High intelligence prevents the negative impact of anxiety on working memory

Adam Chuderski

Institute of Philosophy, Jagiellonian University, Krakow, Poland

Published online: 15 Oct 2014.

To cite this article: Adam Chuderski (2014): High intelligence prevents the negative impact of anxiety on working memory, Cognition and Emotion, DOI: 10.1080/02699931.2014.969683

To link to this article: http://dx.doi.org/10.1080/02699931.2014.969683

Taylor & Francis makes every effort to ensure the accuracy of all the information (the “Content”) contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at http://www.tandfonline.com/page/terms-and-conditions
High intelligence prevents the negative impact of anxiety on working memory

Adam Chuderski

Institute of Philosophy, Jagiellonian University, Krakow, Poland

Using a large sample and the confirmatory factor analysis, the study investigated the relationships between anxiety, working memory (WM) and (fluid) intelligence. The study showed that the negative impact of anxiety on WM functioning diminishes with increasing intelligence, and that anxiety can significantly affect WM only in people below average intelligence. This effect could not be fully explained by the sheer differences in WM capacity (WMC), suggesting the importance of higher-level cognition in coping with anxiety. Although intelligence moderated the impact of anxiety on WM, it was only weakly related to anxiety. In contrast to previous studies, anxiety explained the substantial amount of WMC variance (17.8%) in less intelligent participants, but none of the variance in more intelligent ones. These results can be explained in terms of either increased motivation of intelligent but anxious people to cope with a WM task, or their ability to compensate decrements in WM.

Keywords: Anxiety; Intelligence; Working memory; Confirmatory factor analysis.

Anxiety is defined as the emotion in which feelings of tension, worried thoughts and avoidance tendencies are observed. It is known to negatively affect a large range of mental processes (Eysenck & Derakshan, 2011; MacLeod & Donellan, 1993). One such process is working memory (WM)—the cognitive mechanism responsible for active maintenance and goal-directed manipulation of information (Cowan, 2001), whose capacity (WMC) is measured with a number of items recalled, or the accuracy of respective mental transformations. The disruptive effect of anxiety on WM functioning has considerable consequences for higher-level cognition, as WM substantially underlies such processes as language comprehension, reasoning, planning and problem solving (for a review see Wiley & Jarosz, 2012), which are crucial for the success in academic, professional and daily life (Deary, 2012).

A number of studies have demonstrated that when high anxiety groups are compared to low
anxiety groups, WM functioning and/or high-level cognition are decreased in the former. For example, Ashcraft and Kirk (2001) found lower WM scores in high math anxiety participants than in low anxiety people. Most likely, because of this fact the high anxiety participants also did worse on math problems. Leon and Revelle (1985) demonstrated that high anxiety participants perform worse on geometric analogy problems. A similar effect was shown in case of verbal analogies (Klein & Barnes, 1994). Also, more anxious participants had more problems with valid decision making (Nichols-Hoppe & Beach, 1990).

It could be supposed that, indeed, it is anxiety that disrupts operation of WM, however, it is also possible that ineffective WM does make people more anxious (e.g., because they often fail to cope with a task and/or perceive it as more difficult). Although the latter case cannot be definitely overruled, several experiments directly manipulated the level of state anxiety (the level of currently experienced anxiety reported by people) by using appropriate pressure, stress, threat of shock or stimuli of negative emotional valence, and they demonstrated that higher anxiety may directly deteriorate WM (e.g., Lavric, Rippon, & Gray, 2003; Tohill & Holyoak, 2000), even within the same people (e.g., Lavric et al., 2003).

Several theories attempted to explain this causal link. The most influential explanation (Eysenck, Derakshan, Santos, & Calvo, 2007) predicts that anxiety diverts controlled attention (i.e., the central executive of WM), being a crucial component of WM, from a task to stimuli or events unrelated to that task. Because of that fact, according to Eysenck et al.’s theory, when attention needs to be involved in a task, more anxious participants require more effort and/or cognitive resources to reach the same level of performance as less anxious participants (i.e., the former display a decreased efficiency of performance; for empirical evidence see Eysenck, Payne, & Derakshan, 2005). More automatic processes seem to suffer less from anxiety (if at all). Moreover, during performance on cognitive tasks, anxious participants show more worried thoughts (ruminations), increased self-preoccupation, as well as more concerns about their performance and its future evaluation (Sarason, 1998; Seibert & Ellis, 1991), which also may negatively impact their performance.

