Suspicion of scientific misconduct by Dr. Jens Förster

CONFIDENTIAL – September, 3, 2012

Abstract

Here we analyze results from three recent papers (2009, 2011, 2012) by Dr. Jens Förster from the Psychology Department of the University of Amsterdam. These papers report 40 experiments involving a total of 2284 participants (2242 of which were undergraduates). We apply an F test based on descriptive statistics to test for linearity of means across three levels of the experimental design. Results show that in the vast majority of the 42 independent samples so analyzed, means are unusually close to a linear trend. Combined left-tailed probabilities are 0.000000008, 0.0000004, and 0.000000006, for the three papers, respectively. The combined left-tailed p-value of the entire set is p= $1.96 * 10^{-21}$, which corresponds to finding such consistent results (or more consistent results) in one out of 508 trillion (508,000,000,000,000,000,000). Such a level of linearity is extremely unlikely to have arisen from standard sampling. We also found overly consistent results across independent replications in two of the papers. As a control group, we analyze the linearity of results in 10 papers by other authors in the same area. These papers differ strongly from those by Dr. Förster in terms of linearity of effects and the effect sizes. We also note that none of the 2284 participants showed any missing data, dropped out during data collection, or expressed awareness of the deceit used in the experiment, which is atypical for psychological experiments. Combined these results cast serious doubt on the nature of the results reported by Dr. Förster and warrant an investigation of the source and nature of the data he presented in these and other papers.

Papers:

Förster, J. (2009). Relations Between Perceptual and Conceptual Scope: How Global Versus Local Processing Fits a Focus on Similarity Versus Dissimilarity. *Journal of Experimental Psychology: General, 138,* 88-111.

Förster, J. (2011). Local and Global Cross-Modal Influences Between Vision and Hearing, Tasting, Smelling, or Touching. *Journal of Experimental Psychology: General, 140,* 364-389.

Förster, J. & Denzler, M. (2012). Sense Creative! The Impact of Global and Local Vision, Hearing, Touching, Tasting and Smelling on Creative and Analytic Thought. *Social Psychological and Personality Science, 3,* 108-117.

Statistical approach to test for linearity

The main analyses presented below focus on one-way factorial designs in which subjects were randomly assigned to three levels (k=3) of an experimental factor and measured on the same dependent variable. F values from the standard one-way main effect are computed on the basis of the descriptive statistics in the papers and under the assumption that the cell sizes are equal[1]. The between-group mean square (MS_B) can be computed on the basis of the grand mean (x_G) and the three cell means (x_i) (B. H. Cohen, 2002, Understanding Statistics):

$$MS_B = \frac{n\sum(\bar{x}_i - \bar{x}_G)^2}{k-1} \quad , \qquad (1)$$

where n represents the (equal) cell size and k the number of groups. F then becomes:

$$F = \frac{MS_B}{\frac{\sum s_i^2}{k}}, \qquad (2)$$

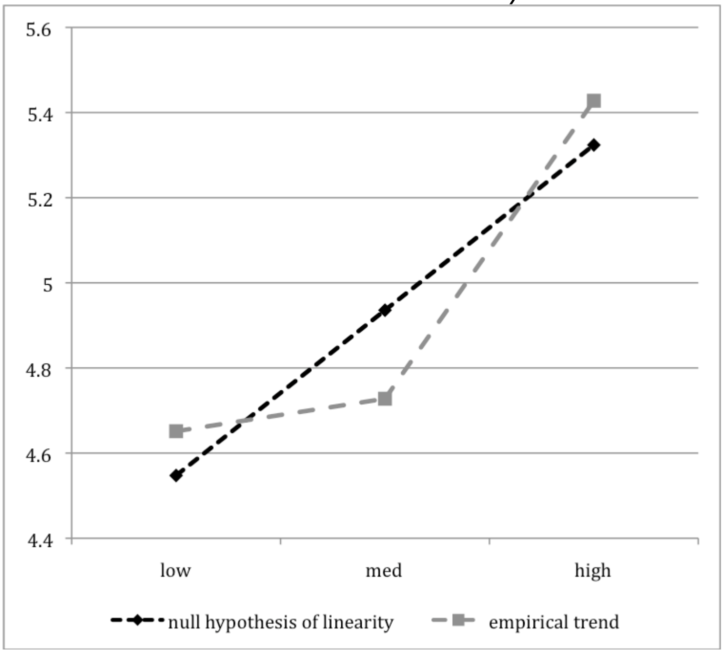
where s_i represents the observed standard deviation in cell i. Under the null hypothesis of equal population means and variances and (i.i.d.) normality, Equation 2 follows an F distribution with k-2 degrees of freedom in the numerator and k(n − 1) degrees of freedom in the denominator. Because ($MS_w = MS_B$ / F), the total sum of squares can be easily computed: $SS_{tot} = SS_B + SS_W = MS_W*(k(n-1)) + MS_B*(k-1)$. It is well known that the one-way ANOVA corresponds to a linear regression with (k-1) dummy coded predictors. This gives rise to eta-squared:

$$eta^2 = \frac{SS_B}{SS_{tot}}, \qquad (3)$$

or the percentage of variance explained by the categorical independent variable.

[1] It is quite common in experimental social psychology to assure equal cell sizes, so we consider this an appropriate assumption. Dr. Förster indicated that cell frequencies were identical in the 2012 paper.

Figure 1
An illustration of the F test for linearity



With k =3, we can compare the fit of the standard F model (with two regression parameters; describing the grey trend line in Figure 1) against a linear regression (with one regression parameter; the black trend line in Figure 1) in which low, medium, and high levels of the independent variable are coded as (-1, 0, 1). The sum of squares of this linear regression can be computed simply by considering the means in the low and high cell:

$$SS_{REG} = [n(M_{high} - M_{low})]^2 / 2n \quad . \qquad (4)$$

The residual sum of squares (SS_{res}) is then simply SS_{tot} - SS_{REG} and so the test statistic for the linear regression (F_{reg}) equals:

$$F_{REG} = \frac{SS_{REG}}{SS_{RES} / (3n - (k-1))}, \qquad (5)$$

whereas the model's predictive power can be expressed in terms of r-squared:

$$r^2 = \frac{SS_{REG}}{SS_{TOT}}$$

Because models underlying F and F_{REG} are nested, we can pit the full model and the linear regression model against each other by computing:

$$\Delta F = \frac{(SS_{REG} - SS_B)}{MS_W} \;, \qquad (6)$$

with DF= 1 in the numerator and DF = 3(n-1) in the denominator.

When the null hypothesis of a perfect linear relation is true, the p-values associated with ΔF are uniformly distributed. Insofar that the relation is non-linear, p-values associated with ΔF will tend towards 0. If empirical results lie too close to the linear trend line, we expect p-values associated with ΔF to be close to 1.

For each independent sample (or levels within an orthogonal factor; see below), we computed the ΔF and collected its p-value. The p-values for each sample are subsequently combined using Fisher's method:

$$\chi_p^2 = -2\sum \ln(p_s). \qquad (7)$$

The statistics defined in Equation 7 follows a χ^2 distribution with twice the number of samples as degrees of freedom.

Appendix A presents results of a simulation study to verify whether the ΔF test functions as expected and whether it is robust to violations of normality of the underlying raw data and rounding of the descriptive statistics that are used as input. These simulations show no bias that is of concern and so support the validity of the ΔF test.

Control papers

To assess the validity of the statistical approach, we looked for similar papers as a control group. To this end, we searched for papers that were similar to the three papers described by Dr. Förster in terms of reference lists (with "find related records" from Web of Science) and that featured a randomized experiment with a factor also involving three levels. We located 10 papers (see Appendix B for DOIs) that enabled the computation of the ΔF test in 21 independent samples. Data are given in Table 1. Trend lines are given in Figure 2 and statistical results are given in Table 2.

Table 1
Means and SDs from 10 control studies with 21 samples

		Low/High		Medium		High /Low	
	N per cell	M	SD	M	SD	M	SD
Hagtvedt_1	141/6	4.39	0.76	3.97	1.26	3.84	1.14
Hagtvedt_2	141/6	3.22	0.98	3.84	1.02	4.11	1.46
Hunt	75/3	1.48	0.82	1.04	0.68	1.04	0.68
Jia	132/3	1.09	0.89	0.70	0.69	0.59	0.62
Kanten_1	269/6	3.29	1.11	3.14	0.94	2.66	0.71
Kanten_2	269/6	3.02	0.80	2.99	0.84	2.85	0.70
Lerouge_1	63/3	4.24	1.51	2.48	2.16	2.14	2.13
Lerouge_2	63/3	2.95	2.44	2.81	1.81	2.62	2.25
Lerouge_3	54/3	4.90	2.22	3.31	2.09	2.79	1.66
Lerouge_4	54/3	3.69	2.78	2.67	2.51	2.50	1.66
Malkoc	521/3	4.72	4.96	5.36	9.08	6.19	10.58
Polman*	65/3	4.69	2.37	3.50	2.09	2.91	2.42
Rook_1	168/6	6.22	3.05	6.13	2.19	4.73	1.95
Rook_2	168/6	5.39	2.14	5.22	2.58	4.61	2.28
Smith_1	73/3	4.38	1.53	4.26	1.36	3.55	1.07
Smith_2	76/3	14.83	4.62	12.69	4.95	11.88	4.75
Smith_3	113/3	0.42	0.20	0.53	0.19	0.56	0.19
Smith_4	140/3	4.70	7.40	7.90	11.40	11.80	20.40
Smith_5	125/3	14.52	2.81	13.43	3.27	12.85	3.94
Smith_6	97/3	10.85	5.07	8.64	3.61	8.32	4.17
Smith_7**	144/3	4.64	1.30	4.84	1.56	5.49	1.28

*Polman reported SEs instead of SDs **Smith_7 is from a separate paper than Smith_1 to Smith_6.

Figure 2

Trend lines for means in the 21 independent samples from control papers given in Table 2.

