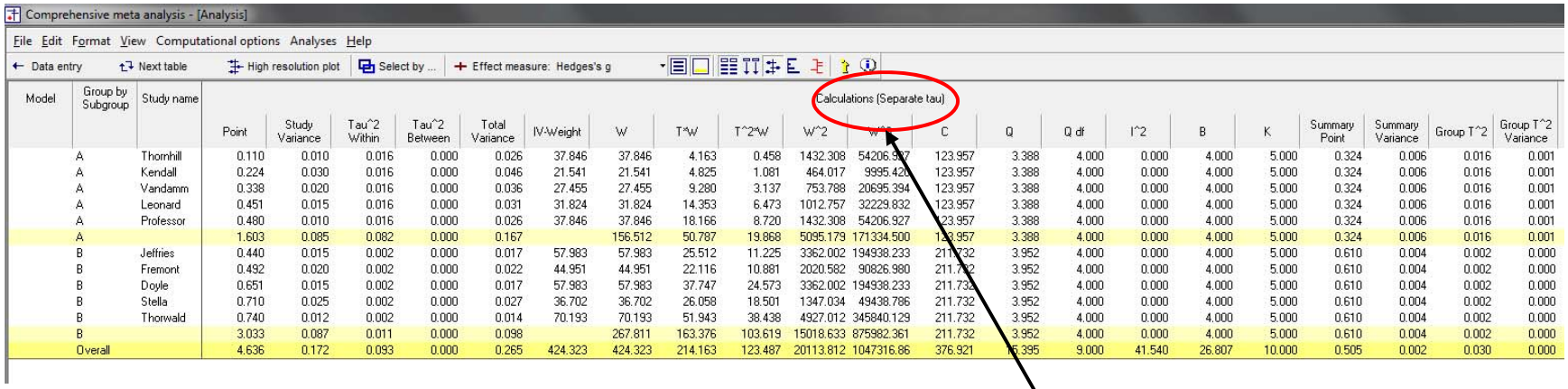
- Where

$$SE_{Diff} = \sqrt{V_{M_A} + V_{M_B}}$$

Random-Effects Model with Separate Estimates of τ^2

- For all three methods (Z-test, Q-test based on ANOVA, and Q-test for heterogeneity) the same computations are used, but with random-effects weights and a separate estimate of τ^2 for each subgroup

Random-Effects Model with Separate Estimates of τ^2



Model	Group by Subgroup	Study name	Point	Study Variance	Tau^2 Within	Tau^2 Between	Total Variance	IV-Weight	W	T*W	T^2*W	W^2	W^3	C	Q	Q df	I^2	B	K	Summary Point	Summary Variance	Group T^2	Group T^2 Variance
	A	Thornhill	0.110	0.010	0.016	0.000	0.026	37.846	37.846	4.163	0.458	1432.308	54206.927	123.957	3.388	4.000	0.000	4.000	5.000	0.324	0.006	0.016	0.001
	A	Kendall	0.224	0.030	0.016	0.000	0.046	21.541	21.541	4.825	1.081	464.017	9995.420	123.957	3.388	4.000	0.000	4.000	5.000	0.324	0.006	0.016	0.001
	A	Vandamm	0.338	0.020	0.016	0.000	0.036	27.455	27.455	9.280	3.137	753.788	20695.394	123.957	3.388	4.000	0.000	4.000	5.000	0.324	0.006	0.016	0.001
	A	Leonard	0.451	0.015	0.016	0.000	0.031	31.824	31.824	14.353	6.473	1012.757	32229.832	123.957	3.388	4.000	0.000	4.000	5.000	0.324	0.006	0.016	0.001
	A	Professor	0.480	0.010	0.016	0.000	0.026	37.846	37.846	18.166	8.720	1432.308	54206.927	123.957	3.388	4.000	0.000	4.000	5.000	0.324	0.006	0.016	0.001
	A		1.603	0.085	0.082	0.000	0.167		156.512	50.787	19.868	5095.179	171334.500	123.957	3.388	4.000	0.000	4.000	5.000	0.324	0.006	0.016	0.001
	B	Jeffries	0.440	0.015	0.002	0.000	0.017	57.983	57.983	25.512	11.225	3362.002	194938.233	211.732	3.952	4.000	0.000	4.000	5.000	0.610	0.004	0.002	0.000
	B	Fremont	0.492	0.020	0.002	0.000	0.022	44.951	44.951	22.116	10.881	2020.582	90826.980	211.732	3.952	4.000	0.000	4.000	5.000	0.610	0.004	0.002	0.000
	B	Doyle	0.651	0.015	0.002	0.000	0.017	57.983	57.983	37.747	24.573	3362.002	194938.233	211.732	3.952	4.000	0.000	4.000	5.000	0.610	0.004	0.002	0.000
	B	Stella	0.710	0.025	0.002	0.000	0.027	36.702	36.702	26.058	18.501	1347.034	49438.786	211.732	3.952	4.000	0.000	4.000	5.000	0.610	0.004	0.002	0.000
	B	Thorwald	0.740	0.012	0.002	0.000	0.014	70.193	70.193	51.943	38.438	4927.012	345840.129	211.732	3.952	4.000	0.000	4.000	5.000	0.610	0.004	0.002	0.000
	B		3.033	0.087	0.011	0.000	0.098		267.811	163.376	103.619	15018.633	875982.361	211.732	3.952	4.000	0.000	4.000	5.000	0.610	0.004	0.002	0.000
	Overall		4.636	0.172	0.093	0.000	0.265	424.323	424.323	214.163	123.487	20113.812	1047316.86	376.921	15.395	9.000	41.540	26.807	10.000	0.505	0.002	0.030	0.000

