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Lack of Publication Bias in Intelligence and Working Memory Research: Reanalysis of Ackerman, Beier, & Boyle, 2005

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A meta-analysis was carried out to demonstrate the existence of publication bias in research on the relationship between measures of fluid intelligence and working memory. Reanalysis of data collected in Ackerman, Beier, & Boyle, 2005 was conducted. A heterogeneous distribution of correlation coefficients in the absence of asymmetry in the distribution of coefficients was observed. According to the author of the analysis, there are no arguments for the presence of publication bias in this particular set of results drawn from research on intelligence and working memory.

Key words: fluid intelligence, working memory, meta-analysis, publication bias

Introduction

Measures of fluid intelligence moderately correlate with wide repertoire of intellectual abilities. This well-known phenomenon is called *positive manifold* (Spearman, 1904). However, the relationship between measures of working memory and fluid intelligence is mostly known in the realm of cognitive psychology. Estimates of common variance of working memory capacity and fluid intelligence measures range from 50% (Kane, Hambrick, & Conway, 2005) to 92% (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004). As a result, working memory is asserted by some researchers as a base of fluid intelligence (Jensen, 1998; Colom, Flores-Mendoza, & Rebollo, 2003; Engle, 2002). These strong correlations affect the imagination of the researchers, who may think that working memory and fluid intelligence are highly related or even identical. Working memory capacity also strongly correlates with the following intellectual abilities considered to be components of intelligence: comprehension (Daneman & Carpenter, 1980), reasoning ability (Kyllonen & Christal, 1990), and test results, which reflect intellectual capacity – the SAT (e.g., Turner & Engle, 1989). It should be noted that there are no other candidates, besides working memory, so closely related to fluid intelligence (Kyllonen, 2002). Due to these facts, researchers might not be interested in reporting moderate correlation coefficients – since this resembles the positive manifold – and publish mostly results depicting strong correlations between working memory capacity and fluid intelligence measures.

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The hypothesis that fluid intelligence and working memory are identical has no theoretical justification. Even the ideal correlation (R = 1) between two measures does not mean that the same mechanism is responsible for the variability of both measures. A good example of such a strong atheoretical correlation, from a slightly different field of science, is the relationship between chocolate consumption and the number of Nobel laureates in different populations (Messerli, 2012). The Pearson correlation coefficient in this case is equal to 0.79. It is unreasonable to interpret this relationship as causal, although there are studies showing a positive effect of the consumption of flavonoids contained in chocolate on cognitive functioning (see Nurk, Refsum, Drevon, Tell, Nygaard, Engedal, & Smith, 2002; Desideri, Kwik-Uribe, & Grassi, 2012; Corti, Flammer, Hollenberg, & Lüscher, 2009; Sorond, Lipsitz, Hollenberg, & Fisher, 2008; Bisson, Nejdi, Rozan, Hidalgo, Lalonde, & Messaoudi, 2008). The correlation is strong, but we do not have a theoretical model, which explains the linkage number of Nobel laureates to chocolate consumption. It can be presumed that this strong correlation is an effect of another variable, e.g. a socio-economic status. In countries characterized by wealth (people with high socio-economic status) there is a greater chance to conduct scientific research as well as to consume chocolate. Thus, even very high values of correlation coefficients between working memory capacity and fluid intelligence measures are not proof that we are dealing with the same phenomenon.

Leaving aside the issues of the mechanisms that are responsible for the observed strong correlations of working memory and fluid intelligence, let us consider this: Is there a phenomenon that can systematically overstate the value of correlation coefficients? The author suspects that correlation coefficients reported in the research on fluid intelligence and working memory are inflated due to these facts: researchers are interested in reporting strong relationships, since low correlations are explained as positive manifold. A higher value of correlation coefficient suggests that the factor is more important in the context of intelligence. Open Science Collaboration (2015) reported that replications usually end with the effects strength lower by half on average, compared to the original studies.

Publication Bias

Publication bias is the effect of the policy of scientific journals. Unfortunately, a large part of scientific publications is focused on publishing innovative results or simply those in which some effect has been demonstrated. In practice, this means that it is far easier to publish the results of a research, in which the null hypothesis has been rejected, than those in which null effect is presented. Research in which the null hypothesis has not been rejected is sometimes considered inconclusive, because it is not entirely clear whether the lack of effect is the result of a mistake in the research procedure, or there is, indeed, no relationship between the measured variables.