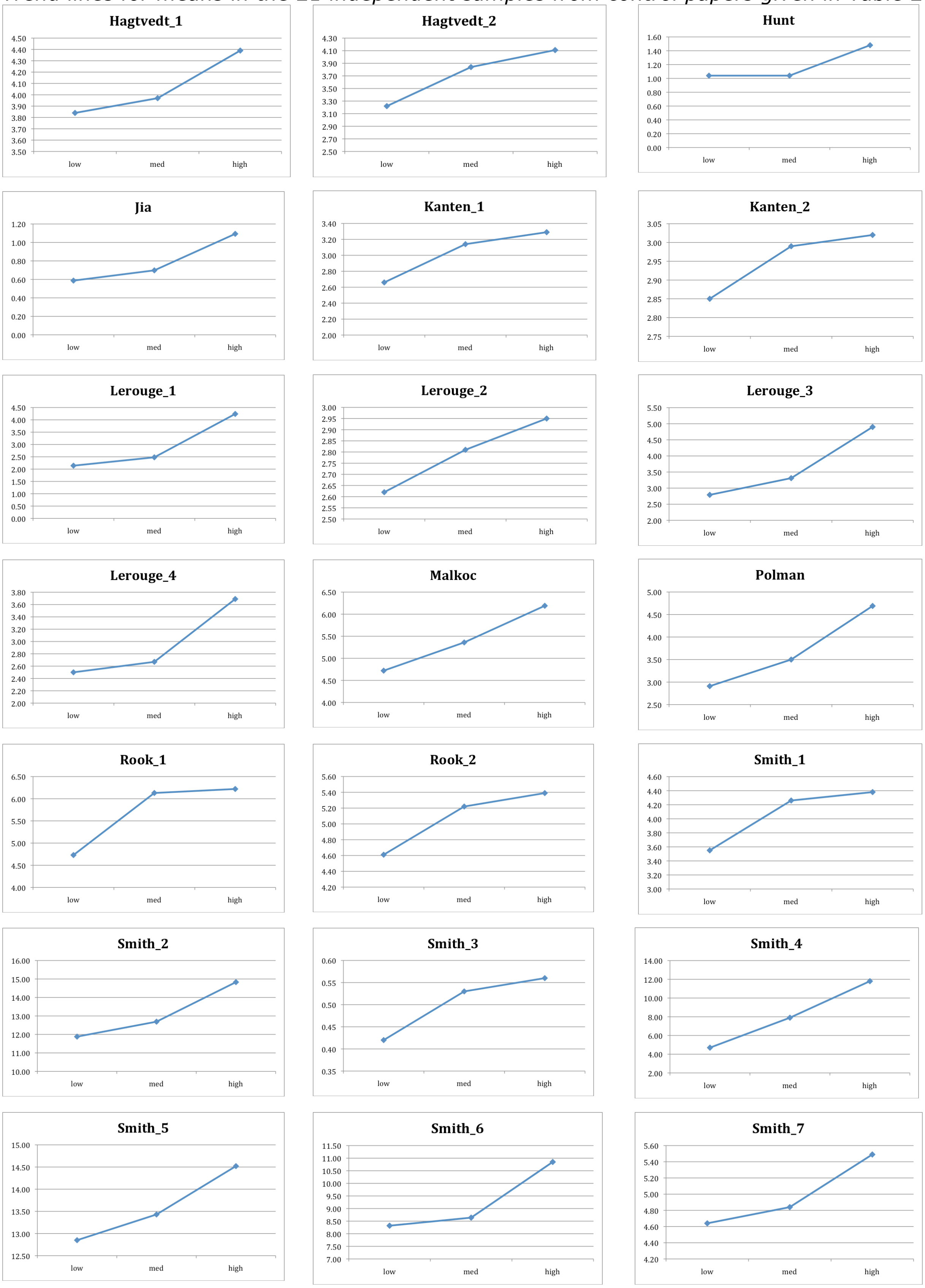


Table 2
Results of standard F test, linear regression, and test for linearity of the 21 independent samples in the 10 control papers

	F	p	Freg	p	Eta^2	r^2	ΔF	p(ΔF)
Hagtvedt_1	1.68	0.1939	3.11	0.0823	0.0475	0.0434	0.28520	0.59508
Hagtvedt_2	3.55	0.0342	6.82	0.0111	0.0952	0.0906	0.34831	0.55705
Hunt	3.03	0.0545	4.51	0.0370	0.0776	0.0582	1.51515	0.22236
Jia	5.65	0.0045	10.22	0.0017	0.0805	0.0729	1.07329	0.30214
Kanten_1	5.56	0.0048	10.19	0.0018	0.0780	0.0714	0.93182	0.33617
Kanten_2	0.60	0.5485	1.07	0.3038	0.0091	0.0080	0.14777	0.70130
Lerouge_1	6.97	0.0019	11.93	0.0010	0.1886	0.1636	1.84385	0.17959
Lerouge_2	0.12	0.8863	0.24	0.6231	0.0040	0.0040	0.00184	0.96596
Lerouge_3	5.41	0.0074	10.00	0.0026	0.1751	0.1613	0.85496	0.35951
Lerouge_4	1.33	0.2728	2.31	0.1350	0.0497	0.0424	0.38742	0.53643
Malkoc	1.29	0.2755	2.58	0.1091	0.0050	0.0049	0.01431	0.90481
Polman	3.36	0.0410	6.56	0.0128	0.0979	0.0943	0.24557	0.62197
Rook_1	3.28	0.0429	5.19	0.0254	0.0748	0.0595	1.34212	0.25006
Rook_2	0.86	0.4270	1.57	0.2136	0.0208	0.0188	0.16492	0.68574
Smith_1	2.75	0.0706	4.73	0.0330	0.0729	0.0624	0.79380	0.37601
Smith_2	2.58	0.0826	4.88	0.0303	0.0660	0.0618	0.32753	0.56888
Smith_3	5.47	0.0054	9.86	0.0022	0.0905	0.0816	1.07427	0.30226
Smith_4	2.95	0.0559	5.91	0.0163	0.0412	0.0411	0.01903	0.89049
Smith_5	2.63	0.0759	5.14	0.0251	0.0414	0.0401	0.15885	0.69092
Smith_6	3.28	0.0420	5.53	0.0208	0.0652	0.0550	1.02892	0.31302
Smith_7	4.94	0.0085	9.04	0.0031	0.0654	0.0598	0.84346	0.35998

Table 2 gives the results of the tests for linearity. Several papers reported F tests or F_{reg} tests on the basis of raw data that enable a comparison to our computations on the basis of equal cell frequencies and rounded descriptive statistics. For standard F tests, the original authors found the following results on the basis of the raw data: Hunt: F=3.04; Jia: F=6.08. In four samples, the authors reported F_{reg} tests: Pollman: F_{reg}=5.19; Smith_1: F_{reg}=4.61; Smith_2: F_{reg}=4.74; Smith_5: F_{reg}=5.10. The differences with the recomputed values (on the basis of descriptive statistics) are minor and can be attributed to rounding. In the case of Jia cell sizes were unequal.

Eta^2 is necessarily larger than or equal to r^2. The differences in explained variance are clear in all control samples except Lerouge_2, where the ΔF test gives a left-tailed probability of $p<.05$. One such result is what is expected by chance in 21 samples under the null hypothesis of linearity.

There were five papers with two or more samples that enabled Fisher's test of a combined p-value. Results are as follows: Hagtvedt: χ^2 (DF = 4) = 2.208, p = .698; Kanten: χ^2 (DF = 4) = 2.890, p = .576; Lerouge: χ^2 (DF = 8) = 6.975, p = .559, Rook: χ^2 (DF = 4) = 3.527, p = .474; and Smith: χ^2 (DF = 12) = 8.772, p = .722. Thus, the analyses of results from the ten control papers show results that are to be expected under the statistical model under the null hypothesis of linearity.

Förster & Denzler[2] (2012)

The 12 randomized experiments in this paper involve a total of 690 undergraduates of which 373 were female. Participants received either 7 Euros or course credit for their one-hour participation.

Studies 1 – 5 involved the same outcome measure but different inductions of local or global processing. All experiments were one-factorial between-subjects designs with three levels. In each experiment, participants were assigned randomly to a local, control, or global condition (as in other analyses presented here). Studies 6-10b involve two dependent variables, namely analytic performance and creative performance. We conduct the analyses for these two variables separately. Descriptive statistics are given in Table 3 for the sole outcome variable in the first five studies and the creativity measure in studies 6-10b. In each experiment, the sample size per cell (N per cell) was identical for the low, medium, and high condition. We acquired SDs and cell frequencies in all twelve studies from Dr. Förster via email. We also requested raw data but this was to no avail. Figure 3 depicts the trend lines for the 12 experiments.

Table 3
Means and SDs from studies of Förster & Denzler (2012)

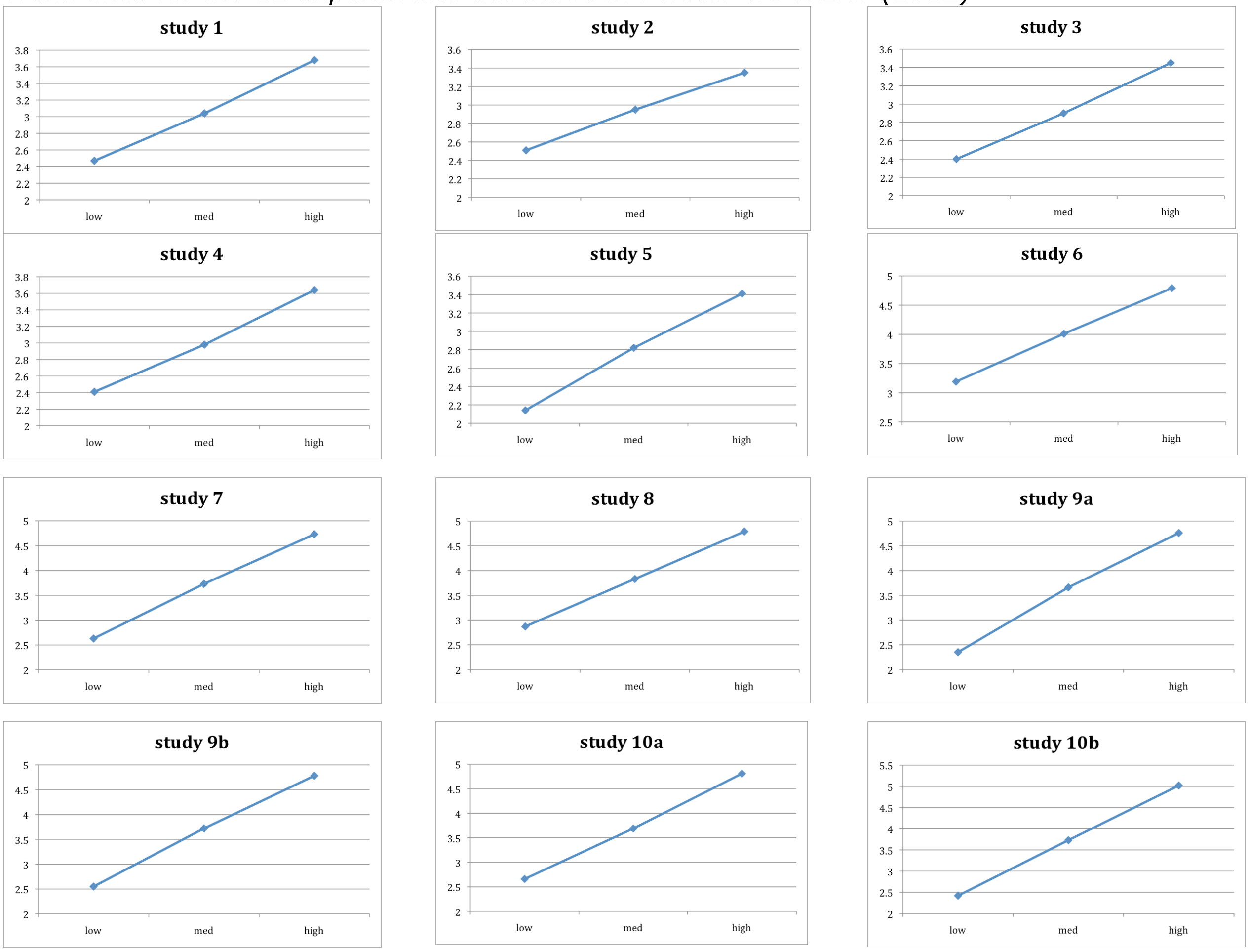
		Low		Medium		High	
	N per cell	M	SD	M	SD	M	SD
Study 1	20	2.47	1.21	3.04	0.72	3.68	0.68
Study 2	20	2.51	0.71	2.95	0.49	3.35	0.64
Study 3	20	2.40	0.86	2.90	0.51	3.45	0.80
Study 4	20	2.41	1.07	2.98	0.51	3.64	0.95
Study 5	20	2.14	1.20	2.82	0.78	3.41	0.71
study 6	20	3.19	1.07	4.01	1.21	4.79	0.82
study 7	20	2.63	1.49	3.73	1.21	4.73	1.55
study 8	20	2.87	1.24	3.83	1.09	4.79	1.53
study 9a	20	2.35	1.01	3.66	1.19	4.76	1.71
study 9b	15	2.55	1.16	3.72	1.00	4.78	1.47
study 10a	20	2.66	1.21	3.69	1.30	4.81	1.54
study 10b	15	2.42	0.82	3.73	1.28	5.02	1.45

(Note: SDs and Ns acquired from Dr. Förster; Ns are equal per cell for all studies in this paper)

[2] Dr. Denzler indicated via email that he did not have the data files from the studies reported in this paper.