Random-effects model with separate estimates of τ^2

Random-Effects Model with Pooled Estimate of τ^2

- For all three methods (Z-test, Q-test based on ANOVA, and Q-test for heterogeneity) the same computations are used, but with random-effects weights and a pooled estimate of τ^2, referred to as τ^2_{within}

Random-Effects Model with Pooled Estimate of τ^2

- The pooled estimate of τ^2, τ^2_{within}, is

$$T^2_{within} = \frac{\sum_{j=1}^{p} Q_j - \sum_{j=1}^{p} df_j}{\sum_{j=1}^{p} C_j}$$

- Where

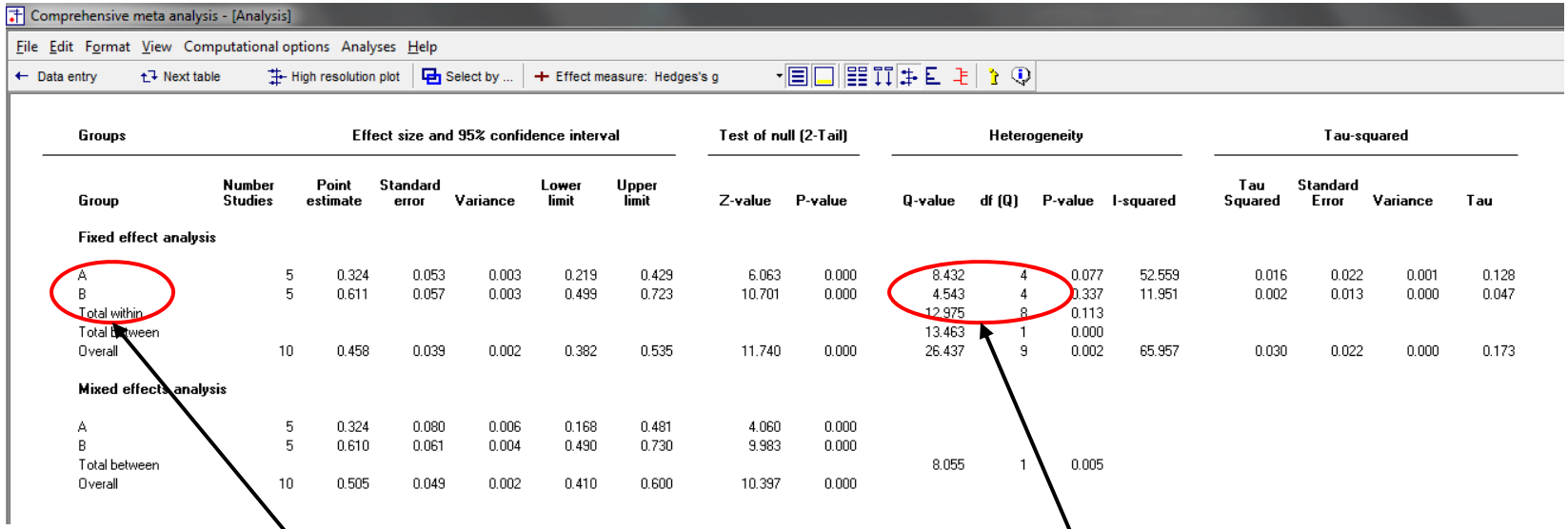
$$C = \sum W_i - \frac{\sum W_i^2}{\sum W_i}$$

