Hypoxia and Cognitive Ability in Humans: A Systematic Review and Meta-Analysis - Supplementary Material

Daniel J McKeown

2025-05-14

This report presents the results of a series of meta-analytic models examining the effects of hypoxia on cognitive performance. For each cognitive domain, two models are presented, as well as a funnel plot and a model accounting for publication bias:

- **Main effect model**: Estimates the overall effect of hypoxia on the cognitive outcome across studies, without accounting for additional predictors.
- **Moderator model**: Includes study-level moderators (e.g., severity , duration, and type of exposure, cognitive domain/task measure, and participant age) to examine whether these factors explain variability in effect sizes across studies.
- **Funnel plot**: Funnel plots are also included to visualise the distribution of effect sizes included in each model.
- **Corrected model**: To control for potentional publication bias, the main effect model was corrected using the trimfill function of the metafor package.

All models were fit using the `metafor` package in R, with standardized mean differences (SMDH) as the effect size metric and random effects specified at the study level.

Cognitive Ability Domain

Table 1: Reduced Model Main Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.441	0.057	-7.754	0	-0.552	-0.329

Table 2: Full Model Moderator Effects

	Estimate	SE	zval	pval	CI_Lower	CI_Upper
intrcpt	-1.416	0.491	-2.884	0.004	-2.379	-0.454
Severity	10.392	3.148	3.301	0.001	4.223	16.561
Duration	-0.028	0.018	-1.508	0.132	-0.064	0.008
Age	0.000	0.008	-0.013	0.990	-0.015	0.015
Domain: executive function	-0.120	0.087	-1.391	0.164	-0.290	0.049
Domain: memory	-0.122	0.079	-1.539	0.124	-0.278	0.033
Domain: processing speed	-0.079	0.102	-0.773	0.439	-0.279	0.121

Domain: psychomotor speed	-0.484	0.117	-4.121	0.000	-0.714	-0.254

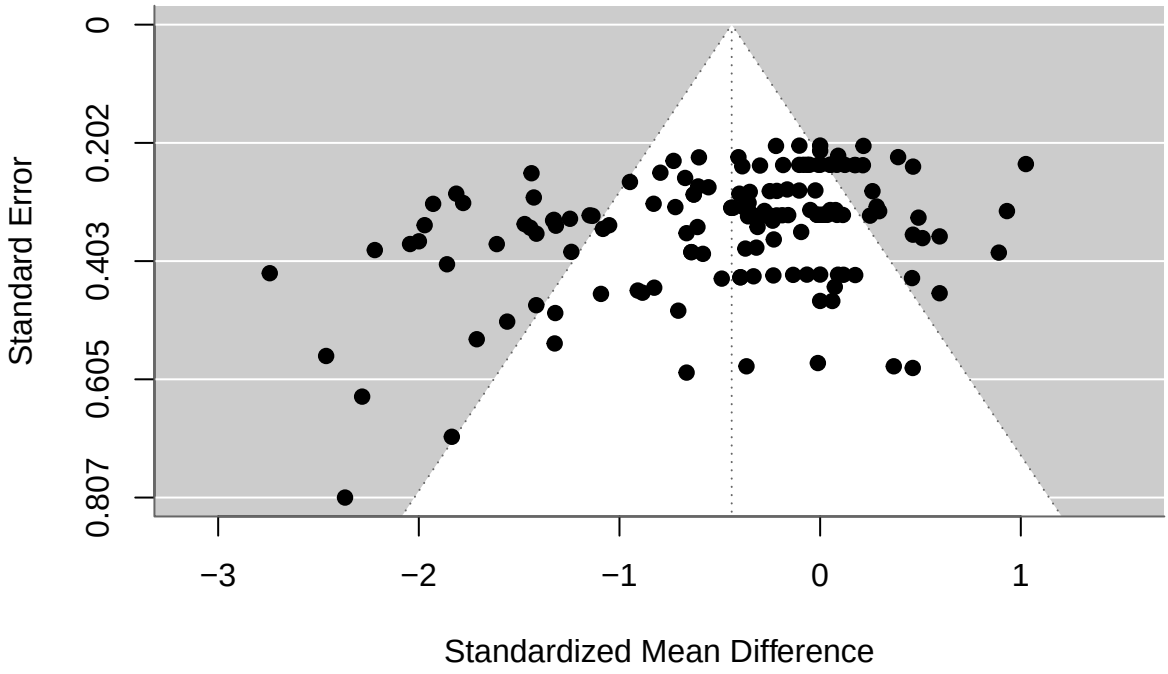

Table 3: Trim and Fill Model Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.441	0.057	-7.754	0	-0.552	-0.329

