

Working memory and the Big Five

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**Highlights**

- Our systematic review showed few direct links between personality and working memory
- Our empirical study showed a negative association between Conscientiousness and n-back
- The empirical study also showed a negative association between Openness and n-back
- There were no links between the Big Five and two other working memory measures in our empirical study
- Overall, we failed to find robust direct associations between WM performance and the Big Five

**Ethical statement**

The study was approved by the Joint Ethics Committee at the Departments of Psychology and Logopedics, Åbo Akademi University. Informed consent was obtained from all participants, participation was anonymous, and all participants were informed of their right to withdraw from the study at any time.

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### Abstract

Previous studies that have investigated associations between working memory (WM) and the Big Five personality traits have yielded mixed results, with some finding statistically significant associations while others have not. The aim of the current study was twofold. First, we systematically reviewed previous studies on WM-Big Five associations. Second, we investigated associations between three WM composites (numerical-verbal WM, visuospatial WM, n-back) and the Big Five in a large-scale study on adults (n=503). Here we controlled for possible confounding caused by the way WM is operationalized, the content domain of the WM tasks (verbal vs. spatial), and sample size. The systematic review revealed that the majority of earlier studies show no association between any of the personality traits and WM performance. As regards our empirical study, the only significant associations were the negative correlations between n-back WM updating performance and the Conscientiousness and Openness traits. This means that the more Conscientious or Open to experiences a participant reported being, the worse was the n-back performance. Overall, our study failed to show any robust relationships between WM performance and the Big Five personality traits. We discuss possible reasons for these findings.

*Keywords:* working memory, cognition, Big Five, personality, n-back

## 1. Introduction

Working memory (WM) is a capacity-limited mental workspace that enables the maintenance and simultaneous processing of currently active information (e.g., Alloway & Gathercole, 2006; Conway, MacNamara, & Engel de Abreu, 2013). It is engaged in any complex intellectual activity such as mental arithmetic or following step-by-step instructions when the instructions are not constantly at hand. WM has been related to, for example, academic achievement (Gathercole & Pickering, 2000) and fluid intelligence (Kane, Hambrick, & Conway, 2005), while impairments in WM have been associated with learning difficulties (Alloway & Gathercole, 2006) and neuropsychiatric disorders such as schizophrenia (Lee & Park, 2005) and ADHD (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005).

WM and other cognitive functions do not work in isolation. Rather, it is a long-standing, generally accepted fact that non-cognitive aspects of an individual influence cognitive performance. For example, already Alfred Binet (1886, as cited in Kaufman & Kaufman, 2001) considered memory to be influenced by experiential context and recognized the interaction between emotions and intellect. David Wechsler (1950) pointed out that “intellectual ability however broadly defined, must be regarded as a manifestation of the personality as a whole” (p. 78) and he also wrote that intelligent adaptive behavior is dependent on non-intellective traits that arise from temperament and personality. To take one concrete example of how personality can affect cognitive performance, Wechsler (1950) mentioned that a highly neurotic individual [might] perform poorly on the Digit span task (a typical WM task) due to test anxiety and not because of poor cognitive faculties. Higher levels of anxiety have indeed often been associated with poorer WM performance (Darke, 1988; Ikeda, Iwanaga, & Seiwa, 1996; Elliman, Green, Rogers, & Finch, 1997; Visu-Petra, Cheie, Benga, & Alloway, 2011). This example highlights

the focus of the current study that addresses the relationships between personality traits and WM performance.

Personality traits have been defined as relatively stable “habitual patterns of behavior, thought, and emotion” that “differ among individuals, and influence behavior” (p. i, Villanueva, 2010). The predominant personality trait theory that provides the theoretical framework also for the present study is the Big Five model that divides personality according to the broad traits of Extraversion, Openness to experience, Conscientiousness, Agreeableness, and Neuroticism (Goldberg, 1993). The Big Five traits have been shown to predict major life outcomes such as mortality, divorce, occupational attainment (Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007), and academic achievement (Paunonen & Ashton, 2001). Notably, personality and WM have predictive value for partly the same outcomes, for example, for academic achievement.