Random-Effects Model with Pooled Estimate of τ^2

	Q	df	C
A	8.4316	4	269.8413
B	4.5429	4	241.6667
Total	12.9745	8	511.5079

$$T^2_{within} = \frac{12.9745 - 8}{511.508} = 0.00974$$

Random-Effects Model with Pooled Estimate of τ^2



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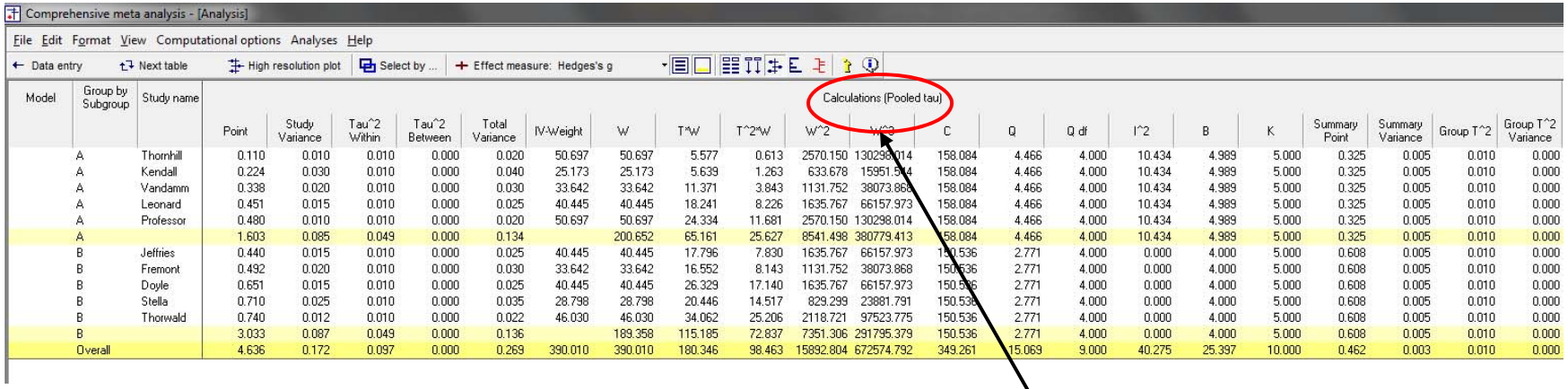
Total between									8.055	1	0.005					
Overall	10	0.505	0.049	0.002	0.410	0.600	10.397	0.000								