Memory Domain

Table 4: Reduced Model Main Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.332	0.105	-3.168	0.002	-0.537	-0.126

Table 5: Full Model Moderator Effects

	Estimate	SE	zval	pval	CI_Lower	CI_Upper
intrcpt	0.674	2.475	0.272	0.785	-4.176	5.524
Severity	7.700	5.661	1.360	0.174	-3.395	18.795
Duration	0.006	0.053	0.116	0.908	-0.098	0.110
Type: hypobaric hypoxia	0.092	1.234	0.075	0.940	-2.326	2.510
Type: intermittent hypoxia	1.047	1.426	0.735	0.463	-1.747	3.842

Type: normobaric hypoxia	0.135	1.401	0.096	0.923	-2.611	2.881
Age	-0.037	0.029	-1.272	0.203	-0.094	0.020
Measure: episodic memory (score)	-2.543	0.934	-2.722	0.006	-4.375	-0.712
Measure: involuntary memory (score)	-0.829	0.826	-1.003	0.316	-2.448	0.791
Measure: learning and memory (score)	-1.329	0.950	-1.398	0.162	-3.191	0.534
Measure: long-term memory (score)	-0.094	0.826	-0.114	0.909	-1.714	1.525
Measure: short-term memory (score)	-1.498	0.815	-1.839	0.066	-3.095	0.099
Measure: verbal memory (score)	-1.071	1.034	-1.036	0.300	-3.098	0.956
Measure: visual memory (score)	-1.995	1.061	-1.880	0.060	-4.075	0.085
Measure: working memory (score)	-0.957	0.783	-1.223	0.221	-2.491	0.577