Figure 3

Trend lines for the 12 experiments described in Förster & Denzler (2012)



Results of the statistical analyses are given in Table 4.

Table 4

Results of standard F test, linear regression, and test for linearity of studies of Förster & Denzler (2012)

	F	p	F_{reg}	p	Eta^2	r^2	ΔF	p(ΔF)
study 1	8.99	0.0004	18.27	<.0001	0.2398	0.2396	0.02004	0.88792
study 2	9.18	0.0003	18.66	<.0001	0.2436	0.2434	0.01387	0.90667
study 3	10.09	0.0002	20.52	<.0001	0.2615	0.2613	0.01525	0.90216
study 4	9.85	0.0002	20.00	<.0001	0.2569	0.2564	0.03510	0.85205
study 5	9.49	0.0003	19.28	<.0001	0.2499	0.2495	0.03173	0.85925
study 6	9.17	0.0004	18.65	<.0001	0.2434	0.2434	0.00382	0.95094
study 7	8.00	0.0009	16.27	.00016	0.2193	0.2191	0.01209	0.91283
study 8	8.13	0.0008	16.54	.00014	0.2219	0.2219	0.00000	1.00000
study 9a	11.68	0.0001	23.68	<.0001	0.2907	0.2899	0.05897	0.80901
study 9b	8.99	0.0006	18.38	.00010	0.2997	0.2995	0.01457	0.90450
study 10a	9.66	0.0002	19.64	<.0001	0.2531	0.2529	0.01127	0.91581
study 10b	9.27	0.0005	18.98	<.0001	0.3063	0.3062	0.00037	0.98483

The F values reported in the paper were based on raw data whereas our F values were based on the descriptive statistics rounded to two decimals. The F values in the paper were 8.93, 9.15, 10.02, 9.85, 9.52, 9.22, 9.01, 8.13, 11.71, 8.99, 9.69, and 9.28, respectively. All differences are minor except for Study 7 and can be ascribed to rounding.

As can be seen, the Eta^2 and r^2 are very close for all studies and all ΔFs are <.06. Under the null hypothesis of perfect linearity, we expect the p-values of ΔF tests to be uniformly distributed between 0 and 1, but in this set of studies all p-values are above .80. Fisher's test gives χ^2 (DF = 24) = 2.377369693, p = 0.999999994. This means that given the assumptions of the ΔF test and the model set-up (i.e., there is actual perfect linearity), such consistent results (or more consistent results) would appear in only 1 out of 179 million cases.

Studies 6-10b involved a second dependent variable called analytic performance. We conduct a separate analysis for this secondary variable. Results are shown in Figure 4 and Tables 5 and 6.

Figure 4
Trend lines for the 7 experiments described in Förster & Denzler (2012) involving analytic task

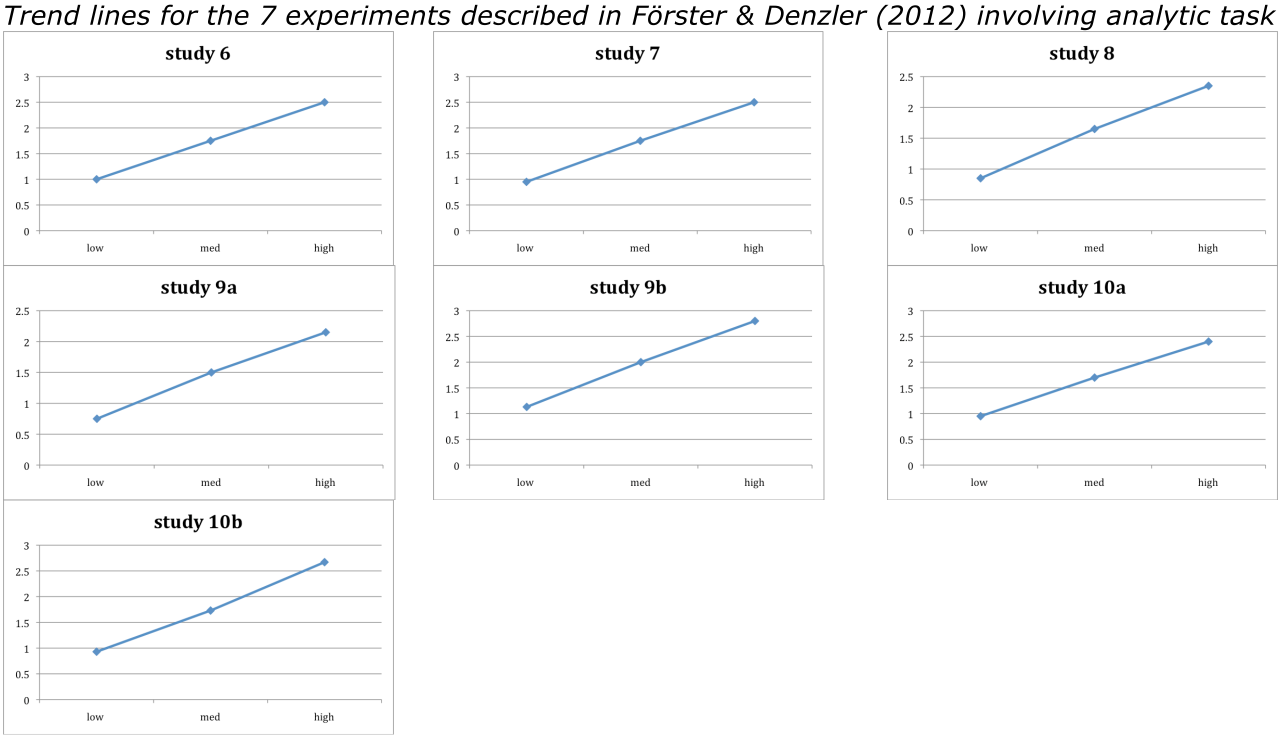


Table 5

Means and SDs from studies 6-10b of Förster & Denzler (2012) for Analytic performance

		low		medium		high	
	N cell	M	SD	M	SD	M	SD
study 6	20	1.00	0.86	1.75	1.21	2.50	1.20
study 7	20	0.95	1.10	1.75	1.21	2.50	1.10
study 8	20	0.85	0.93	1.65	1.09	2.35	1.31
study 9a	20	0.75	0.85	1.50	1.19	2.15	0.81
study 9b	15	1.13	1.13	2.00	1.00	2.80	0.94
study 10a	20	0.95	1.00	1.70	1.30	2.40	0.99
study 10b	15	0.93	0.70	1.73	1.28	2.67	0.98

(Note: SDs and Ns acquired from Dr. Förster)

Table 6

Results of standard F test, linear regression, and test for linearity of studies 6-10b of Förster & Denzler (2012) for Analytic performance

	F	p	F_{reg}	p	Eta^2	r^2	ΔF	p(ΔF)
study 6	9.26	0.0003	18.85	<.0001	0.2453	0.2453	0.00000	1.00000
study 7	9.28	0.0003	18.88	<.0001	0.2457	0.2456	0.00644	0.93634
study 8	8.97	0.0004	18.21	<.0001	0.2393	0.2390	0.02653	0.87119
study 9a	10.54	0.0001	21.40	<.0001	0.2699	0.2695	0.03578	0.85064
study 9b	9.93	0.0003	20.32	<.0001	0.3211	0.3209	0.01163	0.91464
study 10a	8.60	0.0005	17.49	<.0001	0.2317	0.2316	0.00681	0.93451
study 10b	11.05	0.0001	22.55	<.0001	0.3448	0.3440	0.04759	0.82837

Note: DFs for 9b and 10b are (2,42) and (1,43) for F and F_{reg}, resp.

The paper reports F values of 9.22, 9.29, 8.96, 10.50, 9.92, 8.57, and 10.98, respectively on the basis of the raw data. The minor discrepancies with the F values in Table 6 (based on descriptive statistics) can be attributed to rounding.

In this case, Fisher's test gives χ^2 (DF = 14) = 1.4214, p = .9999902, which implies such consistent results or more consistent results in around 1 in 102,000.

Because of the ordinal nature of the scores in the relatively narrow range of [0,4] on the analytic performance measure, we also computed p-values of ΔF on the basis of the simulation described in Figure A2b of Appendix A. This gave p-values of 1, 0.96194, 0.88786, 0.85232, 0.89524, 0.9599, and 0.82067. These values are quite close the figures in the last column of Table 6 and so the results cannot be attributed to the ordinal nature of the raw data.

It is striking that the strong consistency with the linear model appears for both dependent variables in studies 6 – 10b.

Other issues related to Förster & Denzler (2012)

(1) Of the 690 undergraduates, 373 were female. Participants received either 7 Euros or course credit for their one-hour participation. We note that the University of Amsterdam has had around 500 psychology freshmen per year in the last five years and that 72% of these are female (www.uva.nl). The sex distribution in the sample of Förster & Denzler (2012) (54%) deviates strongly from the sex distribution of psychology freshmen.

(2) Page 110 of the paper states that "At the end of the entire session, participants were debriefed; none of them saw any relation between the two phases." It is uncommon to find (psychology) undergraduates with no suspicions concerning the goal of the studies in sample of 690, because these undergraduates are often trained in psychological research methods. It is also uncommon to have no dropout of participants or missing data in such a large sample.

(3) "We also explained the distinction between global and local processing to participants, and asked them to what extent they focused on details versus the whole during the testing phase on scales anchored at 1 (not at all) and 7 (very much). Ratings did not differ across conditions in any of the studies, all Fs < 1" and "For each single experiment, we conducted ONEWAYs to examine effects on moods, or evaluation of the tasks or inductions. There were no significant effects, all Fs < 1." It is unlikely to find F<1 in over 48 F tests even if all null hypotheses were true.

(4) The cognitive test used in experiments 6-10b has only four items, yet the effect sizes are around d = 1.5, which represent very large effects given the expected low reliability of the scale. Also, answers are given in an 5-option multiple choice format. The low means in several conditions (cf. Table 5) suggest that a sizeable portion of participants performed below chance level, which is peculiar for undergraduates.

(5) Effects are overly consistent across the independent studies despite the fact that the manipulations are widely different. Also, the two dependent variables in studies 6-10b show effects that are near mirror images. We ran meta-analyses in Cohen's d (with a small-sample size correction due to Hedges & Olkin, 1985) for comparisons of the low vs. medium, low vs. high, and medium vs. high. In each comparison we ran a fixed-effects model and computed the Q statistic, which entails a test of homogeneity

under the null hypothesis that across each of the five replications the underlying effect is identical. Results are given in Table 7.