Use A and B
and Total within

Q and df

Random-Effects Model with Pooled Estimate of τ^2



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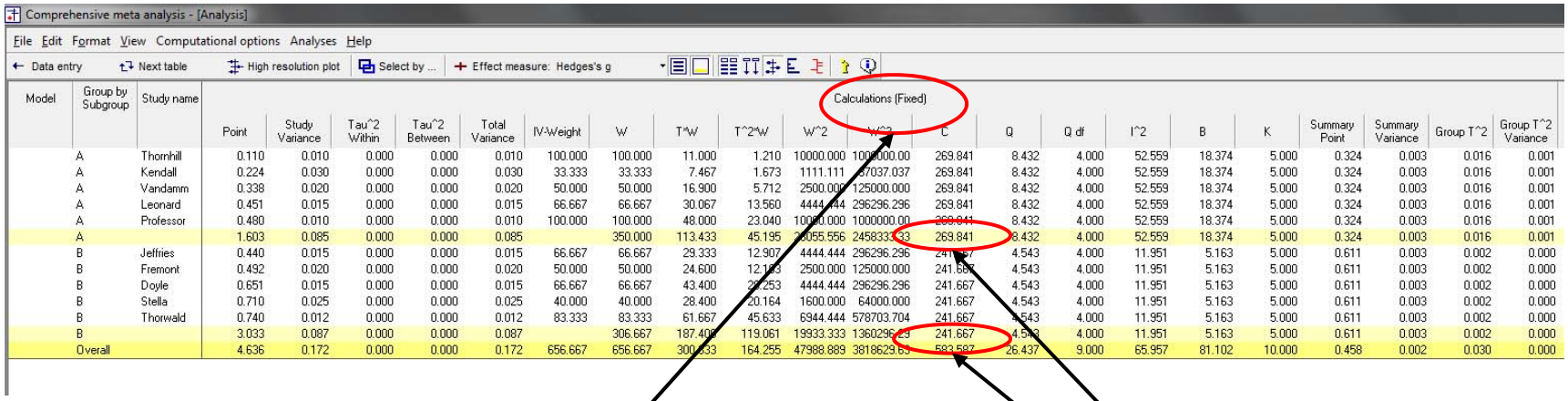
	A	Thornhill	0.110	0.010	0.010	0.000	0.020	50.697	50.697	5.577	0.613	2570.150	130298.014	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Kendall	0.224	0.030	0.010	0.000	0.040	25.173	25.173	5.639	1.263	633.678	15951.514	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Vandamm	0.338	0.020	0.010	0.000	0.030	33.642	33.642	11.371	3.843	1131.752	38073.868	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Leonard	0.451	0.015	0.010	0.000	0.025	40.445	40.445	18.241	8.226	1635.767	66157.973	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Professor	0.480	0.010	0.010	0.000	0.020	50.697	50.697	24.334	11.681	2570.150	130298.014	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A		1.603	0.085	0.049	0.000	0.134		200.652	65.161	25.627	8541.498	380779.413	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	B	Jeffries	0.440	0.015	0.010	0.000	0.025	40.445	40.445	17.796	7.830	1635.767	66157.973	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Fremont	0.492	0.020	0.010	0.000	0.030	33.642	33.642	16.552	8.143	1131.752	38073.868	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Doyle	0.651	0.015	0.010	0.000	0.025	40.445	40.445	26.329	17.140	1635.767	66157.973	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Stella	0.710	0.025	0.010	0.000	0.035	28.798	28.798	20.446	14.517	829.299	23881.791	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Thorwald	0.740	0.012	0.010	0.000	0.022	46.030	46.030	34.062	25.206	2118.721	97523.775	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B		3.033	0.087	0.049	0.000	0.136		189.358	115.185	72.837	7351.306	291795.379	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	Overall		4.636	0.172	0.097	0.000	0.269	390.010	390.010	180.346	98.463	15892.804	672574.792	349.261	15.069	9.000	40.275	25.397	10.000	0.462	0.003	0.010	0.000

Random-effects model with pooled estimate of τ^2

Random-Effects Model with Pooled Estimate of τ^2



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	A	Kendall	0.224	0.030	0.000	0.000	0.030	33.333	33.333	7.467	1.673	1111.111	37037.037	269.841	8.432	4.000	52.559	18.374	5.000	0.324	0.003	0.016	0.001
	A	Vandamm	0.338	0.020	0.000	0.000	0.020	50.000	50.000	16.900	5.712	2500.000	125000.000	269.841	8.432	4.000	52.559	18.374	5.000	0.324	0.003	0.016	0.001
	A	Leonard	0.451	0.015	0.000	0.000	0.015	66.667	66.667	30.067	13.560	4444.444	296296.296	269.841	8.432	4.000	52.559	18.374	5.000	0.324	0.003	0.016	0.001
	A	Professor	0.480	0.010	0.000	0.000	0.010	100.000	100.000	48.000	23.040	10000.000	1000000.00	269.841	8.432	4.000	52.559	18.374	5.000	0.324	0.003	0.016	0.001
	A		1.603	0.085	0.000	0.000	0.085		350.000	113.433	45.195	29055.556	2458333.33	269.841	8.432	4.000	52.559	18.374	5.000	0.324	0.003	0.016	0.001
	B	Jeffries	0.440	0.015	0.000	0.000	0.015	66.667	66.667	29.333	12.907	4444.444	296296.296	241.667	4.543	4.000	11.951	5.163	5.000	0.611	0.003	0.002	0.000
	B	Fremont	0.492	0.020	0.000	0.000	0.020	50.000	50.000	24.600	12.103	2500.000	125000.000	241.667	4.543	4.000	11.951	5.163	5.000	0.611	0.003	0.002	0.000
	B	Doyle	0.651	0.015	0.000	0.000	0.015	66.667	66.667	43.400	28.253	4444.444	296296.296	241.667	4.543	4.000	11.951	5.163	5.000	0.611	0.003	0.002	0.000
	B	Stella	0.710	0.025	0.000	0.000	0.025	40.000	40.000	28.400	20.164	1600.000	64000.000	241.667	4.543	4.000	11.951	5.163	5.000	0.611	0.003	0.002	0.000
	B	Thorwald	0.740	0.012	0.000	0.000	0.012	83.333	83.333	61.667	45.633	6944.444	578703.704	241.667	4.543	4.000	11.951	5.163	5.000	0.611	0.003	0.002	0.000
	B		3.033	0.087	0.000	0.000	0.087		306.667	187.408	119.061	19933.333	1360296.29	241.667	4.543	4.000	11.951	5.163	5.000	0.611	0.003	0.002	0.000
	Overall		4.636	0.172	0.000	0.000	0.172	656.667	656.667	300.833	164.255	47988.889	3818629.63	583.587	26.437	9.000	65.957	81.102	10.000	0.458	0.002	0.030	0.000