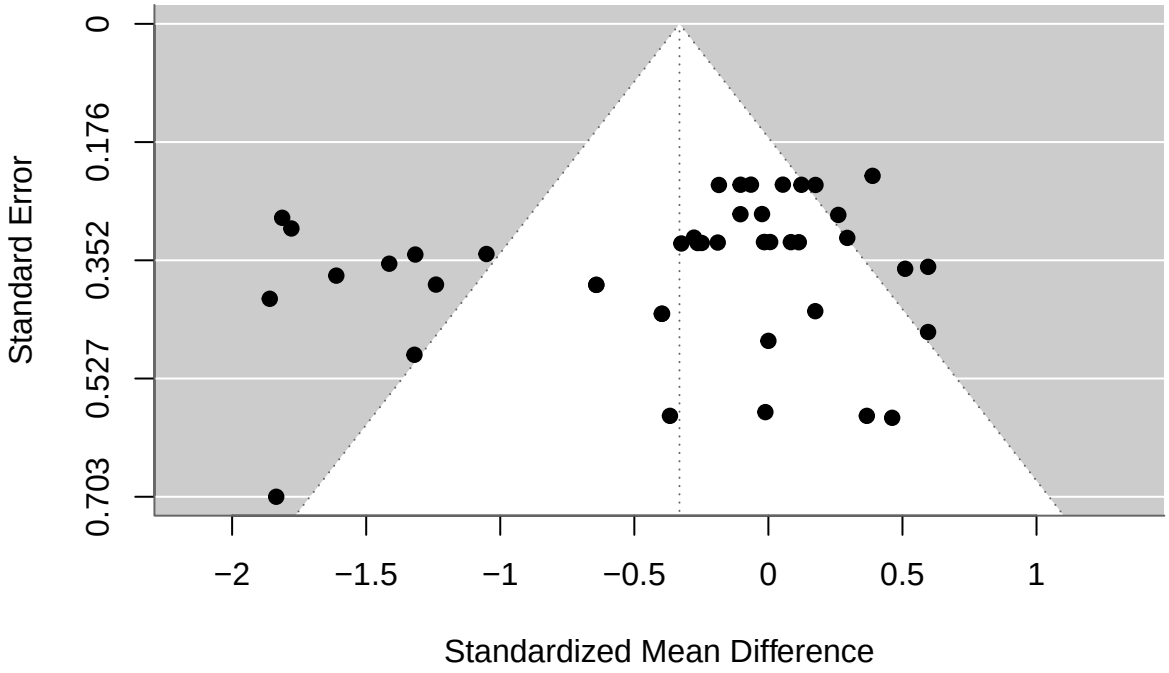

Table 6: Trim and Fill Model Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.332	0.105	-3.168	0.002	-0.537	-0.126

Attention Domain

Table 7: Reduced Model Main Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.248	0.095	-2.614	0.009	-0.434	-0.062

Table 8: Full Model Moderator Effects

	Estimate	SE	zval	pval	CI_Lower	CI_Upper
intrcpt	-0.947	1.134	-0.835	0.404	-3.170	1.276
Severity	8.689	4.845	1.793	0.073	-0.807	18.185
Duration	0.026	0.042	0.616	0.538	-0.057	0.108
Type: intermittent hypoxia	0.390	0.724	0.539	0.590	-1.029	1.809
Type: normobaric hypoxia	-0.147	0.314	-0.470	0.638	-0.762	0.467
Age	-0.012	0.022	-0.548	0.584	-0.055	0.031

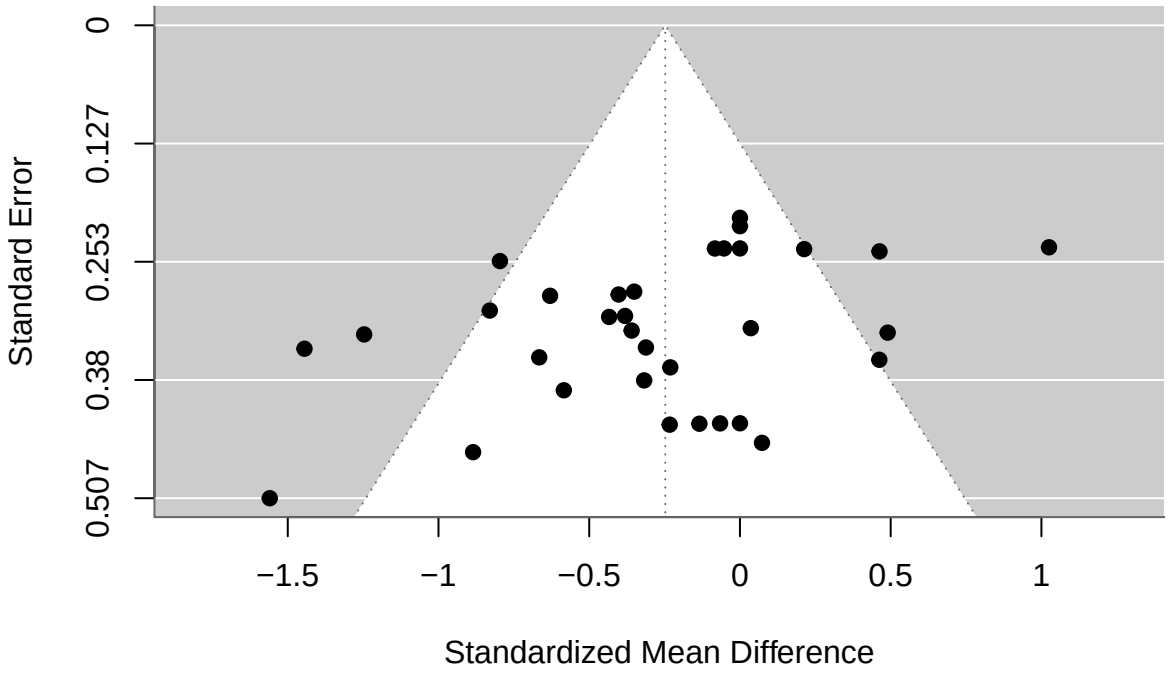

Table 9: Trim and Fill Model Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.248	0.095	-2.614	0.009	-0.434	-0.062