Table 7
Results of meta-analyses of pairwise comparisons in studies 1-5 of Förster & Denzler (2012)

	low vs	med	med vs. high		low vs.	high
	d	SE	d	SE	d	SE
study 1	0.896	0.326	0.561	0.316	1.208	0.339
study 2	0.688	0.320	0.707	0.320	1.218	0.340
study 3	0.804	0.323	0.693	0.320	1.239	0.341
study 4	0.848	0.325	0.667	0.319	1.192	0.338
study 5	0.775	0.322	0.659	0.319	1.263	0.342
MEAN	0.801		0.657		1.224	
Q (DF=4)	0.2373		0.130		0.0263	
p	0.9935		0.9980		0.99991	

As can be seen, the results of all three meta-analyses show medium to large effect sizes and overly consistent results. Under the null hypothesis of a single underlying effect (perfect homogeneity of effects), the p-values of the Q test should show a uniform distribution, but in this set all p-values are >.993. The left-tailed p-values are .0065, .002, and .00009 for getting such consistent or more consistent results with exact replications.

Studies 6 to 10b involved conceptual replications of studies 1-5, but with two dependent measures, viz. Analytic performance and Creative performance. Results of the meta-analyses are given in Tables 8 and 9.

Table 8
Results of meta-analyses of pairwise comparisons in studies 6-10a of Förster & Denzler (2012); Analytic performance

	low vs med		med vs. high		low vs. high	
	d	SE	d	SE	d	SE
study 6	0.700	0.320	0.610	0.318	1.408	0.349
study 7	0.678	0.319	0.636	0.318	1.381	0.348
study 8	0.774	0.322	0.569	0.317	1.294	0.343
study 9a	0.711	0.320	0.626	0.318	1.653	0.363
study 9b	0.793	0.371	0.802	0.371	1.563	0.411
study 10a	0.634	0.318	0.594	0.317	1.428	0.350
study 10b	0.755	0.369	0.802	0.371	1.988	0.442
MEAN	0.7163		0.6512		1.4992	
Q (DF=6)	0.1701		0.4566		2.0045	
p	0.999990		0.99833		0.91928	

Left-tailed probabilities of the homogeneity test again show overly consistent results for low vs. medium (p = 0.00001) and medium vs. high (p = .0016).

Table 9

Results of meta-analyses of pairwise comparisons in studies 6-10a of Förster & Denzler (2012); Creative performance

	low vs med		med vs. high		low vs. high	
	d	SE	d	SE	d	SE
study 6	0.606	0.318	0.620	0.318	1.645	0.362
study 7	0.629	0.318	0.564	0.317	1.354	0.346
study 8	0.630	0.318	0.580	0.317	1.351	0.346
study 9a	0.851	0.325	0.600	0.317	1.682	0.365
study 9b	0.798	0.371	0.660	0.366	1.639	0.417
study 10a	0.651	0.319	0.649	0.319	1.522	0.355
study 10b	0.730	0.368	0.647	0.365	2.148	0.455
MEAN	0.6931		0.6141		1.5816	
Q (DF=6)	0.4982		0.0753		2.5736	
p	0.99786		0.999991		0.86014	

Left-tailed probabilities of the Q test are .002, .0000009 and .14. Such results are quite unlikely when there is perfect homogeneity of effects and even less likely when the underlying effects are actually different. The striking consistency of results is apparent on both dependent measures in Studies 6-10b.

To conclude, the results of studies in Förster & Denzler (2012) are not only overly linear, they are also overly consistent across the different conceptual replications.

Förster (2011)

This paper reports results of 18 randomized experiments involving a total of 823 undergraduates. Of these 509 (61.8%) were female.

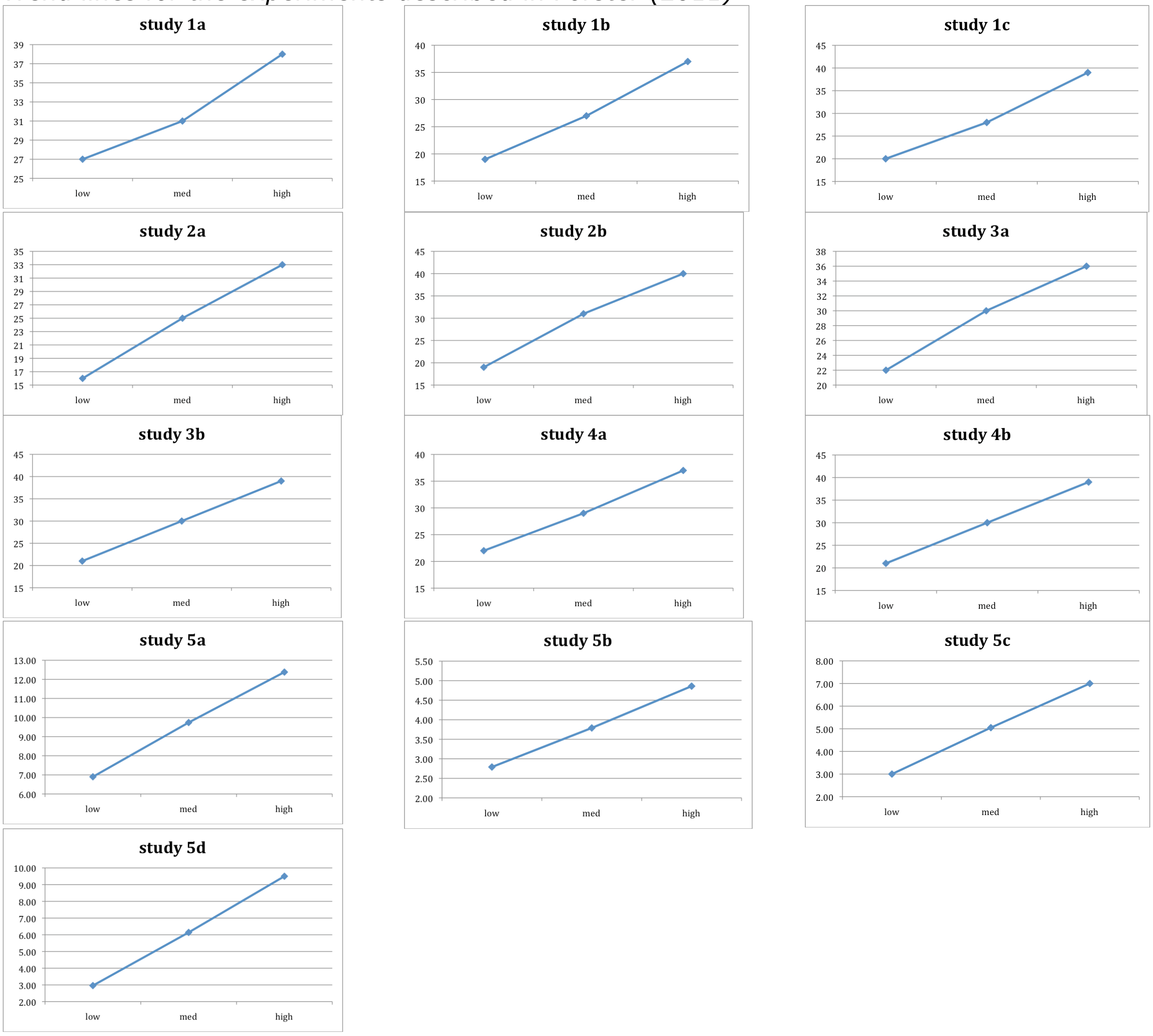
Studies 2c, 3c, 4c, and 6 did not feature 3 levels but 2 and so are not analyzed here. The results of the other 13 independent samples are given in Table 10. Trend lines are depicted in Figure 5.

Table 10
Results of the 13 samples with 3 levels as reported by Förster (2011)

		Low/High		Med		High/Low	
	N cell	M	SD	M	SD	M	SD
study 1a	48/3	38	10	31	13	27	11
study 1b	58/3	37	12	27	14	19	13
study 1c	57/3	39	10	28	11	20	12
study 2a	61/3	33	13	25	15	16	14
study 2b	45/3	40	10	31	9	19	15
study 3a	44/3	36	14	30	13	22	14
study 3b	44/3	39	9	30	11	21	13
study 4a	44/3	37	13	29	11	22	15
study 4b	43/3	39	10	30	9	21	13
study 5a	42/3	6.90	3.06	9.74	3.71	12.38	3.23
study 5b	42/3	2.79	1.31	3.79	1.19	4.86	1.51
study 5c	42/3	3.00	1.20	5.05	2.22	7.00	3.61
study 5d	42/3	2.96	1.26	6.14	3.80	9.50	5.96

Figure 5

Trend lines for the experiments described in Förster (2011)



Statistical results are given in Table 11 and again show very small differences between Eta^2 and r^2.

Table 11

Results of standard F test, linear regression, and test for linearity of studies of Förster (2011)

	F	p	Freg	p	Eta^2	r^2	ΔF	p(ΔF)
study 1a	3.82	0.0295	7.58	0.0084	0.1450	0.1415	0.18462	0.66949
study 1b	9.27	0.0003	18.77	0.0001	0.2521	0.2510	0.07597	0.78387
study 1c	14.21	0.0000	28.59	0.0000	0.3448	0.3420	0.23425	0.63035
study 2a	7.48	0.0013	15.19	0.0003	0.2050	0.2048	0.01723	0.89602
study 2b	12.30	0.0001	24.92	0.0000	0.3694	0.3669	0.16626	0.68553
study 3a	3.87	0.0289	7.86	0.0076	0.1588	0.1577	0.05229	0.82027
study 3b	9.61	0.0004	19.68	0.0001	0.3191	0.3191	0.00000	1.00000
study 4a	4.81	0.0133	9.84	0.0031	0.1901	0.1899	0.01424	0.90560
study 4b	9.95	0.0003	20.40	0.0001	0.3323	0.3323	0.00000	1.00000
study 5a	9.40	0.0005	19.27	0.0001	0.3253	0.3251	0.00834	0.92769
study 5b	8.32	0.0010	17.05	0.0002	0.2990	0.2989	0.00634	0.93696
study 5c	8.66	0.0008	17.76	0.0001	0.3076	0.3075	0.00361	0.95241
study 5d	8.71	0.0007	17.87	0.0001	0.3089	0.3088	0.00440	0.94745

The paper reports F values of 3.60, 9.44, 13.46, 8.35, 12.81, 3.88, 9.08, 4.63, 9.66, 9.39, 8.32, 8.66, and 8.84, respectively on the basis of the raw data. These values deviate somewhat from our recomputed values based on summary statistics because of rounding effects and minor differences in cell frequencies.

In this set, the p-values of ΔF again deviate strongly from the uniform distribution expected under the null hypothesis of linearity. The majority of p-values is larger than .80. Fisher's test gives χ^2 (DF = 26) = 4.2676, p = 0.999999574. This means that under perfect linearity, we would expect such consistently linear results (or even more linear results) in one in 2.35 million cases. Again, any actual deviation from the linear trend would even lower these probabilities.