Fixed-effect model for quantities to calculate C_{total} $(C_A + C_B)$

C_A and C_B

Proportion of Explained Variance

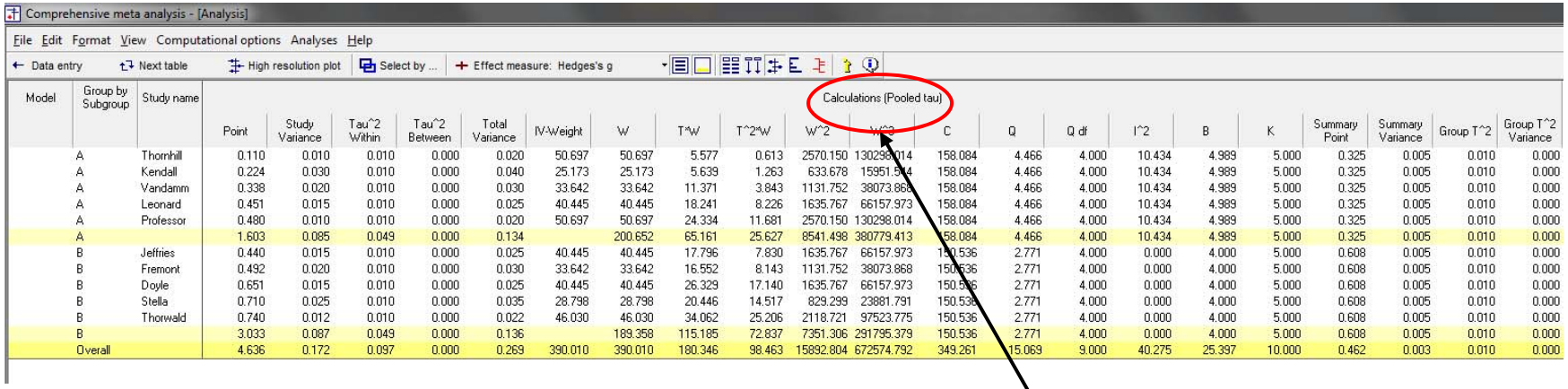
- Unlike the traditional interpretation of R^2 (i.e., the ratio of explained variance to total variance), R^2 as used in meta-analysis is interpreted as proportion of true variance to total variance explained by covariates
- Computational model assumes that τ^2 is the same for all subgroups (i.e., pooled τ^2)

Proportion of Explained Variance

- In a meta-analysis, R^2 is the between-studies variance within subgroups divided by the total between-studies variance (within-subgroups plus between-subgroups)