Executive Function Domain

Table 10: Reduced Model Main Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.67	0.123	-5.448	0	-0.911	-0.429

Table 11: Full Model Moderator Effects

	Estimate	SE	zval	pval	CI_Lower	CI_Upper
intrcpt	-0.835	1.093	-0.764	0.445	-2.978	1.308
Severity	11.809	4.057	2.911	0.004	3.857	19.760
Duration	-0.178	0.086	-2.072	0.038	-0.347	-0.010
Type: normobaric hypoxia	-0.567	0.287	-1.974	0.048	-1.130	-0.004
Age	-0.055	0.019	-2.856	0.004	-0.093	-0.017
Measure: coding (score)	0.046	0.352	0.130	0.896	-0.643	0.735
Measure: cognitive flexibility (score)	1.880	0.414	4.547	0.000	1.070	2.690
Measure: decision-making (score)	1.815	0.515	3.524	0.000	0.805	2.824
Measure: executive function (score)	1.336	0.343	3.892	0.000	0.663	2.009
Measure: incorrect answers (score)	3.130	0.520	6.017	0.000	2.110	4.150
Measure: map compass (score)	1.905	0.332	5.737	0.000	1.254	2.555
Measure: neurocognitive index (score)	0.851	0.593	1.434	0.152	-0.312	2.014
Measure: non-verbal fluency (score)	2.246	0.621	3.614	0.000	1.028	3.464
Measure: number comparison (score)	-0.678	0.374	-1.815	0.069	-1.410	0.054
Measure: pattern recognition (score)	0.354	0.343	1.034	0.301	-0.317	1.026
Measure: proof-reading (score)	1.418	0.694	2.043	0.041	0.058	2.778
Measure: reasoning (score)	1.981	0.445	4.452	0.000	1.109	2.853
Measure: risk-taking (score)	1.790	0.382	4.685	0.000	1.041	2.538
Measure: spatial tracking (score)	1.448	0.363	3.992	0.000	0.737	2.159
Measure: tower task (score)	0.641	0.337	1.900	0.057	-0.020	1.302
Measure: verbal fluency (score)	2.685	0.564	4.758	0.000	1.579	3.790
Measure: visual acuity (score)	-0.808	0.547	-1.478	0.139	-1.879	0.264