With such substantial effects of anxiety on WM, their strong correlation might be expected. Surprisingly, in psychometric studies which accounted for such a correlation in large and full (i.e., not based on extreme anxiety groups) samples found either weak or null links between anxiety and WMC. For example, Salthouse, Berish, and Siedlecki (2004) found non-significant correlations between neuroticism (a personality trait strongly associated with anxiety) and both attention control and storage capacity components of WM, whereas the link between the former and reasoning was significant, but very weak ($r = -0.13$). Similarly, weak (and this time non-significant) links between neuroticism and both general and fluid intelligence (Gf; ability to use reasoning in order to solve novel abstract problems) were found by DeYoung, Peterson, and Higgins (2005). A slightly stronger neuroticism–Gf correlation ($r = -0.22$) was observed by Unsworth et al. (2009), but they found no link with WM measures. Finally, the meta-analysis of 156 studies (Seipp, 1991) estimated the link between anxiety and academic performance (related to WM and Gf) also to be weak ($r = -0.21$).

There were fewer studies which correlated WM and state anxiety. One such study recently suggested an important clue for why the strong experimental effects of anxiety on cognitive processing were not accompanied by strong correlations between both. Owens, Stevenson, Hadwin, and Norgate (2014) found, in a sample of 96 adolescents, the opposite relationships between anxiety and scores on Gf tests: while a substantial negative correlation ($r = -0.35$) was found for low-WMC children, a positive link ($r = 0.49$) pertained to high-WMC ones (no link was found for the average-WMC group). So, the impact of anxiety on test performance may depend on WM resources available. However, as a relatively small sample of children was studied by Owens et al., it is not known if their results generalise onto the adult population. For example, Johnson and
Gronlund (2009) found a weaker correlation between anxiety and the index of dual-task performance in high-WMC participants than in medium- and low-WMC ones; however, unlike in Owens et al. (2014), in all three groups this correlation was negative (higher anxiety deteriorated dual-task performance; $r_s = - .63, - .41$, and $- .19$, respectively). Moriya and Sigiura (2013) found a negative impact of anxiety on speeded target identification in low-WMC participants, but no relationship—in high-WMC ones. However, both latter studies used very small adult samples ($N = 50$ and $N = 40$, respectively), what undermines the reliability of the results observed.

The goal of this paper is to assess the links between three theoretical constructs which are fundamental to psychology: anxiety, intelligence and WM, by using an especially large sample of adult people. The main hypothesis predicts that the strong experimental effects of anxiety on WM result in relatively strong correlations between both these constructs, but only in people with low cognitive capacities. It is predicted that participants demonstrating high WMC and/or intelligence, possibly due to more effective reasoning and comprehension processes, are able to attenuate negative effects of anxiety on their WM.

**METHOD**

Two methodological developments were introduced in order to reliably test the above prediction. First, unlike most studies (but see Unsworth et al., 2009), here the examined constructs were assessed using a particularly large sample as well as confirmatory factor analysis (CFA; see below). Second, as much as six diverse WM tests were used in order to tap more broadly the WM construct (i.e., three WM functions were tested: storage capacity, binding of information in WM and control over WM). This allowed for the examination of whether various WM functions are influenced by anxiety in the same or different way.

**Participants**

Volunteer participants were recruited via publicly accessible social networking websites. Each participant gave informed consent and was paid the equivalent of 10 euro in Polish zloty. A total of 525 people participated (317 women). Two other participants’ data were discarded due to missing more than one test. The mean age was 23.3 years ($SD = 4.35$, range 18–45). All participants had normal or corrected-to-normal vision. Participants were asked to sit comfortably, with their eyes located approximately 60 cm from the screen. Participants were informed that they were free to leave the lab at any time. They knew the general aim of the study (‘links between cognitive functions’), and were aware that their results would be kept anonymous.