We also computed p-values for ΔF for studies 1-4 on the basis of the simulation described in Figure A3b of Appendix A. The results were 0.68367, 0.80763, 0.64634, 0.93607, 0.68727, 0.80843, 0.93611, 0.93611, and 0.93611. These p-values are close to the values in Table 11 and so the rounding effects do not account for the results in this set of studies.

We repeated the analysis of the studies 5 for the variable "Global versus local descriptions (expert ratings)" (studies 5a, 5c,5d) or "Global touching (expert ratings)" (study 5b). The trend lines are given in Figure 6.

Figure 6

Trend lines for "Global versus local descriptions (expert ratings)" (studies 5a, 5c,5d) or "Global touching (expert ratings)" (study 5b) of Förster (2011)

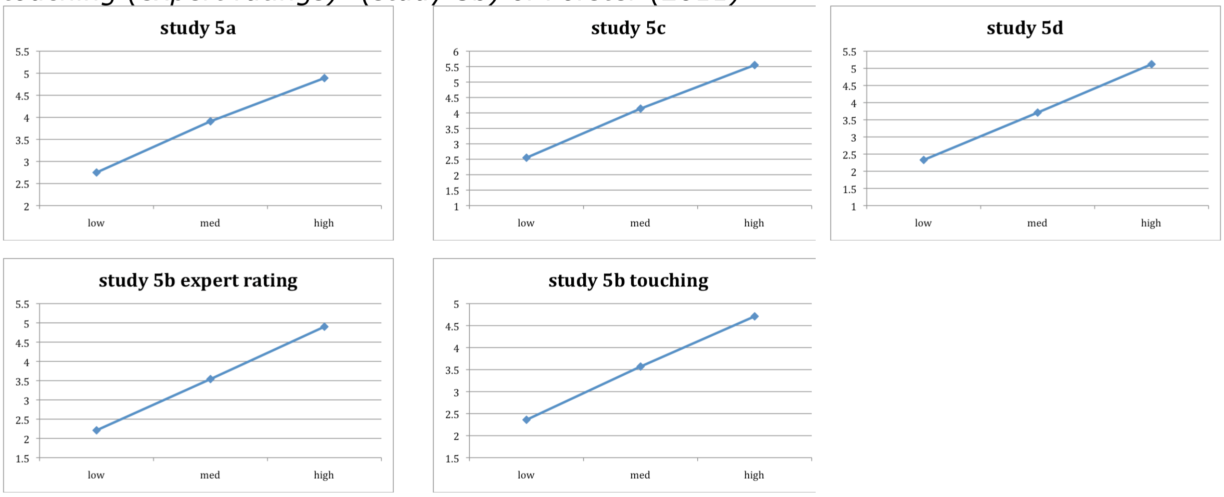


Table 12

Results of studies 5a-5d of Förster (2011); "Global versus local descriptions (expert ratings)"

		high		med		low	
	N	M	SD	M	SD	M	SD
study 5a	42/3	4.89	1.33	3.91	1.10	2.75	1.38
study 5b	42/3	4.90	1.60	3.54	2.07	2.21	1.37
study 5c	42/3	5.55	1.73	4.14	2.04	2.55	1.87
study 5d	42/3	5.12	1.82	3.71	1.93	2.33	1.34

Table 13

Results of standard F test, linear regression, and test for linearity of studies 5a-5d of Förster (2011); "Global versus local descriptions (expert ratings)"

	F	p	F_{reg}	p	Eta^2	r^2	ΔF	p(ΔF)
study 5a	9.87	0.0003	20.17	0.0001	0.3361	0.3353	0.04644	0.83049
study 5b	8.71	0.0007	17.87	0.0001	0.3088	0.3088	0.00072	0.97870
study 5c	8.88	0.0007	18.19	0.0001	0.3130	0.3126	0.02129	0.88474
study 5d	9.25	0.0005	18.98	0.0001	0.3218	0.3218	0.00071	0.97883

The paper reports F values of 9.91, 8.65, 8.87, and 9.23. These values are quite close to the recomputed values.

In this set, Fisher's test gives χ^2 (DF = 8) = 0.7023, p = 0.999520918, or one out of 2087.

Study 5b has a third dependent variable ("Local descriptions (expert ratings)"; F=8.34) that gives the following results:

Table 14
Results of standard F test, linear regression, and test for linearity of study 5b of Förster (2011); "Local descriptions (expert ratings)"

	F	p	F_{reg}	p	Eta^2	r^2	ΔF	p(ΔF)
study 5b	8.29	0.0007	16.99	0.0001	0.2983	0.2982	0.00059	0.98072

So the near-perfect linearity (p>.97) in study 5b reappears on all three dependent variables.

Other issues related to Förster (2011)

(1) Of the 823 undergraduates, 509 (61.8%) were female. The sex distribution in the sample deviates from the sex distribution of psychology freshmen at the University of Amsterdam.

(2) All 823 participating undergraduates were probed for suspicion concerning the relation between the tasks in the experiment. None of them saw any relation between the tasks. This is highly unlikely in such a large sample containing undergraduates who are typically trained in psychological research methods and who are often quite experienced as research participants. The lack of missing data and dropout is also not characteristic of psychological experiments of this type in such a large sample.

(3) The paper reports a disproportionally large number of F tests with values < 1, which is not to be expected even if all null hypotheses were true.

(4) Effects are overly consistent across the independent studies despite the fact that the manipulations are widely different. We ran meta-analyses in Cohen's d (with a small-sample size correction due to Hedges & Olkin, 1985) for comparisons of the low vs. medium, low vs. high, and medium vs. high conditions. In each comparison we ran a fixed-effects model and computed the Q statistic, which entails a test of homogeneity under the null hypothesis that across each of the replications the underlying effect is identical. Results are given in Table 15 for studies 5a-5b. Table 16 gives the results of studies with "explicit manipulations" (as categorized by Förster, 2011 on page 379). Table 17 gives the results of studies with "implicit manipulations" (as categorized by Förster, 2011 on page 379).

In each set, we find overly consistent results.

Table 15
Results of meta-analyses of pairwise comparisons in studies 5a-5d of Förster (2011)

	low vs. med		med vs high		low vs high	
	d	SE	d	SE	d	SE
Study 5a	0.811	0.384	0.737	0.381	1.691	0.435
Study 5b	0.776	0.382	0.764	0.382	1.422	0.416
Study 5c	1.115	0.398	0.632	0.377	1.444	0.417
Study 5d	1.091	0.396	0.653	0.378	1.474	0.419
MEAN	0.9424		0.6958		1.5039	
Q (DF=3)	0.6365		0.0856		0.2504	
p	0.8880		0.9935		0.9691	

Table 16

Results of meta-analyses of pairwise comparisons in studies with explicit manipulations in Förster (2011)

	low vs d	med SE	med vs d	high SE	low vs d	high SE
Study 1a	0.588	0.353	0.324	0.347	1.020	0.369
Study 2a	0.559	0.314	0.608	0.315	1.234	0.338
Study 3a	0.432	0.364	0.576	0.367	0.972	0.382
Study 4a	0.646	0.369	0.517	0.366	1.039	0.385
MEAN	0.5563		0.5096		1.0765	
Q (DF=3)	0.1844		0.4173		0.3243	
p	0.9801		0.9366		0.9554	

Table 17

Results of meta-analyses of pairwise comparisons in studies with implicit manipulations in Förster (2011)

	low vs d	med SE	med vs d	high SE	low vs d	high SE
Study 1b	0.751	0.327	0.580	0.322	1.409	0.355
Study 1c	1.024	0.340	0.680	0.327	1.684	0.374
Study 2b	0.920	0.376	0.944	0.377	1.603	0.414
Study 2c*					0.784	0.336
Study 3b	0.871	0.378	0.727	0.372	1.565	0.416
Study 4b	0.919	0.384	0.782	0.378	1.506	0.414
Study 4c*					0.894	0.383
MEAN	0.8938		0.7285		1.3162	
Q (DF=4/6)	0.3517		0.5813		5.8061	
p	0.9862		0.9651		0.4453	

Note: *Studies 2c and 4c do not feature an intermediate control group.

So in Tables 15, 16, and 17, we found p-values that lie close to one, indicating that the results in (conceptual) replications reported by Förster (2011) are overly consistent. The left-tailed p-values are based on perfect homogeneity of effects, so they would be even smaller when in actuality the underlying effects are heterogeneous.

What is remarkable about the result in Table 17 is that the effects are similar when the experiment involved a control group (cf. comparisons of low vs med and med vs. high), but not when the control group was omitted (studies 2c and 4c).

To conclude, the results presented in Förster (2011) show overly linear trends and show overly strong consistencies across conceptual replications.

Förster (2009)

This paper reports a total of 12 experiments, involving 736 undergraduates and 42 business managers. The designs of the experiments are given in Table 18.

Table 18
Designs of experiments by Förster (2009)

Study	1st factor	2nd factor
1	3 between	2 within
2	3 between	2 between
3a	3 between	2 between
3b	3 between	2 between
4	3 between	2 within
5	3 between	2 within
6	3 between	-
7a	3 between	2 between
7b	3 between	2 within
8a	2 between	2 between
8b	3 between	2 between
9	3 between	2 between

Analyses involved all but study 8a, which had only 2 factors. Given that the second factor was between-subject (implying independence of data points), studies 2, 3a, 3b, 7a, 8b, and 9 present two independent samples, giving a total of 17 samples. Descriptive statistics are given in Table 19 and trend lines in Figure 7.

Table 19
Results of the 17 independent samples with 3 levels as reported by Förster (2009)

		High/low		med		Low/high	
	N cell	M	SD	M	SD	M	SD
study 1_dis	54/3	7.33	3.22	6.72	2.74	6.17	3.54
study 2_dis	88/6	7.36	1.86	6.31	2.77	5.00	2.08
study 3a_dis	75/6	7.00	0.95	5.23	1.83	3.75	2.18
study 3b_dis	71/6	5.50	1.62	3.64	1.43	2.46	1.56
study 4_dis	55/3	2.56	2.36	1.50	1.15	0.42	0.90
study 5_loc	50/3	675	63	735	63	786	86
study 6_dis	42/3	7.10	1.14	8.00	1.62	8.93	0.83
study 7a_dis	101/6	7.35	3.14	7.00	2.80	6.24	3.56
study 7b_dis	60/3	10.05	3.25	9.15	3.01	8.00	1.95
study 8b_dis	45/6	7.13	2.20	6.73	1.87	6.27	2.02
study 9_dis	90/6	7.67	3.11	6.67	2.47	5.67	2.97
study 2_sim	88/6	5.43	1.83	6.60	3.16	7.71	3.93
study 3a_sim	75/6	3.00	1.29	4.00	1.54	5.00	0.71
study 3b_sim	71/6	4.72	1.42	6.42	1.88	8.00	2.49
study 7a_sim	101/6	4.76	2.39	6.76	2.46	8.59	2.09
study 8b_sim	45/6	5.00	2.00	7.40	2.32	8.53	1.73
study 9_sim	90/6	4.87	2.17	7.00	2.23	8.67	2.06

Note: dis: dissimilarity; sim: similarity; loc: local

Figure 7

Trend lines for experiments described by Förster (2009)