Since it is more likely to publish results in which the null hypothesis was rejected, researchers are more likely to prepare manuscripts of articles from research in which the null hypothesis was rejected. We deal with the so-called *file drawer effect* (Rosenthal, 1979); results in which the null hypothesis could not be rejected, more often go to the researcher's desk drawer and no one but the researcher himself, knows that such a study was carried out. One can imagine that in an extreme situation, some research is carried out repeatedly, and only the results in which the null hypothesis is rejected are published. If we use the conventional statistical test significance level ($\alpha = .05$), then with 20 replications of a particular test procedure, we will obtain 1 result indicating the presence of an effect that does not actually exist (the so-called first type error). Therefore, it should be expected that in the literature we will face over-representation of the research, in which the null hypothesis was rejected, despite the lack of a given effect in reality.

The impact of publication bias is difficult to estimate. In order to estimate publication bias in psychology, a reproducibility project has been set up and conducted by Open Science Collaboration. The aim of the project is to replicate 100 studies published in the magazines of prestigious psychological journals, Psychological Science, Journal of Personality and Social Psychology, and Journal of Experimental Psychology: Learning, Memory, and Cognition. The first results of the project show that from the set of articles, which contains 97% of results with the null hypothesis rejected, only 36% of replications reproduced null rejections. Moreover, the strength of replication effects observed in replication is on average lower by half, compared to the original studies (Open Science Collaboration, 2015).

Gilbert, Pettigrew, and Wilson (2016) are critical in their approach to the results obtained by Open Science Collaboration. They argue that the conclusion drawn from the results of the reproducibility project actually supports the opposite conclusion. First of all, they accuse Open Science Collaboration of making a crucial mistake in the way research is selected for replication. The application of the criterion of replicating results from specific journals leads to obtaining an idiosyncratic data set, which is not representative of the typical results in psychology. Secondly, they claim that obtaining results for which only some of the effects are reproducible should not be surprising, since replications are carried out on samples that do not match the same population. In addition, using the wrong statistical procedure is lowering the power of the effects, states Gilbert and his collaborators.

The power of publication bias can be observed in the example of research for which all replications have been registered. Turner, Matthews, Linardatos, Tell, and Rosenthal (2008) have analyzed the collection of studies on the effectiveness of antidepressants registered by the US Food and Drug Administration. The Food and Drug Administration data show that 74 experimental studies were carried out. In 38, the null hypothesis was rejected, while 36 failed to reject the null hypothesis. Then, the researchers checked what part of these results was published in scientific journals. It turned out that 37/38 studies in which the effectiveness of antidepressants was shown and only 3 out of 36 in which no effect was demonstrated. This gross disproportion illustrates the strong publication bias: 97% of results were published in which the null hypothesis was rejected and only 8% of those in which the null hypothesis was not rejected.

A publication bias is a significant threat in the case of a meta-analysis, because it is possible that the meta-analysis is based on results in which there are no negative results (the null hypothesis could not be rejected). Thus, a false image of reality is obtained, despite the large number of research attempts. The way to determine if we are dealing with publication bias is to compare the distributions of estimators obtained in studies with their expected theoretical distributions. For this purpose, we use funnel plots, in which the effect size (on the horizontal axis) and the sample size or error of measurement are plotted. In the absence of publication bias, one should expect a set of points arranged in a symmetrical inverted funnel on the graph. An asymmetrical shape of the chart – the advantage of results in which high power was obtained in comparison with those of low power, is the premise for the belief that we are dealing with publication bias (Sterne, Sutton, Ioannidis, Terrin, Jones, & Lau, 2011).

The Strength of the Gf - WMC Correlation

The meta-analysis by Ackerman, Beier, and Boyle (2005) shows the relationship between the working memory capacity and fluid intelligence measures at 25%. Oberauer, Schulze, Wilhelm, and Süß (2005) critically commented on Ackerman, Beier, and Boyle (2005), stressing the use of unappropriated fixed effect model in the metanalysis and unjustified selection of working memory tasks. Oberauer et al. (2005) decided that a re-analysis is necessary and undertook it within the appropriate statistical model. The relationship between fluid intelligence and working memory measures proved to be much stronger, accounting for 72% of the common variation. The authors of both previous meta-analysis did not analyze the results in terms of publication bias.

It should be noted that measures of the strength of the relationship between fluid intelligence and working memory are characterized by a wide confidence interval (average interval = 0.17 based on data from the meta-analysis by Ackerman, Beier, and Boyle 2005). Considering the existence of publication bias in other areas of science, one should assume that research on fluid intelligence and working memory relationship is not free from this phenomenon. It can be assumed that inflated correlations coefficients are especially probable in the field of working memory and fluid intelligence research. Since fluid intelligence correlates moderately with wide repertoire of cognitive abilities, several influential papers claimed that working memory and fluid intelligence are identical or that working memory capacity is not isomorphic with fluid intelligence but that it is a very strong predictor of fluid intelligence.