As regards the hypothetical links between the Big Five traits and cognitive performance, there are differing views of whether and why they purportedly exist. Three major general standpoints are as follows: 1) M and the Big Five are not meaningfully related, 2) personality affects cognitive performance (cf. the example of Neuroticism affecting digit span performance given above), 3) they share a developmental relationship where personality affects how a person invests in cognitive ability and shapes it on the long-term (von Stumm, Chamorro-Premuzic, Ackerman, 2011). In a review article focusing on older adults, Curtis, Windsor, and Soubelet (2015) summarize more specific hypotheses from the previous literature. For Extraversion, opposing hypotheses have been proposed: a positive association would result from faster response-speed, higher assertiveness, and lower arousal (Chamorro-Premuzic & Furnham, 2004); and a negative association from discomfort with formal testing, lower tolerance for repetition, and shorter deliberation times (Costa, Fozard, McCrae, & Bossé, 1976 [as cited in Curtis et al., 2015]; Gold & Arbuckle, 1990; Graham & Lachman, 2014). For Openness, a positive association

has been proposed due to the assumedly greater engagement in cognitively stimulating behaviors in individuals scoring higher on this personality trait (e.g., Sharp, Reynolds, Pedersen, & Gatz, 2010). Opposing hypotheses have been proposed for Conscientiousness: a positive association has been suggested to result from healthy behaviors (e.g., exercise) and commitment to school and work (Sutin et al., 2011); and a negative association from compensatory actions (i.e., lower cognitive ability is compensated by orderliness and industriousness; see e.g., Moutafi, Furnham, & Paltiel, 2004). According to Curtis et al. (2015), no conceptual rationale has been presented for an association between Agreeableness and cognitive performance. Finally, for Neuroticism, a negative association has been proposed due to the detrimental effects of anxiety on cognitive performance (see above) and due to neuronal damage resulting from prolonged arousal (e.g., Chapman et al., 2012).

The results of the narrative review by Curtis et al. (2015), which is based on the cross-sectional data of 34 separate studies, showed that the majority of the included studies supported the hypothesis that Neuroticism is negatively related to cognitive ability and WM. Furthermore, as has been hypothesized, Openness was found to be positively related to cognitive ability in most of the included studies. There was, however, not evidence for an association between cognitive ability and Extraversion, Conscientiousness, and Agreeableness.

While Curtis et al. (2015) reported two cognition – Big Five relationships that followed earlier hypotheses and that they considered to be relatively consistent, the empirical evidence still seems mixed concerning WM - Big Five associations. To obtain a comprehensive and up-to-date picture of existing research, we started by conducting a systematic review of previous studies that have investigated the associations between WM and the Big Five, against which our own empirical results in the present study could then be related.

### **1.1 Working memory and the Big Five: A systematic review**

While a number of studies have reported on associations between various cognitive functions and the Big Five personality traits, to the best of our knowledge, this is the first systematic review that focuses specifically on the relationship between WM and the Big Five personality traits.. Also, several relevant studies have been published after Curtis et al. (2015) systematic literature review roughly five years ago, and their review focused on older adults only. Hence, we collected and analyzed previous studies reporting WM-Big Five associations. We included only studies that reported direct associations between at least one of the Big Five traits or facets and specifically WM measures. We focused on studies conducted in healthy adults. We included all relevant studies obtained from a systematic literature search performed using Google Scholar, and the PubMed and PsycINFO databases as well as the studies included in the Curtis et al. (2015) narrative review (for a more detailed description of the inclusion criteria and literature search, see the Appendix). Altogether 39 studies were included.

In terms of the statistical significance and the direction of the significant associations, our systematic review showed mixed results for all the traits (see Appendix and Table 1 for a more detailed description of the results). For Extraversion, Conscientiousness, and Agreeableness, less than 15% of the included samples (Extraversion: two of 25 samples, Conscientiousness: three of 23 samples, Agreeableness: one of 17 samples) revealed a statistically significant relationship with WM performance. For Extraversion and Agreeableness, all statistically significant associations indicated that a higher trait score was related to a better WM performance. For Conscientiousness, a lower trait score was associated with a better WM performance in two samples (8.7%) and a higher trait score with a better WM performance in one sample (4.3%). For Neuroticism, 22.2% of the included samples (six of 27 samples) revealed a statistically significant negative relationship with WM performance (lower trait score, better performance).

For Openness, 26.1% of the samples (six of 23 samples) reported significant positive associations, but a negative association was reported in one (4.3%) sample. One should also note that the proportion of significant associations would be even lower for some of the traits if it would be related to the number of analyses rather than the number of samples. All in all, the review results showed no robust direct relationships between WM and any of the Big Five traits.