$$R^2 = 1 - \left(\frac{T^2_{within}}{T^2_{total}} \right)$$

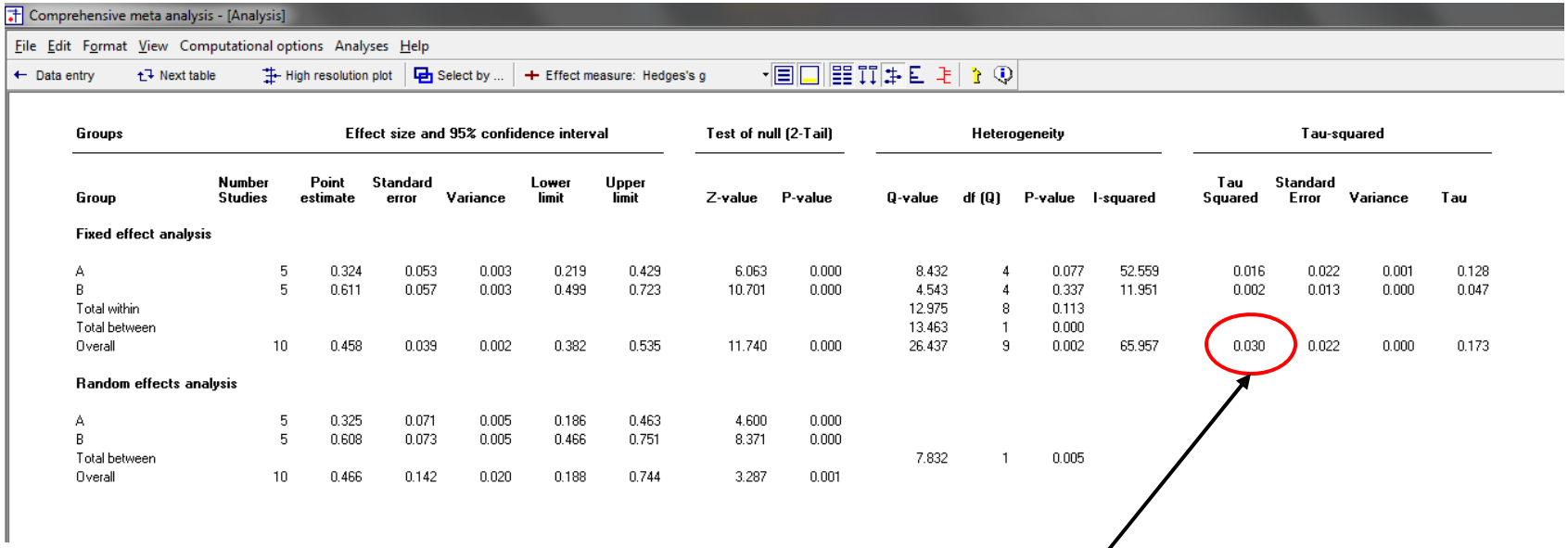
Calculating R^2



Model	Group by Subgroup	Study name	Point	Study Variance	Tau^2 Within	Tau^2 Between	Total Variance	IV-Weight	W	T*W	T^2*W	W^2	W^2	C	Q	Q df	I^2	B	K	Summary Point	Summary Variance	Group T^2	Group T^2 Variance
	A	Thornhill	0.110	0.010	0.010	0.000	0.020	50.697	50.697	5.577	0.613	2570.150	130298.014	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Kendall	0.224	0.030	0.010	0.000	0.040	25.173	25.173	5.639	1.263	633.678	15951.514	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Vandamm	0.338	0.020	0.010	0.000	0.030	33.642	33.642	11.371	3.843	1131.752	38073.868	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Leonard	0.451	0.015	0.010	0.000	0.025	40.445	40.445	18.241	8.226	1635.767	66157.973	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A	Professor	0.480	0.010	0.010	0.000	0.020	50.697	50.697	24.334	11.681	2570.150	130298.014	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	A		1.603	0.085	0.049	0.000	0.134		200.652	65.161	25.627	8541.498	380779.413	158.084	4.466	4.000	10.434	4.989	5.000	0.325	0.005	0.010	0.000
	B	Jeffries	0.440	0.015	0.010	0.000	0.025	40.445	40.445	17.796	7.830	1635.767	66157.973	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Fremont	0.492	0.020	0.010	0.000	0.030	33.642	33.642	16.552	8.143	1131.752	38073.868	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Doyle	0.651	0.015	0.010	0.000	0.025	40.445	40.445	26.329	17.140	1635.767	66157.973	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Stella	0.710	0.025	0.010	0.000	0.035	28.798	28.798	20.446	14.517	829.299	23881.791	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B	Thorwald	0.740	0.012	0.010	0.000	0.022	46.030	46.030	34.062	25.206	2118.721	97523.775	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	B		3.033	0.087	0.049	0.000	0.136		189.358	115.185	72.837	7351.306	291795.379	150.536	2.771	4.000	0.000	4.000	5.000	0.608	0.005	0.010	0.000
	Overall		4.636	0.172	0.097	0.000	0.269	390.010	390.010	180.346	98.463	15892.804	672574.792	349.261	15.069	9.000	40.275	25.397	10.000	0.462	0.003	0.010	0.000