**Materials**

*Fluid reasoning tests*

Raven’s Advanced Progressive Matrices (Raven, Court, & Raven, 1983) and the figural analogy test (see Chuderski & Necka, 2012) were applied. Each item of the Raven test includes a three-by-three matrix of figural patterns which is missing in the bottom-right pattern, and eight response options are the patterns which could potentially match the missing one. The task is to discover the rules that govern the distribution of patterns and to apply them to response options in order to choose the one and only right pattern. The analogy test includes 36 figural analogies in the form “A is to B as C is to X”, where A, B and C are types of relatively simple patterns of figures, A is related to B according to between two and five latent rules (e.g., symmetry, rotation, change in size, colour, thickness, number of objects, etc.), and X is an empty space. The task is to choose one figure from a choice of four which relates to figure C, as B relates to A. The total number of correctly answered items in 60 and 45 minutes (i.e., almost no time pressure was applied) were the scores on the Raven and analogy tests, respectively.
Anxiety questionnaire

Anxiety was assessed with two administrations of the Polish adaptation of X-1 part of the State-Trait Anxiety Inventory (STAI) questionnaire (Spielberger, Gorsuch, & Lushene, 1970). X-1 measures state anxiety. It contained 20 questions about the current emotional state of a questioned person, like “I am relaxed” or “I am nervous”. There are four possible answers: “definitely not” (1 point), “rather not” (2), “rather yes” (3) or “definitely yes” (4), and the total score is the sum of points for all questions (reversed for positive states). Internal consistency of .9 or more was reported for STAI (Muris, Merckelbach, Ollendick, King, & Bogie, 2002).

WM tasks

Each of the 90 trials of each of two array-comparison tasks (Cowan, 2001) consisted of a virtual, $4 \times 4$ array filled with a few (a random number from four to nine) stimuli, picked up from either 10 Greek symbols (e.g., $\alpha$, $\beta$, $\chi$, etc.), or squares in 10 distinctive colours, in letter and colour variants, respectively. Each stimulus was approximately $2 \times 2$ cm in size (the visual angle of 1.9°). The array was presented for a period equal to the number of items multiplied by 300 ms, and then followed by a black square mask of the same size as the array, presented for 1.2 s. In a random 50% of trials, the second array was identical to the first one, whereas in the remaining trials, both arrays differed by exactly one item in one position which was always a new item (not an item from another position). If the arrays differed, then the new item was highlighted by a square red border. If they were identical, a random item was highlighted. The task was to press one of two response keys depending on whether the highlighted item differed or not in two arrays (in a 4 s limit). The trials were self-paced. The score on this task was the estimated sheer capacity of WM (Cowan, 2001) calculated as the difference between the proportion of correct responses for arrays with one item changed and incorrect responses for unchanged arrays, multiplied by the set size.

Two relation monitoring tasks tapped the capacity to construct and integrate the bindings among objects maintained in WM (Oberauer, Süß, Wilhelm, & Wittmann, 2008). The tasks consisted of the presentation of a continuous sequence of symbol patterns (trials). Each trial (out of 100 trials in each task) included a $3 \times 3$ array (approximately $6 \times 6$ cm in size, the visual angle of 5.7°) of three-symbol strings (each string approximately $1.5 \times 1.2$ cm in size, $1.4^\circ \times 1.1^\circ$ of visual angle), either three letters out of a set of ten consonants or three-digit numbers, in the letter and number versions, respectively. Participants were asked to detect if three strings ending with the same digit were located in one row or column. In each task, in half the arrays, there were exactly three strings fulfilling the rule, and all other letters/digits in an array could not match the rule. In the other half of arrays, no pattern matched that rule. Participants were instructed to respond only to trials which included the target relation, and to withhold their responses in all other (i.e., no-relation) trials. In each trial, 5 s (plus 0.1 s blink separating the subsequent arrays) was allowed. From one to four strings (at random) in each subsequent array was the same as in the preceding array. The dependent variable was mean accuracy in the relation trials minus the mean proportion of incorrect, no-relation trials.