Method

Reanalysis was conducted on Ackerman, Beier and Boyle (2005). All the analyses were conducted in R with package "metafor" (Viechtbauer, 2010). These data contain correlation coefficients taken from 57 publications (including 4 doctoral dissertations). The meta-analysis is based on 86 independent research trials, in which 9778 people took part. The data from 40 trials were classified in this analysis (all the coefficients were statistically significant). A theoretical criterion was used – the author used data, which represents the correlation between measures of intelligence and working memory capacity measures.

The purpose of this analysis is to examine the distribution of correlation coefficients between working memory measures and the test results used to measure fluid intelligence. The model was introduced with uncorrected correlation coefficients of fluid intelligence measures (Raven's test, *g*, reasoning measures: spatial, numerical and verbal), working memory capacity measures (verbal, numerical and spatial), number of individual samples, and standard error of estimation of the correlation coefficient.

Results

The analysis was conducted using a random effect model. Heterogeneity of estimators was observed $I^2 = 85.5\%$, $Q(39) = 387.2$, $p < 0.0001$ ($AIC = -70.61$, $BIC = -67.29$).

Figure 1 illustrates correlation coefficients in 40 samples subject to meta-analysis.

Pearson correlation coefficients between working memory capacity and *Gf* measures is on average equal to .35, $CI_{95}\%$ [.32, .38]; $se = .015$, $z = 23.2$, $p < .0001$.

Figure 2 presents the relationship between the value of the correlation coefficient (horizontal axis) and the standard error of the measurement in a given sample (vertical axis). Correlation coefficients are distributed symmetrically around the value of .35. The hypothesis of a zero asymmetry test in the funnel chart ($t = -1.77$, $df = 38$, $p = .085$) could not be rejected.

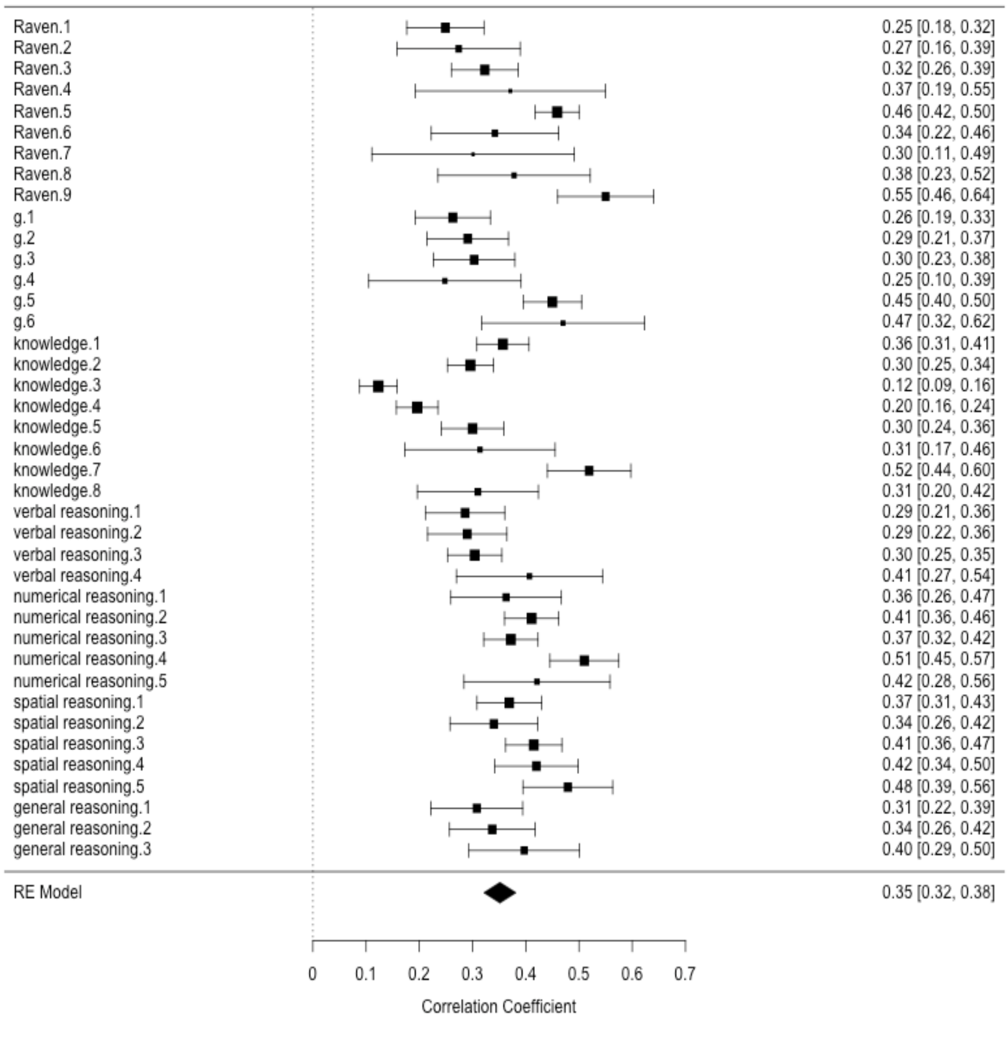

Figure 1 Forest plot: correlation coefficients and standard errors in 40 analyzed trials (Effect Size and 95% confidence interval).