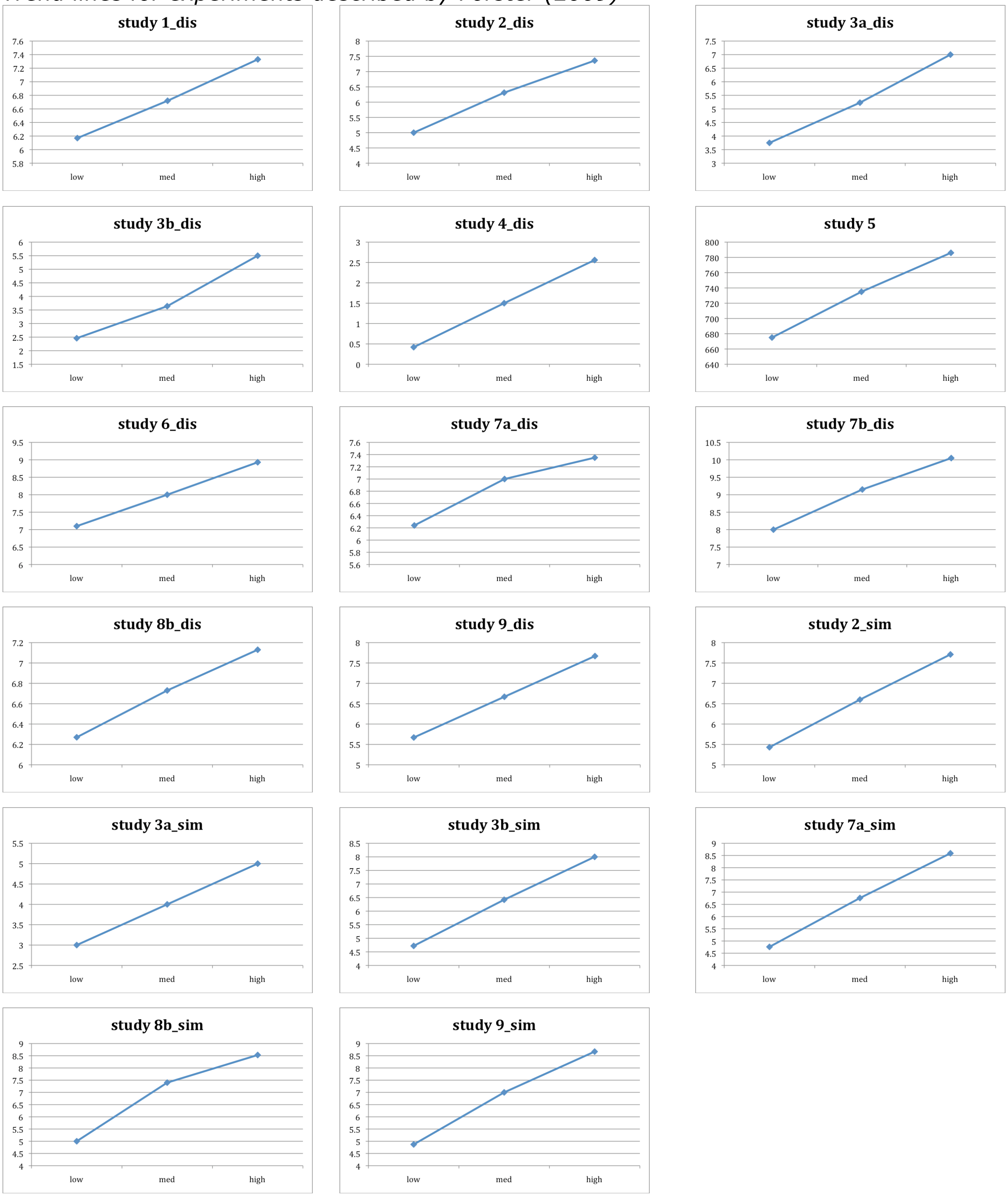


Table 20

Results of standard F test, linear regression, and test for linearity of studies in Förster (2009)

	F	p	F_{reg}	p	Eta^2	r^2	ΔF	p(ΔF)
study 1_dis	0.60	0.5538	1.22	0.0025	0.0229	0.0229	0.00107	0.97409
study 2_dis	3.98	0.0263	8.11	0.0284	0.1626	0.1619	0.03207	0.85876
study 3a_dis	11.03	0.0002	22.60	0.0920	0.3900	0.3889	0.05838	0.81053
study 3b_dis	11.74	0.0002	23.53	0.1334	0.4194	0.4126	0.38518	0.53924
study 4_dis	8.18	0.0008	16.67	0.1150	0.2392	0.2392	0.00048	0.98268
study 5_loc	10.07	0.0002	20.50	0.0000	0.2999	0.2992	0.04402	0.83472
study 6_dis	7.62	0.0016	15.64	0.2222	0.2811	0.2810	0.00137	0.97071
study 7a_dis	0.54	0.5889	1.04	0.0026	0.0220	0.0211	0.04658	0.83006
study 7b_dis	2.70	0.0755	5.47	0.0070	0.0867	0.0862	0.02668	0.87083
study 8b_dis	0.34	0.7191	0.70	0.0554	0.0333	0.0332	0.00109	0.97404
study 9_dis	1.83	0.1730	3.75	0.0065	0.0801	0.0801	0.00000	1.00000
study 2_sim	1.99	0.1500	4.07	0.0035	0.0884	0.0884	0.00092	0.97598
study 3a_sim	8.26	0.0012	17.00	0.2268	0.3238	0.3238	0.00000	1.00000
study 3b_sim	8.13	0.0014	16.75	0.0562	0.3334	0.3333	0.00725	0.93267
study 7a_sim	11.49	0.0001	23.44	0.0247	0.3260	0.3258	0.01508	0.90279
study 8b_sim	5.91	0.0101	11.62	0.0558	0.3773	0.3617	0.48875	0.49296
study 9_sim	11.72	0.0001	23.82	0.0368	0.3582	0.3565	0.11396	0.73736

Differences between Eta^2 and r^2 are again very small except in samples study 3b_dis and study_8b_sim. In the preponderance of samples the p-values associated with the ΔF test are >.90.

Fisher's test gives χ^2 (DF = 34) = 5.5864, p = 0.999999992, or 1 out of 128 million. Any actual deviation from linearity would lower the left-tailed probabilities and hence lower the overall probability.

Four experiments that are featured in Table 19 involved a secondary dependent variable (because the secondary factor was within-subjects). We re-analyzed these data and found similar results (Figure 8 and Tables 21 and 22).

Table 21

Results of secondary dependent variable in 4 experiments by Förster (2009)

		High/low		med		Low/high	
	N cell	M	SD	M	SD	M	SD
study 1_sim	54/3	4.67	2.35	6.56	2.53	8.67	2.25
study 4_sim	55/3	0.83	1.29	1.17	1.04	1.79	1.44
Study 5_glob	50/3	759	138	689	91	594	88
Study 7b_sim	60/3	8.20	2.84	9.90	2.63	11.00	2.37

Note: dis: dissimilarity; sim: similarity; glob: global

Figure 8

Trend lines of secondary dependent variable in 4 experiments by Förster (2009)

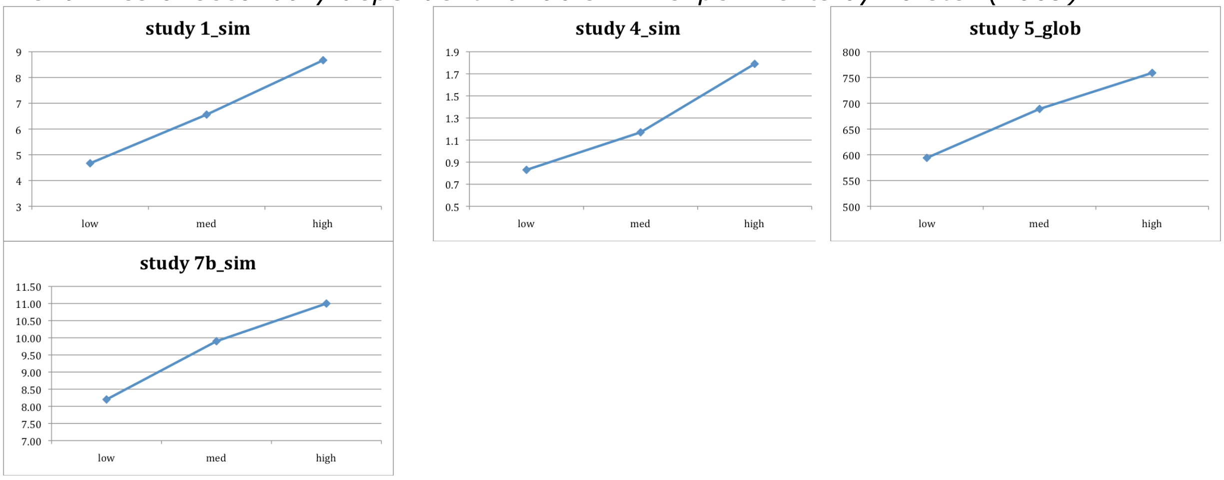


Table 22

Results of standard F test, linear regression, and test for linearity of studies with a secondary dependent variable in Förster (2009)

	F	p	F_{reg}	p	Eta^2	r^2	ΔF	p(ΔF)
study 1_sim	12.73	0.0000	25.92	0.0210	0.3330	0.3326	0.02564	0.87340
study 4_sim	2.70	0.0763	5.34	0.2105	0.0942	0.0916	0.14912	0.70095
study 5_glob	9.78	0.0003	19.76	0.0000	0.2938	0.2916	0.14852	0.70170
study 7b_sim	5.80	0.0051	11.58	0.0112	0.1690	0.1665	0.17476	0.67748

Again, the similarity of overly linear results across two dependent variables is striking.

Other issues related to Förster (2009)

(1) All participants were probed for suspicion concerning the goal of the studies. None of the 736 undergraduates and 42 business managers raised the possibility that the different study phases were related. This is quite unexpected in such a large sample containing undergraduates who are often trained in psychological research methods and are experienced as participants.

(2) The paper does not report any dropout or missing data among any of the 778 participants. This is atypical of psychological experiments.

Discussion

Across 42 independent samples with three factorial levels that were reported in the three papers by Dr. Förster, the smallest p-value associated with the ΔF test for linearity was .493, while the vast majority of p-values was larger than .80. Such results deviate strongly from theoretical (uniform) distributions under the null hypothesis and distributions in similar studies by others (Figure 9). Fisher's test gives χ^2 (DF = 24) = 2.377369693, p =0.999999994 (1 out of 179 million) for Förster & Denzler (2012), χ^2 (DF = 26) = 4.2676, p = 0.9999996 (1 out of 128 million) for Förster (2011), and χ^2 (DF = 34) = 5.5864, p = 0.999999992 (1 out of 2.35 million) for Förster (2009). The left-tailed probabilities of finding such linear results (or more linear results) are p=0.0000000056, 0.0000000078, and 0.00000043 for the three papers, respectively. The combined left-tailed p-value of the entire set is p= 1.96 * 10^{-21}, which corresponds to finding such consistent results (or more consistent results) in one out of 508 trillion (508,000,000,000,000,000,000). The simulations in the appendix show that these results cannot be attributed to the use of ordinal data or rounding of descriptive statistics. Our result suggests a level of linearity that is extremely unlikely to have arisen from standard sampling under the null hypothesis of linearity. Any actual deviation from perfect linearity would even lower these probabilities. We are not familiar with any theoretical or methodological reason why the three means would follow perfect linearity to begin with.