#### INSERT TABLE 1 ABOUT HERE

These variable and largely negative findings may in part be due to methodological issues. One potential concern is the way WM is operationalized: some studies have used only a single task to assess WM, while others have used, for example, a factor score calculated from several WM tasks. As has been pointed out (e.g., Schmiedek, Hildebrandt, Lövdén, Lindenberger, & Wilhelm, 2009), the use of a single task potentially restricts the generalizability of the results if the associations are specifically related to that task or the stimulus material of the task. A second potential confound is the content domain of the WM tasks. Previous research has indicated that a verbal/spatial (or what/where) distinction is a fundamental aspect of the WM system (e.g., Nee et al., 2013; Waris et al., 2017). Hence, combining tasks from different content domains into general WM scores could mask potential content-specific WM-Big Five associations. For example, in a previous brain imaging study (Kapogiannis, Sutin, Davatzikos, Costa, & Resnick, 2013), higher Neuroticism was associated with smaller right hemispheric dorsolateral prefrontal cortex volume, which might associate Neuroticism more selectively with visuospatial WM that is also partly subserved by right prefrontal systems. On the other hand, according to the Processing efficiency theory (Eysenck & Calvo, 1992), anxiety elicits worrisome inner thought that mainly affects the phonological loop (in addition to central executive functions) rather than visuospatial



WM. A third possible confound is the huge variability in sample size (range 11-4974 participants, see Table 1) that affects the reliability of the findings.

All in all, while our systematic literature review failed to find consistent, robust associations between the Big Five traits and WM performance, certain confounds could have clouded the picture. Our empirical study addressed this issue by investigating Big Five-WM associations in a large participant sample that had been tested with an extensive battery of WM tasks. Importantly, our empirical study took into account three potential confounds that may have affected the results from previous research. First, our composite WM measures were constructed on the basis of the latent factor structure of our sample (Waris et al., 2017) rather than on single tasks. This also means that our WM framework is empirically based – it does not build on a specific theoretical model of WM, although it could be seen as compatible with several of them, e.g., the multicomponent model (Baddeley and Hitch, 1977) or the embedded-processes model (Cowan, 1999) (for a discussion, see Waris et al., 2017). Second, we took into account the content-specific nature of WM (numerical-verbal; visuospatial) that clearly emerged also in the latent factor analysis. Third, we employed a comparatively large sample to provide higher statistical power for our analyses.

## **2. Method**

### **2.1 Participants and procedure**

This completely online study used the same data set as Waris and colleagues (2017). The WM tests and an extensive questionnaire were administered using an in-house developed web-based test platform, and participants were recruited using the crowdsourcing site Amazon Mechanical Turk. To avoid both less experienced and extremely experienced MTurk workers, we included only those with more than 100 but less than 1000 work assignments. In order to support our data

quality, we required participants to have an approval rating of at least 95%. Moreover, to minimize possible issues with testing language, all participants had to be located in the USA as identified by a US bank location (see Waris et al., 2017 for further details). The study was completed by 711 participants. Altogether 43 participants were excluded for reporting the use of external tools such as drawing during task performance ( $n = 38$ ), missing data on any of the tasks ( $n = 4$ ), or for taking over a day to complete the study ( $n = 1$ ). In order to exclude the possible effect of depressive symptoms on WM performance (especially considering the positive association between Neuroticism and depressive symptoms, see Bianchi & Laurent, 2016), only those participants whose depression scores corresponded to none or mild depressive symptoms (Quick Inventory of Depressive Symptomatology, Rush et al., 2003) were included. This excluded 136 participants and an additional 16 for missing depression scale data. Next, the sample that at this point included 516 participants was analyzed for multivariate outliers on the WM variables using Mahalanobis distance. Thirteen participants were excluded for being multivariate outliers, and thus the final sample consisted of 503 participants (see Table 2 for demographic information of the final sample). The WM tasks included five tests with numerical-verbal stimuli and five tests with visuospatial stimuli, and the employed task paradigms were the simple span forward, simple span backward, complex span, running memory, and n-back (2-back). The numerical-verbal tasks used the digits 1-9 as stimuli, while the visuospatial tasks used a 3x3 matrix with nine possible spatial locations (see Waris et al., 2017, for detailed descriptions of the tasks). Each simple span task consisted of seven trials (span lengths 3-9). Complex span tasks included five trials (span lengths 3-7) and running memory spans included seven trials (span lengths 5-11, a 4-item trial was also present but not included in the outcome variable). Within each span task, the trial order was randomized for each participant. Each n-back task consisted of 48 items that required a response (16 target items, 16 no-target items, and 16 so-