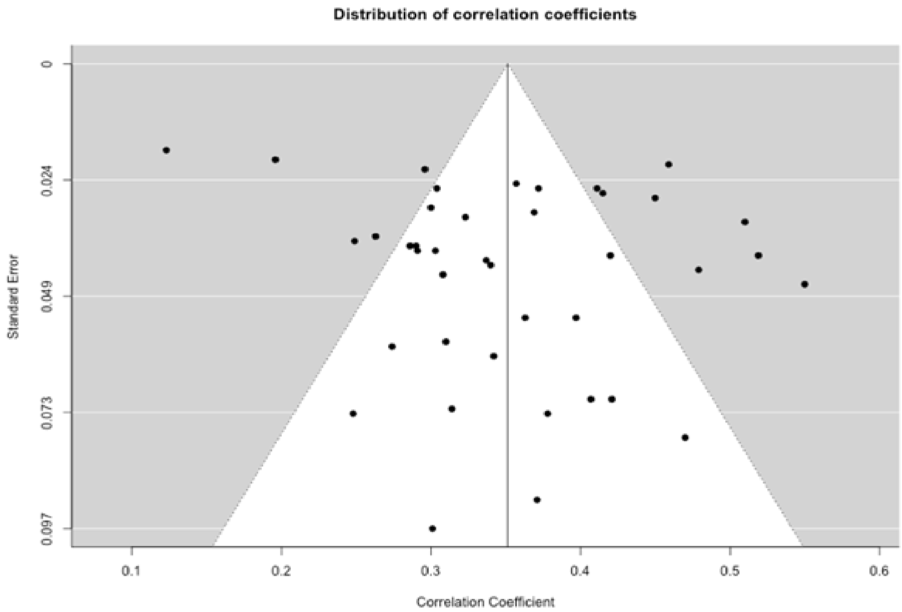

Figure 2 Funnel plot: symmetrical distribution of correlation coefficients.

Discussion

Publication bias is a serious threat to science, since it creates a false image of the observed phenomenon. Presence of publication bias in psychology is indicated by the results of replication studies (Open Science Collaboration, 2015). In these studies, less than 40% of the significant results were found with half the magnitude of the original effects. The main purpose of this analysis is to answer the question whether the results published in an influential paper, which has over 1000 citations (Ackerman, Beier, & Boyle, 2005), were free of publication bias. The author expected to see an asymmetric distribution of results on the funnel chart, which would indicate the effect of publication bias. The hypothesis has not been confirmed in the results of the statistical analysis.

Although this meta-analysis did not bring forth a concern about the results of the original paper, we must be careful not to draw farfetched conclusions, considering the limitations of this study. This result does not prove that other meta-analyses of the relationship between fluid intelligence and working memory are free from publication bias. In this case, a specific set of observations was subjected to an analysis, therefore, we cannot generalize the conclusions to the whole realm of *Gf* and working memory relations. In order to determine the presence of publication bias in this field of research, a wide range of results published to date should be analyzed. Nevertheless, the results of this meta-analysis indicate clearly that the results of Ackerman, Beier, and Boyle (2005) are not influenced by publication bias.

The observed heterogeneity of the results (Figure 2) does not undermine the conclusions about the relationship between working memory and fluid intelligence. The heterogeneity is the result of introducing to the analysis tests that are not identical. Narrowing the set only to coefficients of one type would limit heterogeneity. However, the division into groups would contribute to obtaining funnel charts, where visible asymmetry is the result of division into groups, and not the actual impact of publication bias. Therefore, a decision was made to uphold the analysis of a heterogeneous set of results.

A symmetric distribution of correlation coefficients was observed in the funnel chart (Figure 2). The lack of a clear asymmetry suggests that an absence of publication bias in the meta-analysis of Ackerman, Beier, and Boyle (2005). A more detailed inspection of the funnel plots leads to the conclusion that low precision (high standard error value) and a high Pearson correlation coefficient were published less frequently. This is not surprising. Lack of precision of working memory capacity and fluid intelligence measures leads to underestimating the empirical Pearson correlation coefficient. We can suspect that researchers do not publish results in which the Pearson correlation coefficient exceeds standardized reliability measures for working memory capacity and fluid intelligence.

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