Figure 9a
P-values of 21 ΔF tests for linearity in the 10 control papers

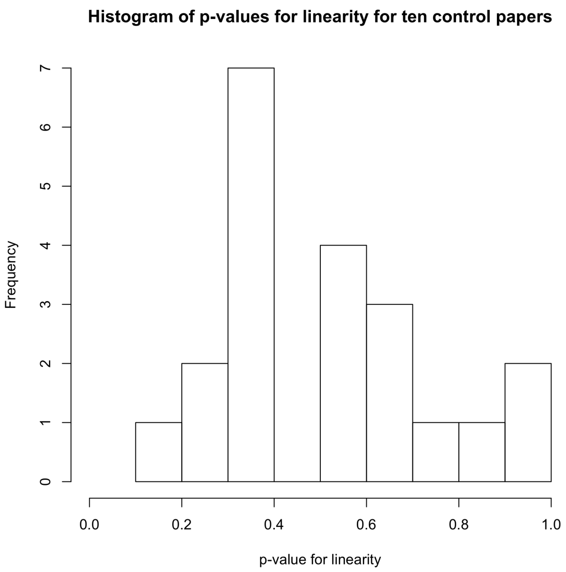
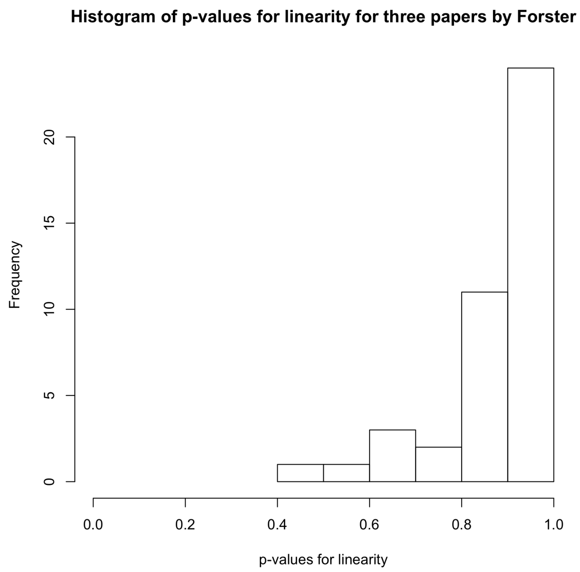


Figure 9b
P-values of 42 ΔF tests for linearity in the 3 papers by dr. Förster



Given the exceptionally large number of studies and undergraduates who participated in these studies (2242; while the UvA has only around 500 psychology freshmen per cohort), publication bias (i.e., the notion that Dr. Förster published only the most linear findings from a larger set of studies) is an unlikely explanation for the current results. We also note that the cost of data collection (materials, personnel cost, and financial rewards for participants) must have been substantial. Dr. Förster employs identical or highly similar outcome measures across different studies. We consider it unlikely that he selected in each study the most linear outcome measure from a subset of outcome measures. In fact, seven of the studies from Förster & Denzler (2012), four studies from Förster (2011), and four studies from Förster (2009) entailed two dependent variables, both of which showed the exact same overly strong level of linearity. In one sample, all three outcome measures showed the same unexpectedly high level of linearity.

None of the 2242 participating undergraduates raised any suspicions concerning the goal of the studies or the deceit used in the experiments. Given their education in (psychological) research methods and their expected seasonality as research participants, we consider this an extremely unlikely outcome. Also, there is no mention of dropout or missing data in any of the studies (except for a few participants who were allergic to particular foods and hence did not participate), which is not characteristic for psychological experiments of durations of 1 to 2 hours. Although the origin of the undergraduates is not explicated, it is likely that they were (predominantly) from the University of Amsterdam, at least for the 2011 and 2012 papers. The sex distribution in the 2011 and 2012 papers deviates from the sex distribution of psychology freshmen at the University of Amsterdam in the years since Dr. Förster arrived there. All participants were debriefed after each experiment, so it is implausible that undergraduates returned for later experiments by Dr. Förster without any of them expressing awareness of the research hypothesis of (or the deceit used in) the later experiment. So the number of undergraduates participating in the 40 experiments cannot be attributed to the reuse of undergraduates from the same pool of participants. This raises further questions about the origin of the data.

Our meta-analyses showed overly consistent findings across widely different replications in Förster & Denzler (2012) and Förster (2011). So not only are these results too linear, they are also overly similar across conceptual replications. Moreover, effect sizes reported by Dr. Förster (median Eta^2 for the 2009, 2011, and 2012 papers were .281, .308, and .252, respectively) are quite large in comparison to those found in creativity research (mean r is .18; Baas et al., 2008, Psychological Bulletin) and in the 10 control papers (median $Eta^2 = .066$; see Figure 10).

These large effects occurred despite supposedly feeble manipulations. For instance, Studies 6-10b in Förster & Denzler (2012) involved manipulations of global vs. local processing on the basis of smelling different scents (Studies 10a-10b), tasting different flavors of cereal (Studies 9a-9b), hearing different poems (Study 7), touching differently shaped objects (Study 8), or viewing different types of letters (Study 6). As can be seen in Table 8, these inductions invariably influenced analytic test performance by approximately d = 1.5, which amounts to 22.5 IQ points. Such consistently large effects are unprecedented in cognitive ability research. That these manipulations affect creativity in the opposite direction to the same degree (cf. Table 9) renders Förster & Denzler's (2012) results even more remarkable.[3]

Figure 10a. Effect sizes (Eta^2) for 21 independent samples in the 10 control papers.

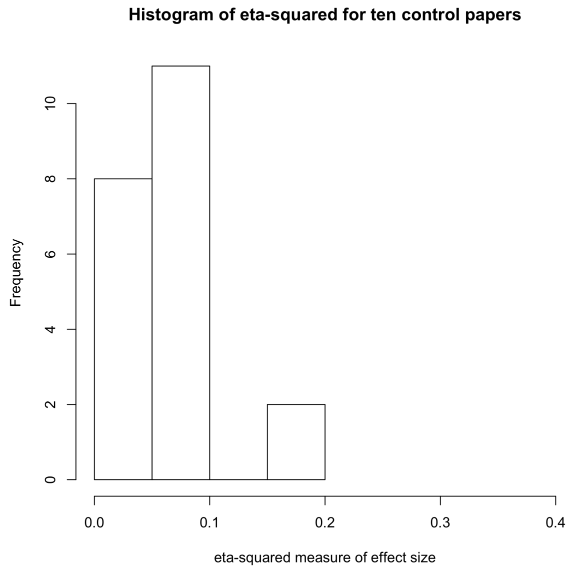
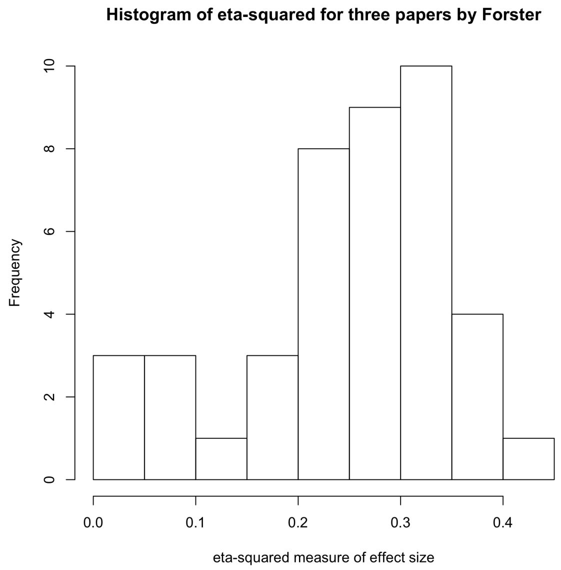


Figure 10a. Effect sizes (Eta^2) for 42 independent samples in the 3 papers by Dr. Förster.



Thus, the results reported in the three papers by Dr. Förster deviate strongly from what is to be expected from randomness in actual psychological data. The effect sizes are overly consistent in two of the papers. Dr. Förster reports quite large effects compared to results presented by other researchers who conduct similar research. The total number of undergraduates participating in the studies reported in the three papers is rather large given the size of the available pool of psychology

[3] The size of effects reported by Förster & Denzler (2012) led us to scrutinize Dr. Förster's results.

undergraduates at the University of Amsterdam (around 500 per year) and the sex distribution in Dr. Förster's samples deviates from the sex distribution among psychology students at the University of Amsterdam. It is unusual that none of the participating students raised any suspicions about the experimental design and hypothesis. The lack of dropout or missing data is atypical for psychological experiments of this type.

The extraordinary nature of results presented by Dr. Förster in these three papers raise the possibility of improper conduct and warrant an investigation of the source and nature of the data he presented in these and other papers.

Appendix A

Simulations to assess robustness against rounding and non-normality

We ran several simulations to determine the robustness of the approach to deviations of normality of the underlying raw data and rounding of the descriptive statistics. In the first simulation, we simulated random normal data without rounding and the following distributions: Low ~ N(90,15); Medium ~ N(100,15); High ~ N(110,15), with cell sizes n = 20. All simulations are based on 100,000 runs. The distribution of the p-values of ΔF are given in Figure A1a and show the expected uniform distribution both when the ΔF was based on the raw data (Figure A1a; no rounding of descriptive statistics) and when ΔF was based on descriptive statistics rounded to two decimals (Figure A1b).

Figure A1a. Distribution of p-values of ΔF under the null hypothesis, normal raw data and no rounding of descriptive statistics.

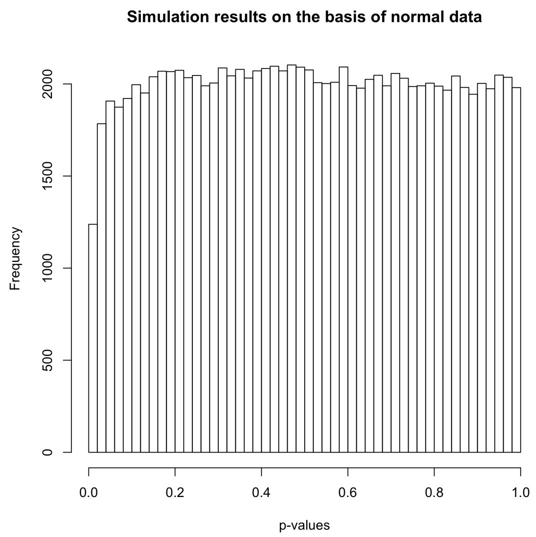
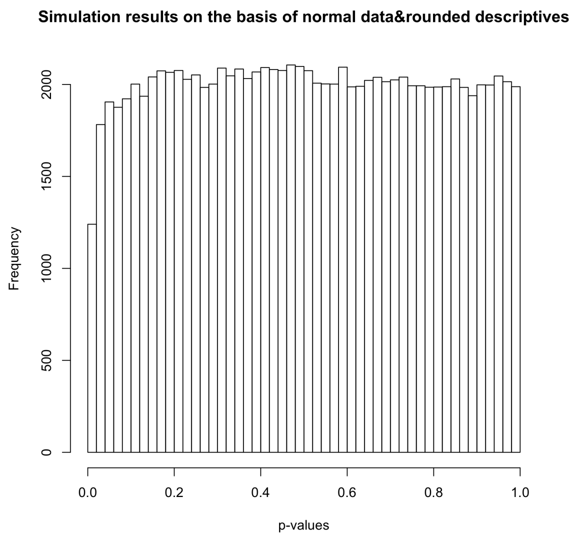


Figure A1b. Distribution of p-values of ΔF under the null hypothesis, normal data and rounding of descriptive statistics (2 decimals).