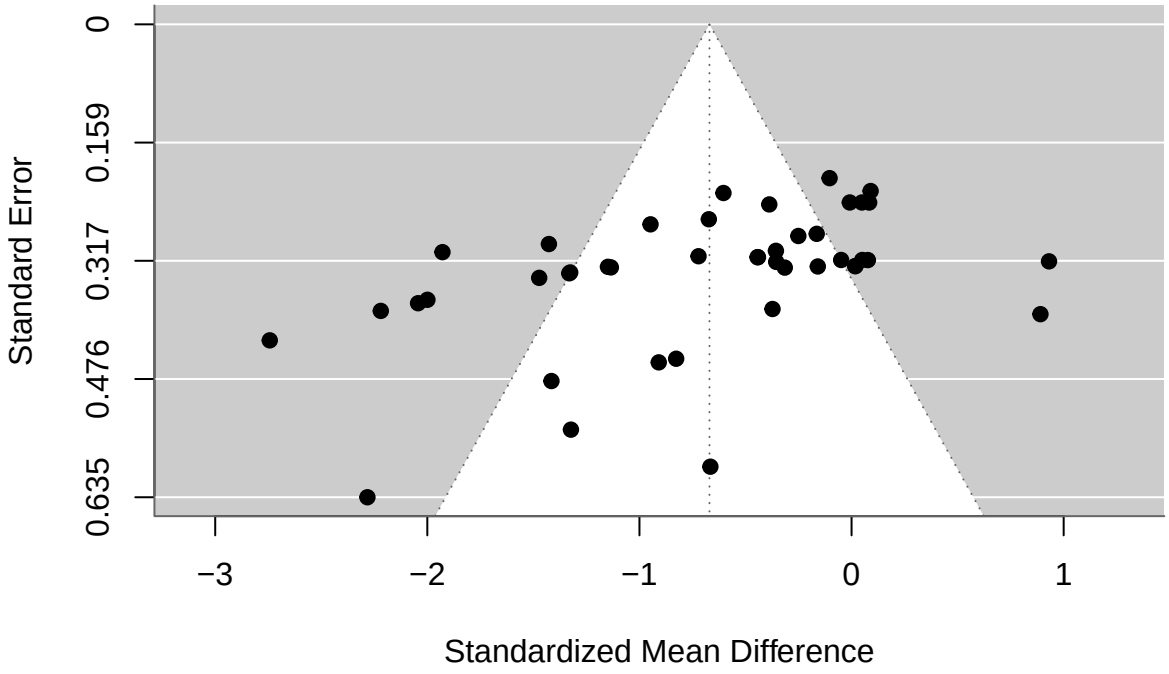

Table 12: Trim and Fill Model Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.67	0.123	-5.448	0	-0.911	-0.429

Processing Speed Domain

Table 13: Reduced Model Main Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.298	0.126	-2.369	0.018	-0.545	-0.051

Table 14: Full Model Moderator Effects

	Estimate	SE	zval	pval	CI_Lower	CI_Upper
intrcpt	0.219	3.748	0.058	0.953	-7.127	7.564
Severity	2.582	13.224	0.195	0.845	-23.336	28.499
Duration	-0.040	0.063	-0.632	0.527	-0.164	0.084
Type: hypobaric hypoxia	-0.422	1.766	-0.239	0.811	-3.884	3.040
Type: intermittent hypoxia	-0.362	1.289	-0.281	0.779	-2.888	2.165
Type: normobaric hypoxia	-0.571	2.050	-0.279	0.780	-4.590	3.447
Age	-0.002	0.045	-0.043	0.965	-0.090	0.086

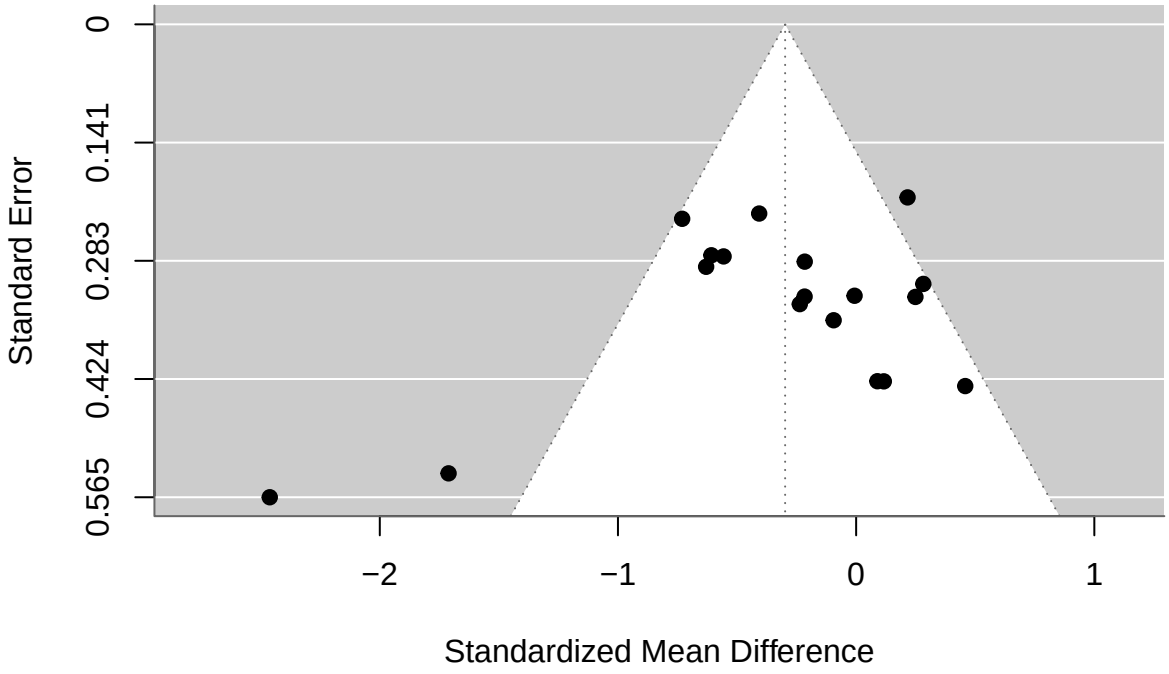

Table 15: Trim and Fill Model Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.298	0.126	-2.369	0.018	-0.545	-0.051