The antisaccade task (Unsworth, Schrock, & Engle, 2004), meant to tap the attention-control function of WM, consisted of 40 test trials. Each test trial consisted of four events. First, a cue presented for 1.5 s informed that a target would be presented in the middle of the side opposite to a flashing square. Next, a fixation point was presented in the centre of the screen for 1–2 s. Then, a rapidly flashing black square (3 cm in size, the visual angle of 2.9°) was shown in the middle of the left or right side of the screen, about 16 cm from the fixation point, for 0.15 s. Finally, a small, dark grey arrow pointing left, down or right was presented in the location opposite to the square for only 0.2 s, and was then replaced by a mask. The visual angle from both the square and the arrow to the fixation point was approximately 15°. The task was to direct attention away from the flashing square and to press the key in the location of the arrow as rapidly as possible.
square, to detect the direction of the arrow, and to press the associated key. The trials were self-paced. The dependent variable was mean accuracy.

The figure-word task measures specifically the control over interference in WM. The stimuli, presented at the centre of the computer screen, consisted of four figures (square, rhombus, circle and trapezium, all approximately 4 cm in size, the visual angle of 3.8°), printed in blue, with a black border. Each congruent stimulus (random 60 trials) contained a word (also approximately 4 cm × 1 cm in size, 3.8° × 0.9°), meaning this very figure. For incongruent stimuli (another 40 trials), a word did not match a figure. There was a constraint that the direct repetition of the target stimuli was not possible. Trials lasted until a response was given, or for a maximum of 2.2 s. An 800 ms mask separated the subsequent trials. The instruction was to avoid reading a word and to press a response key assigned to a presented figure. The dependent variable was the difference between mean accuracy in the incongruent and congruent trials (see Kane & Engle, 2003). Each WM task included detailed instructions and several training trials.

Procedure

The study was administered in two sessions. The WM session, which consisted of several computerised WM tasks, lasted about three hours. In another session, which also lasted three hours, the Raven test and paper-and-pencil analogies were applied. The order of sessions was random. They were separated by a one-hour break. The STAI questionnaire was applied in the middle of each session. In the WM session, from two to eight (depending on a sub-sample) other computerised tasks were applied, which either were tasks not related to the present study (e.g., response inhibition, memory updating, selective attention tasks) or were WM tasks that included manipulations aimed to experimentally test some other research hypothesis and were not applied to the whole sample. In the paper-and-pencil session, some participants also fulfilled a relation discovery test as well as an analogical mapping task, both unrelated to goals of the present study.

The sample size and data analysis

It has been recommended that the size of the sample in a CFA study should not be less than 200 participants (Kline, 1998). As the comparison of two groups (low- vs. high-capacity) was aimed, the optimal size of the sample examined was doubled (set to about 500 people). The analysis of Cook’s (1977) distance statistics indicated that there were no substantial multivariate outliers in the sample (the maximum distance was \( d = 0.16 \)). A total of 21 (0.4%) missing values were substituted with respective means.

The data were analysed using a number of CFA models. In a CFA model, by using observed measures of a given theoretical construct (e.g., six WM task scores), a latent variable (e.g., WMC) is calculated that represents variance shared by all these measures, avoiding task specific variance. The correlation paths between latent variables, which were allowed to correlate, can be estimated. The fit of CFA models was evaluated by three indices of fit (see Hu & Bentler, 1999; Kline, 1998): Bentler’s comparative fit index (CFI should exceed .90), root mean square error of approximation (RMSEA should be less than .08) and its 90% confidence interval, and standardised root mean square residual (SRMR should be less than .08). For group models, the population gamma index (\( \gamma \)) was calculated instead of CFI (as CFI cannot be calculated in such a case). When comparing alternative models, it was tested whether a more complex model yielded a significant increase in \( \chi^2 \) statistic (if it did, then a simpler model should have been chosen).

RESULTS

Table 1 presents the summary of measures. All measures had satisfactory reliability and well approximated the normal distribution.