Next, we simulated random normal data (again with n = 20 in each cell) with Low ~ N(1,1); Medium ~ N(1.75,1); High ~ N(2.5,1) and subsequently rounded the raw data to integers and bounded the scores to the interval [0,4]. This aligns with results from the analytic performance measure in studies 6-10b of Förster & Denzler (2012) and represents the most severe rounding of raw data in all studies described below. Figure 4 gives the distribution of the p-values of ΔF under this set-up on the basis of raw data (Figure A2a) and on the basis of descriptive statistics that were rounded to two decimals (Figure A2b).

Figure A2a. Distribution of p-values of ΔF under the null hypothesis, ordinal raw data and no rounding of descriptive statistics.

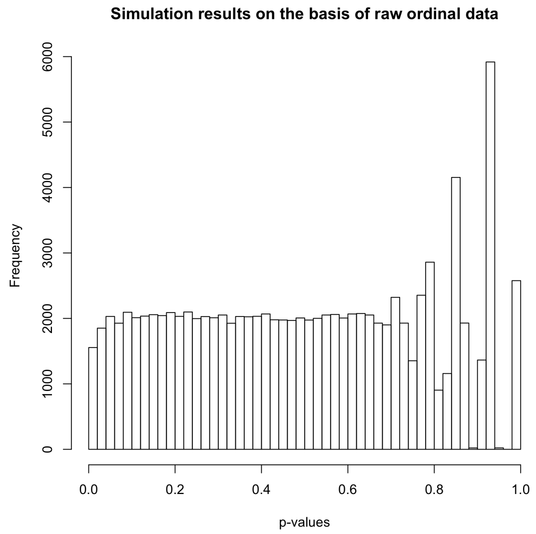
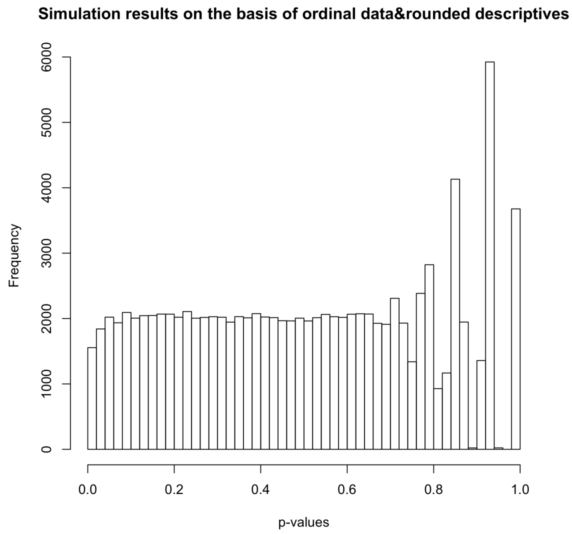


Figure A2b. Distribution of p-values of ΔF under the null hypothesis, ordinal data and rounding of descriptive statistics (2 decimals).



Results on the basis of raw data (Figure A2a) are nearly identical to results based on rounded descriptive statistics (Figure A2b). The effect of ordinal data is evident from stepwise fluctuations in the upper ranges of the p-value distribution. However, the mean and median of p-values associated with ΔF continue to be close to the true value of .5 (M=0.5016 and Med=.5009 for values in Figure 4b) and so the p-values are no longer exact but provide reasonable approximations. For the six studies that feature this severe level of rounding of raw data, we also computed p-values on the basis of the current simulation set-up (see main text) and found no systematic bias.

A final set of simulations is based on the rounding of the descriptive statistics in Studies 1-4 of Förster (2011). In line with empirical means and SDs in these studies, we simulated random normal data according to the following distributions: Low ~ N(22,12); Medium ~ N(30,12); High ~ N(38,12) and rounded the values to integers in the interval [0,48]. Subsequently, we rounded the descriptive statistics to integers as well. Results are given in Figure A3.

Figure A3a. Distribution of p-values of ΔF under the null hypothesis, ordinal raw data and no rounding of descriptive statistics.

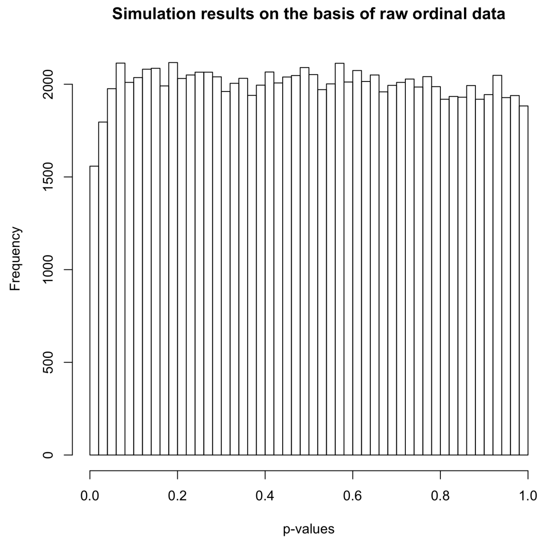


Figure A3b. Distribution of p-values of ΔF under the null hypothesis, ordinal data and rounding of descriptive statistics (integers).

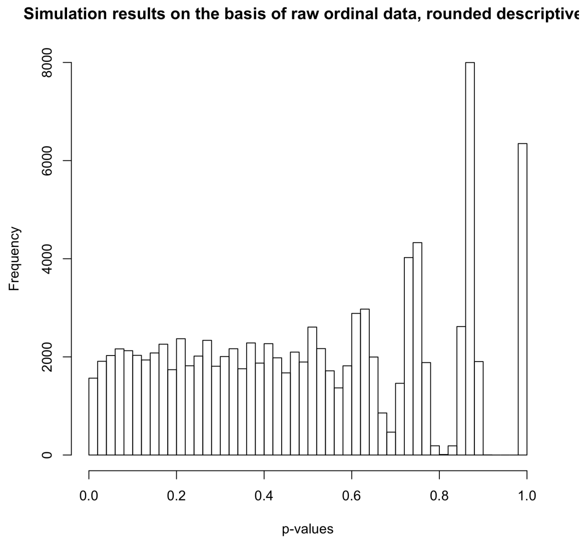


Figure A3a is nearly identical to Figure A1a, as is to be expected. The rounding of the descriptive statistics (Figure A3b) again leads to stepwise-distributions of the p-values associated with smaller ΔFs. Albeit no longer exact, the p-values in this set up continue to show a mean and median close to the theoretical values (M=0.4990, Med=.4963). For studies 1-4 in Förster (2011) we computed p-values on the basis of this simulation and found no systematic bias that is of concern.

To conclude, the ΔF test appears to function well with the sample sizes typical for the studies described below. Like other F-tests, ΔF is relatively robust to deviations from normality due to rounding of the raw data. With more severe rounding of raw data and descriptive statistics, p-values continue to show means of .5, but some stepwise effects in the upper ranges of the distribution. However, even in these extreme scenarios, p-values associated with ΔF show no systematic bias that is of concern.

Appendix B

DOIs for the control papers

Table B1

DOIs for the 10 control papers

sample	DOI
Hagtvedt_1	10.1177/0146167211415631
Hagtvedt_2	10.1177/0146167211415631
Hunt	10.1002/acp.1352
Jia	10.1016/j.jesp.2009.05.015
Kanten_1	10.1016/j.jesp.2011.04.005
Kanten_2	10.1016/j.jesp.2011.04.005
Lerouge_1	10.1086/599047
Lerouge_2	10.1086/599047
Lerouge_3	10.1086/599047
Lerouge_4	10.1086/599047
Malkoc	10.1016/j.obhdp.2010.07.003
Polman*	10.1177/0146167211398362
Rook_1	10.1080/10400419.2011.621844
Rook_2	10.1080/10400419.2011.621844
Smith_1	10.1037/0022-3514.90.4.578
Smith_2	10.1037/0022-3514.90.4.578
Smith_3	10.1037/0022-3514.90.4.578
Smith_4	10.1037/0022-3514.90.4.578
Smith_5	10.1037/0022-3514.90.4.578
Smith_6	10.1037/0022-3514.90.4.578
Smith_7**	10.1016/j.jesp.2006.12.005

**Smith_7 is from a separate paper than Smith_1 to Smith_6.

Appendix C

R script used for simulation of Figure A3a

```
nsim=100000
nC=20          #cell size
sd1=sd2=sd3=12
m1=38
m2=30
m3=22
scmax=48 #maximum score on measure
descr<-matrix(,nsim,6)
Ftests<-matrix(,nsim,4)
score1=score2=score3=rep(NA,nC)
for(i in 1:nsim)
{
        theta1=rnorm(nC,m1,sd1)
        theta2=rnorm(nC,m2,sd2)
        theta3=rnorm(nC,m3,sd3)
        for(j in 1:nC)
                {
                score1[j]=round(theta1[j])
                score2[j]=round(theta2[j])
                score3[j]=round(theta3[j])
                if(score1[j]<0){score1[j]<-c(0)}
                if(score2[j]<0){score2[j]<-c(0)}
                if(score3[j]<0){score3[j]<-c(0)}
                if(score1[j]> scmax){score1[j]<-c(scmax)}
                if(score2[j]> scmax){score2[j]<-c(scmax)}
                if(score3[j]> scmax){score3[j]<-c(scmax)}
                }
        df<-
data.frame(dum1=c(rep(1,20),rep(0,40)),dum2=c(rep(0,20),rep(1,20),rep(0,20)),regr=c(rep(-
1,20),rep(0,20),rep(1,20)), val=c(score1,score2,score3))
 lm(val ~ dum1 + dum2, data=df)->Fc
 lm(val ~ regr, data=df)->Fr
anova(Fr,Fc, test="F")->Fdif
Fdif[2,5]->Ftests[i,1]
1-pf(Fdif[2,5],1,(nC-3))->Ftests[i,2]
        descr[i,1]<-mean(score1)
        descr[i,3]<-mean(score2)
        descr[i,5]<-mean(score3)
        descr[i,2]<-sd(score1)
        descr[i,4]<-sd(score2)
        descr[i,6]<-sd(score3)
        m1r<-round(mean(score1),0)
        m2r<-round(mean(score2),0)
        m3r<-round(mean(score3),0)
        sd1r<-round(sd(score1),0)
        sd2r<-round(sd(score2),0)
        sd3r<-round(sd(score3),0)
        grandm<-mean(cbind(m1r,m2r,m3r))
        MSb<-((m1r-grandm)^2 + (m2r-grandm)^2 + (m3r-grandm)^2)*nC/2
        MSw<-(sd1r^2+sd2r^2+sd3r^2)/3
        Fccomp<-MSb/MSw
        SStot<-MSb*2 + MSw*(nC-3)
        SSreg<-((nC*m3r -nC*m1r)^2)/(nC*2)
        Fregco<-SSreg/((SStot-SSreg)/(nC-2))
        Fdifco<-(MSb*2-SSreg)/MSw
        Ftests[i,3]<-Fdifco
        Ftests[i,4]<-1-pf(Fdifco,1,(nC-3))
        }

hist(Ftests[,2],xlab="p-values", main="Simulation results on the basis of raw ordinal data",nclass=40)
```