called lure items). On all tasks, accuracy rates were used as dependent measures. For the simple spans, complex spans, and running memory spans, the total number of accurately recalled items (i.e., correct individual digits or locations irrespective of span length) was used as the dependent measure, and for the n-back, the proportion of hits minus the proportion of false alarms. The Big Five personality traits were assessed using the self-evaluated Ten Item Personality Inventory<sup>1</sup> (TIPI; Gosling, Renfrow, & Swann, 2003). Despite its brevity, the TIPI has shown adequate psychometric properties in earlier research. It has a mean test-retest correlation of .72, and interscale trait correlations range from .65 to .87 between the Big Five Inventory (John, Donahue, & Kentle, 1991; Benet-Martinez & John, 1998) and the TIPI, and from .56 to .68 between the NEO-PI-R and the TIPI (Gosling et al., 2003).

INSERT TABLE 2 ABOUT HERE

## **2.2 Statistical analyses**

Prior to performing the analyses, the WM measures were Box-Cox transformed to better approximate normal distribution (Osborne, 2010). Previous factor analyses of the present WM data (Waris et al., 2017) yielded either two factors (numerical-verbal; visuospatial plus both n-back variants) or three factors (numerical-verbal; visuospatial; n-back). In order to maintain content-specificity, we chose the three-factor solution for the compilation of WM composite scores used in the present analyses. Hence we calculated (1) a numerical-verbal WM composite score consisting of the numerical-verbal simple span forward, simple span backward, running memory, and complex span tasks; (2) a visuospatial WM composite including the spatial simple span forward, simple span backward, running memory, and complex span tasks; and (3) an n-

back composite encompassing both the numerical-verbal and spatial n-back tasks. All relevant task measures were z-transformed and summed when creating the respective composites.

The associations between the Big Five personality traits and the three WM composites were assessed using hierarchical multiple linear regression. At step 1, we entered the control variables age, subjective assessment of household wealth during childhood, education (highest attained degree), and state anxiety (STAI-6, Marteau & Bekker, 1992). At step 2, we entered the five personality traits that were the predictors of interest. Given that the three WM composites served as dependent measures, we ran three separate multiple regression analyses.

### 3. Results

Table 3 depicts the zero-order correlations between the WM composites and the Big Five personality traits. The hierarchical multiple linear regression analyses revealed that the first step involving the control variables predicted 2.4% in verbal WM performance,  $F(4, 498) = 3.068, p = .016, R^2 = .024$ ; 6.3% in spatial WM performance,  $F(4, 498) = 8.390, p < .001, R^2 = .063$ , and 3.7% in n-back performance,  $F(4, 498) = 4.835, p = .001, R^2 = .037$ . Age was negatively associated with spatial WM,  $\beta = -.205, t(498) = -4.666, p < .001, pr^2 = .042$ , and n-back performance,  $\beta = -.181, t(498) = -4.065, p < .001, pr^2 = .032$ . In other words, older participants performed worse on the spatial WM and n-back composites. Education was positively associated with verbal WM performance,  $\beta = .114, t(498) = 2.539, p = .011, pr^2 = .013$ , with participants reporting higher educational attainment performing better on the numerical-verbal WM composite. State anxiety was negatively associated with verbal WM performance,  $\beta = -.090, t(498) = -2.024, p = .044, pr^2 = .008$ , and spatial WM performance,  $\beta = -.158, t(498) = -3.614, p < .001, pr^2 = .026$ , with more anxious participants performing worse on these composites.

Step 2 was statistically significant only for n-back performance,  $\Delta F(5, 493) = 3.156, p = .008, \Delta R^2 = .030$ , where the personality traits accounted for an additional 3% of the variance. Of

the five traits, Conscientiousness,  $\beta = -.115$ ,  $t(493) = -2.507$ ,  $p = .013$ ,  $pr^2 = .013$ , and Openness,  $\beta = -.095$ ,  $t(493) = -2.021$ ,  $p = .044$ ,  $pr^2 = .008$ , showed statistically significant negative associations with n-back performance. Thus, participants higher in Conscientiousness and Openness showed worse performance on the n-back composite.