First, the CFA model, including three correlated factors: anxiety (loaded by scores on both
STAI questionnaires), WM (six WM tasks) and Gf (both intelligence tests), was estimated (see Figure 1). The fit of this model was acceptable, $N = 525$, $df = 19$, $\chi^2 = 108.86$, CFI = .940, RMSEA = .068 [.055 – .082], SRMR = .046 (zero-order correlations underlying this and other models are shown in Table 2). Two correlations were significant: between WM and Gf ($r = .703$), and WM and anxiety ($r = −.255$). The former closely matched the estimate from a meta-analysis of 14 studies done by Kane, Hambrick, and Conway (2005). The latter was similar to the above mentioned Unsworth et al.’s (2009) and Seipp’s (1991) estimates. The correlation between anxiety and Gf was not significant ($r = −.095$). Although strongly correlated, the WM and Gf factors were clearly separable, as setting their correlation to unity substantially decreased the model’s fit, $\Delta \chi^2(1) = 97.60, p < .001$.

Although the correlation between Gf and anxiety was not significant, it was wondered if Gf could moderate the WM–anxiety link. Such a possibility was suggested by the results of linear regression, which predicted the WM factor

<table>
<thead>
<tr>
<th>Task</th>
<th>$M$</th>
<th>SD</th>
<th>Range</th>
<th>Skew</th>
<th>Kurtosis</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAI administration 1</td>
<td>34.65</td>
<td>7.62</td>
<td>20–67</td>
<td>1.05</td>
<td>1.69</td>
<td>n/a</td>
</tr>
<tr>
<td>STAI administration 2</td>
<td>38.36</td>
<td>8.34</td>
<td>20–67</td>
<td>0.62</td>
<td>0.22</td>
<td>n/a</td>
</tr>
<tr>
<td>Raven APM</td>
<td>22.87</td>
<td>6.14</td>
<td>3–36</td>
<td>−0.55</td>
<td>0.25</td>
<td>.87</td>
</tr>
<tr>
<td>Figural analogies</td>
<td>23.82</td>
<td>6.08</td>
<td>6–35</td>
<td>−0.45</td>
<td>−0.46</td>
<td>.83</td>
</tr>
<tr>
<td>Colour arrays</td>
<td>2.85</td>
<td>1.27</td>
<td>−0.86 to 6.00</td>
<td>−0.34</td>
<td>−0.13</td>
<td>.67</td>
</tr>
<tr>
<td>Letter arrays</td>
<td>2.57</td>
<td>1.46</td>
<td>−1.33 to 6.40</td>
<td>−0.11</td>
<td>−0.57</td>
<td>.68</td>
</tr>
<tr>
<td>Letter monitoring</td>
<td>0.75</td>
<td>0.18</td>
<td>−0.10 to 1.00</td>
<td>−1.43</td>
<td>2.64</td>
<td>.82</td>
</tr>
<tr>
<td>Number monitoring</td>
<td>0.71</td>
<td>0.20</td>
<td>−0.05 to 1.00</td>
<td>−1.00</td>
<td>0.92</td>
<td>.83</td>
</tr>
<tr>
<td>Spatial antisaccade</td>
<td>0.60</td>
<td>0.23</td>
<td>0–1.00</td>
<td>−0.53</td>
<td>−0.56</td>
<td>.92</td>
</tr>
<tr>
<td>Figure-word</td>
<td>0.97</td>
<td>0.08</td>
<td>0.45–1.15</td>
<td>−3.14</td>
<td>14.68</td>
<td>.93</td>
</tr>
</tbody>
</table>

*Note: N = 525. Reliability = Cronbach’s alpha. n/a, not available.*
Table 2. Correlation matrix for measures used in confirmatory factor analyses, calculated separately for the full sample (N = 525), the sub-sample scoring below median in intelligence factor (N = 263) and the sub-sample scoring above median (N = 262)