Psychomotor Speed Domain

Table 16: Reduced Model Main Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.716	0.198	-3.613	0	-1.104	-0.328

Table 17: Full Model Moderator Effects

	Estimate	SE	zval	pval	CI_Lower	CI_Upper
intrcpt	13.275	6.956	1.908	0.056	-0.359	26.909
Severity	14.109	16.069	0.878	0.380	-17.386	45.604
Duration	-0.168	0.069	-2.430	0.015	-0.304	-0.033
Type: hypobaric hypoxia	-5.990	2.666	-2.246	0.025	-11.216	-0.764
Type: normobaric hypoxia	-8.514	3.789	-2.247	0.025	-15.939	-1.088
Age	-0.227	0.112	-2.020	0.043	-0.447	-0.007
Measure: motor speed (score)	-0.009	1.021	-0.009	0.993	-2.010	1.991

Measure: psychomotor speed (score)	-0.138	0.902	-0.153	0.878	-1.906	1.630

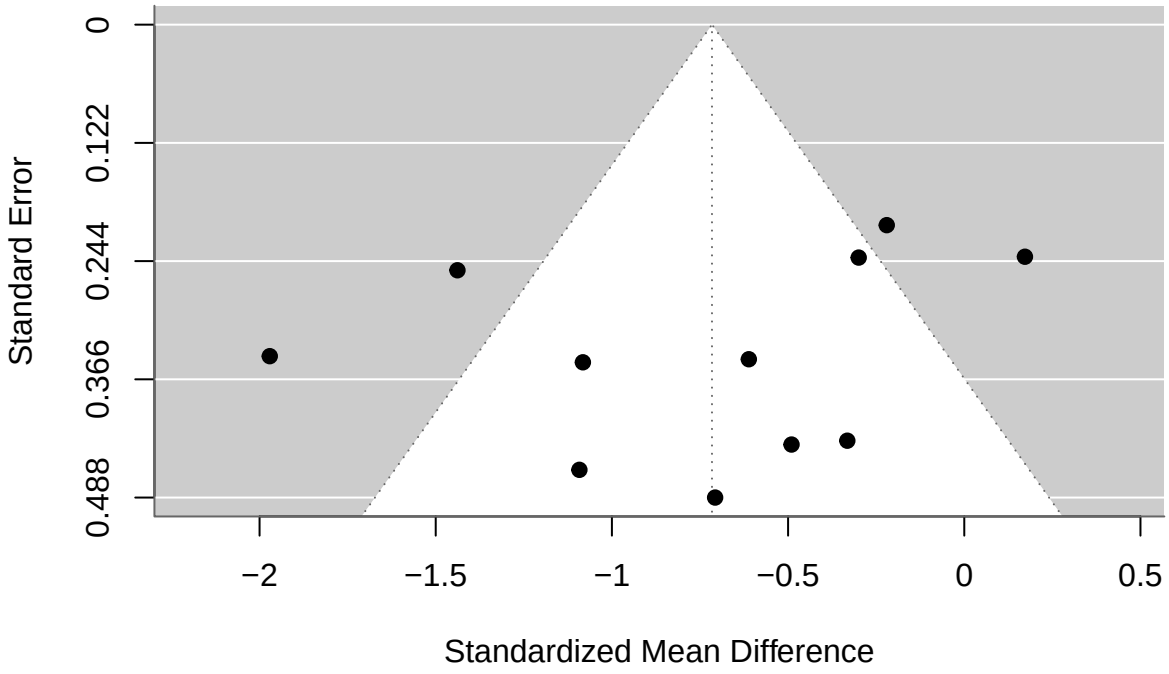

Table 18: Trim and Fill Model Effect

	Estimate	SE	zval	pval	ci.lb	ci.ub
intrcpt	-0.716	0.198	-3.613	0	-1.104	-0.328