INSERT TABLE 3 BOUT HERE

#### 4. Discussion

We investigated WM – Big Five associations both by a systematic review of earlier studies and by conducting an empirical study of our own. Our own empirical study took into account three potential confounds that may have affected the results of earlier studies that have investigated WM-Big Five associations, namely employing composite WM measures based on latent WM structure rather than single tasks, taking into account the pervasive content-specific organization of WM (numerical-verbal; visuospatial), and employing a comparatively large sample for higher statistical power.

Our systematic review was prompted by the marked variability in previously reported associations between WM and the Big Five. The review results indicated that the majority of the relevant earlier studies show no association between any of the personality traits and WM performance. In the present empirical study, we observed significant negative associations between n-back WM updating performance and the Conscientiousness and Openness traits, but no associations between the personality traits and performance on the other two WM composites.

The negative association between n-back performance and Conscientiousness that we observed in our empirical study has, to the best of our knowledge, not been reported previously

(see Table 1), but the direction of the association is the same as in two previous studies showing a significant negative relationship between Conscientiousness and other WM performance measures (Soubelet, 2011; Costantini et al., 2015; see also Schell & Reilly, 2004; however, see Baker & Bischel, 2006). It might reflect the compensation hypothesis (Moutafi, Furnham, & Paltiel, 2004), according to which lower WM performance is compensated by higher levels of Conscientiousness. One can also speculate if the current negative association could reflect an individual's proneness to experience stress and anxiety in situations that one is not familiar with and/or does not master. Persons higher in Conscientiousness could possibly experience greater levels of anxiety in such a situation due to a desire and internal pressure to perform well, which could negatively impact a person's performance. One might argue that this hypothetical explanation is discredited by the fact that we controlled for anxiety. However, the anxiety questionnaire was completed before the WM tasks, i.e., before the WM tasks could have temporarily increased anxiety levels, and hence this hypothetical explanation cannot be completely ruled out. Be it as it may, we do not know whether our participants actually perceived the n-back to be more novel, confusing and/or demanding than the other WM tasks. Thus, we cannot rule out the possibility that the present statistically significant association could simply be a chance finding.

The negative association between n-back performance and Openness that was observed in our empirical study conforms to one previous experiment (Smillie et al., 2016) in our systematic search, but contradicts the results of six studies that observed a positive association (note, however, that the vast majority of samples reported non-significant associations). To the best of our knowledge, there is no viable theoretical account of why Openness would be negatively associated with WM performance. Rather, the investment hypothesis suggests that Openness, or

more precisely the Intellect<sup>2</sup> aspect of Openness, would be positively associated with WM and cognition more broadly (e.g., DeYoung et al., 2009).

This takes us to one aspect of WM – Big Five links worth discussing, namely the possible role of facet-level personality measures that represent more specific attributes within each Big Five trait. While the majority of the relevant earlier studies in our review showed no association between any of the personality traits and WM performance, several of the ones that did had included facet-level personality measures (DeYoung et al., 2009; Gregory, Nettelbeck, & Wilson, 2010; Aiken-Morgan et al., 2012; Costantini et al., 2015; Smeekens & Kane, 2016; Smillie, Varavsky, Avery, & Perry, 2016). It is thus possible that more specific facets would be better in predicting distinct behaviors, and that information may be lost when using aggregated trait variables (Paunonen & Ashton, 2003). This issue has been raised particularly for the Openness trait, where WM has been argued to be positively associated with the Intellect aspect of Openness (DeYoung et al., 2009). DeYoung and colleagues (2009) reported significant associations between the Ideas and Values<sup>3</sup> facets of Openness and WM updating performance, and between the Ideas facet and WM capacity. These results were taken to indicate the presence of an association between the Intellect aspect of Openness (represented by the Ideas facet) and WM. However, this conclusion is called into doubt as only one out of the six other studies that investigated facets of Openness observed a significant association between the Ideas (or Intellect) facet and WM performance (Hultsch, Hertzog, Small, & Dixon, 1999; Gregory et al., 2010; Aiken-Morgan et al., 2012; Smeekens & Kane, 2016; Smillie et al., 2016; Chapman et al., 2017).