<table>
<thead>
<tr>
<th>Task</th>
<th>Full sample</th>
<th>Below-median sub-sample</th>
<th>Above-median sub-sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. STAI administration 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. STAI administration 2</td>
<td>.56</td>
<td>.62</td>
<td>.50</td>
</tr>
<tr>
<td>3. Raven APM</td>
<td>-.08</td>
<td>-.11</td>
<td>-.03</td>
</tr>
<tr>
<td>4. Figural analogies</td>
<td>-.09</td>
<td>-.17</td>
<td>-.01</td>
</tr>
<tr>
<td>5. Colour arrays</td>
<td>-.12</td>
<td>-.19</td>
<td>-.01</td>
</tr>
<tr>
<td>6. Letter arrays</td>
<td>-.05</td>
<td>-.06</td>
<td>-.02</td>
</tr>
<tr>
<td>7. Letter monitoring</td>
<td>-.17</td>
<td>-.26</td>
<td>-.02</td>
</tr>
<tr>
<td>8. Number monitoring</td>
<td>-.17</td>
<td>-.23</td>
<td>-.09</td>
</tr>
<tr>
<td>9. Spatial antisaccade</td>
<td>-.19</td>
<td>-.31</td>
<td>-.03</td>
</tr>
<tr>
<td>10. Figure-word</td>
<td>-.18</td>
<td>-.15</td>
<td>-.07</td>
</tr>
</tbody>
</table>

Note: All ps < .05, except for correlations presented in italic.
Eigenvalue = 2.60) with the anxiety factor and the product of the anxiety and Gf factors (mean z scores). Both predictors were significant (ps < .002). The former yielded $\beta = -0.136$, and the latter yielded $\beta = 0.189$, $F(2, 521) = 17.02, p < .001$, $R^2 = 0.061$.

The first group CFA model allowed for a deeper look into this interaction. In the model, there were only two factors (anxiety and WM), whereas the value of the Gf factor was used to identify two equipotent (the low-Gf and high-Gf) groups, based on the median split of Gf. The model estimated the correlation coefficient between both factors separately for both groups. However, the model assumed, in both groups, the equal loadings of each factor on respective manifest measures (i.e., scores in WM tasks/STAI), as there was no reason to expect that particular tasks reflected the underlying constructs differently between groups. The fit of the model presented in Figure 2 (top panel) was acceptable, $N = 525$, $df = 46, \chi^2 = 117.58, \gamma = .951, \text{RMSEA} = .077 [.060 – .095], \text{SRMR} = .073$. Importantly, the WM–anxiety correlation in the low-Gf group ($r = -0.422$) was significantly stronger than in the high-Gf group ($r = -0.070, \text{n.s.}$), $t(524) = 4.40, p < .001$. The significance of the difference was also shown by a deteriorated fit of the model in which these correlation coefficients were forced equal, $\Delta \chi^2(1) = 9.08, p = .003$.

It was also tested whether using the median split in WMC may lead to a similar difference in WM–anxiety correlation or in Gf–anxiety correlation. Regarding the former link, due to restricted range, it is not recommended to use the same variables as both predictors and group division criterion. Thus, two measures were picked up as such a criterion (the colour two-array task and the letter relation monitoring tasks), whereas the four remaining WM measures loaded the WM factor. Still, the
indicators of each WM facet (i.e., storage, binding and control) contributed to this factor. Although this second group model fit well, $N = 525$, $df = 22$, $\chi^2 = 38.85$, $\gamma = .976$, RMSEA = .054 [.024 – .082], SRMR = .067, no significant difference in WM–anxiety link was found between the groups ($r_{\text{low-WMC}} = -.235$ vs. $r_{\text{high-WMC}} = -.297$). This was demonstrated by the insignificant change of fit when both paths were forced equal, $\Delta \chi^2(1) = 0.36$, $p = .548$.

An interesting result (see Figure 2, bottom panel) was found when by using the third group CFA model both groups were tested for the difference in anxiety–intelligence path, $N = 525$, $df = 6$, $\chi^2 = 13.02$, $\gamma = .980$, RMSEA = .005 [.007 – .116], SRMR = .056. The results ($r_{\text{low-WMC}} = -.127$ vs. $r_{\text{high-WMC}} = .204$), $t(524) = 4.24$, $p < .001$, indicated that though there was no significant link between anxiety and Gf in low-WMC participants, in high-WMC people increased anxiety was significantly associated with (slightly) increased intelligence. Forcing both paths equal significantly decreased the fit of the model, $\Delta \chi^2(1) = 7.98$, $p = .005$.