Random-effects model with pooled estimate of τ^2

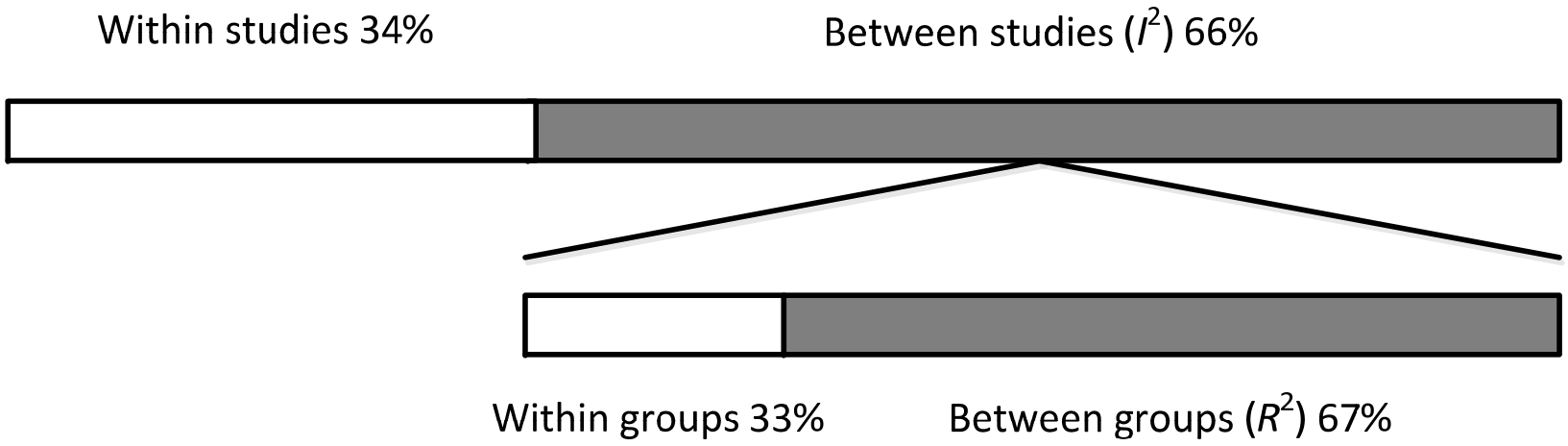
Calculating R^2



Groups		Effect size and 95% confidence interval					Test of null (2-Tail)		Heterogeneity				Tau-squared			
Group	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau Squared	Standard Error	Variance	Tau
Fixed effect analysis																
A	5	0.324	0.053	0.003	0.219	0.429	6.063	0.000	8.432	4	0.077	52.559	0.016	0.022	0.001	0.128
B	5	0.611	0.057	0.003	0.499	0.723	10.701	0.000	4.543	4	0.337	11.951	0.002	0.013	0.000	0.047
Total within									12.975	8	0.113					
Total between									13.463	1	0.000					
Overall	10	0.458	0.039	0.002	0.382	0.535	11.740	0.000	26.437	9	0.002	65.957	0.030	0.022	0.000	0.173
Random effects analysis																
A	5	0.325	0.071	0.005	0.186	0.463	4.600	0.000								
B	5	0.608	0.073	0.005	0.466	0.751	8.371	0.000								
Total between									7.832	1	0.005					
Overall	10	0.466	0.142	0.020	0.188	0.744	3.287	0.001								

T^2_{total}

Variance Explained by Subgroup Membership



Summary Effects in Subgroup Analyses

- Depends on questions and the nature of data
- If question is one of superiority, best not to report a summary effect across subgroups
- If question is one of equivalence, a summary effect across subgroups may or may not be warranted
- Most important are substantive implications and what summary effect represents

Models for Subgroup Analyses

- Three models
  - Fixed-effect analysis: Fixed-effect model within and across subgroups
  - Mixed-effect analysis: Random-effects model within subgroups and fixed-effect model across subgroups (generally recommended model)
  - Fully random-effects analysis: Random-effects model within and across subgroups

Today's In-Class Activity

- From the "Tutoring Subgroup.CMA" data set
  - Using Method 1 (*Z*-test) calculate the mean difference, *p*, and the *LL* and *UL* of the mean difference between subgroups A and B for the fixed-effect model, random effects model with separate estimates of τ^2 and random effects model with pooled estimate of τ^2
  - Calculate and interpret R^2