Finally, because six WM measures were available, it could also be checked whether, in the low-Gf group, the various facets of WM yield the same or different correlations with anxiety (the high-Gf group was not further tested as it did not yield a significant link between anxiety and WM). Three factors were formed reflecting the three functions of WM: storage capacity (the array-comparison tasks), binding in WM (the relation monitoring tasks) and control over WM (the antisaccade and figure-word tasks). The CFA model (see Figure 3), which fit very well, $N = 263$, $df = 14$, $\chi^2 = 18.97$, CFI = .989, RMSEA = .037 [.000 – .075], SRMR = .033, yielded strong correlations between WM factors. Moreover, each factor correlated with anxiety, but the correlation of the storage capacity factor was significantly weaker ($r = -.226$) than of the two remaining factors, $t(262) = 2.25$, $p = .012$, $t(262) = 2.25$, $p = .001$, for the binding ($r = -.408$) and control ($r = -.468$), respectively. Not surprisingly then, the model in which all three correlation coefficients were forced equal yielded poorer fit, $\Delta \chi^2(2) = 7.78$, $p = .020$.

**GENERAL DISCUSSION**

The study yielded the novel result showing that the impact of anxiety on WM diminishes with increasing fluid intelligence (see the results of linear regression), and that anxiety significantly affects WM only in people below median intelligence (see the results of CFA modelling). Unlike
in previous studies, the substantial amount of variance in WMC (17.8%) could be explained by anxiety in the low-Gf group. In contrast, above-median intelligence successfully prevented the negative impact of anxiety on WM. Moreover, the study replicated and extended Owens et al.’s (2014) findings, showing that in high-WMC participants anxiety may be positively related to intelligence. However, when the large, adult sample was examined, the moderating effect of WM on the anxiety–Gf link appeared to be much weaker than that observed by Owens et al. Finally, low vs. high levels of WMC did not affect the WM–anxiety link.

The above results suggest that sheer cognitive resources like WMC, even if they are substantial, do not suffice to attenuate the negative effects of anxiety (although they may help in coping with it). More may be needed to prevent such effects, and the present study predicts that this “more” consists of effective high-level processes, like reasoning, comprehension and problem solving, which are typically associated with fluid intelligence. Although no correlational study can explain why intelligence moderates the WM–anxiety link, at least two plausible explanations may be considered.

First, more intelligent people may be able to better recognise the fact that anxiety deteriorates their WM performance, and, for such people, increased anxiety may be associated with increased motivation to perform well on tasks. This possibility is supported by observations that in some conditions, increased motivation allowed anxious participants to catch up with the scores of emotionally stable people (e.g., in order to avoid negative evaluation), but, did so at the cost of lower efficiency of processing (e.g., more time was needed to get a comparable score; see Eysenck & Derakshan, 2011). Anxious but intelligent participants could focus their attention on a WM task more, or implement a more careful response strategy, and, due to such an increased effort, might improve their results. In contrast, anxious but less intelligent participants might not recognise that their WM was distorted by anxiety and, because of that fact, these people put no additional effort into that task.

Following the suggestion of a reviewer, in order to test the above hypothesis, reaction times (RTs) in five WM tasks were analysed (in the antisaccade task the real indicator of the processing speed is the eye-movement latency, which was not recorded in the present study). These RTs loaded on two separate factors: one for tasks with time pressure (the Stroop and two relation monitoring tasks), and the other for tasks with no pressure (two array-comparison tasks). The former factor seems to reflect primarily the processing speed, whereas the latter one may indicate participants’ speed-accuracy trade-off strategies. Both factors correlated only weakly ($r = .181$), but significantly (95% CI = [0.093–.269]). Most importantly, both the speeded RT factor ($r = .098$, 95% CI = [0.008–.188]), and the unspeeded factor ($r = .126$, 95% CI = [.0460–.206]) positively correlated with anxiety. This means that it took more anxious participants more time to respond, in comparison to less anxious people. The fit of the model was relatively poor, but still acceptable, $N = 525$, $df = 11$, $\chi^2 = 70.46$, CFI = .935, RMSEA = .098 [0.076–.121], SRMR = .062. Adding intelligence level as a group factor, and correlating RTs and anxiety separately for high and low ability people, did not significantly increase the model’s fit, $\Delta \chi^2(2) = 2.94$, p = .767, and both groups yielded the similar RT–anxiety correlations. Those results seem to support the above explanation provided by attention control theory. However, a relative weakness of correlations observed leaves room for other alternative explanations.

For example, perhaps WM resources of both less and more intelligent people get reduced due to anxiety in a similar way, but the latter are able to somehow overcome such decrements, for instance by switching to cognitive strategies that less consume WMC, or by using other cognitive processes which normally would not be recruited for performance in a WM task (e.g., imagination, rapid learning, discovery of hidden rules in the task, etc.). So, although the negative effects of anxiety would be comparable for people with different intelligence levels, highly intelligent people would cope better with these effects, compensating for WM decrements with other mental
faculties. As intelligence is known to rely not only on WM, but also on attention (Schweizer, 2010), learning (Kaufman, DeYoung, Gray, Brown, & Mackintosh, 2009) and long-term memory (Unsworth, Fukuda, Awh, & Vogel, 2014), which might be less prone to or even sometimes benefit from anxiety (like selective attention; see Matthews, Mackintosh, & Fulcher, 1997), intelligent people may be able to use these processes in fulfilling a WM task. This possibility would also be consistent with Spearman’s (1927) more general “Law of Diminishing Returns”, which predicts that due to a larger heterogeneity of cognitive abilities in more intelligent people, various factors correlate less with Gf in such people than in less intelligent people, who rely on more homogenous cognitive mechanisms.

Moreover, the positive relationship between anxiety and intelligence observed in high-WMC participants suggests that not only cognitive processes can overcome the effects of negative emotions, but also such emotions may be a beneficiary factor for thinking and reasoning, given that one possesses sufficient cognitive resources to cope with a task even under increased anxiety. This speculation is consistent with data indicating that negative mood, comparing to positive mood, is associated with more systematic and analytic cognitive processing (Pham, 2007), which was shown to be crucial for high performance on intelligence tests (Carpenter, Just, & Shell, 1990). Anxious and intelligent people may also strategically control their processing to a larger extent (because they are more worried about errors) than emotionally stable participants, and cognitive control over reasoning strategies is also known to positively influence reasoning effectiveness (Carpenter et al., 1990).

Regarding various functions of WM, the present study showed that control in WM is affected by anxiety to a larger extent than sheer storage capacity. This result is consistent with several theories of cognitive consequences of anxiety, which suggested that anxiety impacts primarily the executive and attentional functions of WM (Eysenck & Derakshan, 2011; Eysenck et al., 2007; Mathews et al., 1997; Tohill & Holyoak, 2000). However, storage functions of WM are also believed to rely to some extent on attention (Cowan, 2001), so the observed (weak) link between storage and anxiety is unsurprising. A relatively novel measure of WM functioning, the relation monitoring tasks, brought results similar to executive control tasks, suggesting that some form of attention may be needed also to form bindings in WM. Although relational monitoring tasks might be objected as a valid measure of WMC (as they do not require to memorise any objects), recent findings have shown that they share a vast amount of variance with other, better established WM tasks (e.g., Chuderski, 2014; Wilhelm, Hildebrandt, & Oberauer, 2013); thus, the former tasks also properly capture WMC.

Finally, the study, showing how disruptive anxiety can be in people with intellectual deficits, also has fundamental consequences for applied psychology. It suggests that special care should be taken of conditions in which less intelligent people study or work (and are tested for results), because any potential sources of anxiety (e.g., time pressure, negative feedback, stereotype threat, extreme difficulty, etc.) yield especially disruptive effects in the cases of such people (in comparison to high ability people), and thus, may have severe social consequences (like underperformance or learned helplessness).
REFERENCES