Curtis et al. (2015) speculated whether sample size and lacking statistical power might explain the varying results in previous studies. This is a potentially relevant notion, also given the fact that the (as such statistically significant) effect sizes are miniscule in the study with the largest sample ( $n = 4974$ , Graham & Lachman, 2012; see also Wilson et al., 2007b). In that

study, the personality traits significantly predicted WM performance, but they only explained an additional 1% of the variance in WM performance when controlling for age, education, sex, health, and hearing. Hence, while direct associations may exist between WM and Neuroticism and also Openness, where Graham and Lachman observed significant associations, the associations have a minimal effect size and questionable practical relevance. Note, however, that Graham and Lachman only employed one WM test (Digit span backward), and hence the associations they report could be task-specific (but see Wilson et al., 2007b).

One potential limitation in this research field, which is also discussed by Curtis et al. (2015), concerns the considerable variability in the personality and WM measures that have been used. This variability could possibly account for some of the inconsistent results. Concerning our empirical study, one limitation is the brevity of the personality inventory that was used. The TIPI has been shown to have adequate levels of convergent and discriminant validity as well as test-retest reliability, but according to its authors it is still somewhat inferior to established lengthier inventories (Gosling et al., 2003). Another possible limitation in our study is its online nature. Even though administering every aspect of the study online allowed us to collect a relatively large sample, it could potentially produce more error variance due to the non-proctored and unstandardized assessment settings. Also, the current sample consisted of MTurk workers, which potentially limits the generalizability of our results. However, it can be argued that our sample is demographically more diverse than e.g. student samples employed in some earlier relevant studies. Furthermore, as discussed by Curtis et al. (2015), a limitation concerning this study approach as a whole is the possible existence of non-linear or interacting Big Five associations that might muddle the presently investigated direct relationships (e.g., see Eysenck and Graydon, 1989). However, analysis of our empirical data indicated no robust signs of curvilinear associations between the Big Five traits and WM performance<sup>4</sup>. Still another potential



issue is the cross-sectional nature of the present study that prevents the observation of potential longitudinal associations between personality and WM (see Curtis et al., 2015).

In conclusion, our systematic review and empirical study failed to find robust direct associations between WM performance and the Big Five. In future research, it might be fruitful to explore the associations between WM and more specific aspects of personality by paying particular attention to the contexts in which personality features become realized. This has already been done to some extent regarding facets of personality traits (see e.g., DeYoung et al., 2009), but the possible interactions between personality facets and situational factors would be important to investigate further. For example, to provide evidence for the hypothesis that a negative association between WM and Neuroticism reflects test anxiety, state and test anxiety measures should be added to the test battery. Regarding other situational factors, the low-stakes testing in our study (i.e., the participants' reward was not affected by their performance) as well as in previous studies might obfuscate potential associations between, for example, Neuroticism and WM performance. If WM were to be assessed in a more high-stakes situation such as an entrance exam, a more clear association between WM and Neuroticism might emerge as a result of higher levels of anxiety and stress. Another example would be to assess WM with a task involving social interaction, such as taking orders at a restaurant without the help of a notepad, and examine whether Extraversion would be more strongly related to WM when tested in this context. In other words, it is possible that situational factors could play an important role in WM - Big Five associations. In the same vein, personality tests aim to assess typical behavior of an individual, while cognitive tests assess maximal performance (Ackerman and Heggestad, 1997). This discrepancy in what is being assessed may partly explain the largely non-significant associations between the Big Five traits and WM performance. Perhaps estimates of "typical WM

performance” that reflect how much WM engagement and effort a person typically exerts on an everyday basis would yield associations between WM and personality.

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## Footnotes

<sup>1</sup>The TIPI question 9 that belongs to the Emotional Stability trait was reverse coded in order to obtain an estimate of Neuroticism.

<sup>2</sup>Intellect within the Openness/Intellect framework refers to a person's interest in intellectual activities, reasoning ability, and perceived intelligence; while Openness is viewed to reflect a person's fantasy and artistic and sensory interests. A common denominator of both aspects is cognitive exploration, which is exemplified by, for example, curiosity and imagination (DeYoung et al., 2014).

<sup>3</sup>These are separate facets of Openness derived from the NEO-PI-R (Costa & McCrae, 1992). The rest are Fantasy, Aesthetics, Feelings, and Actions.

<sup>4</sup>To test for non-linear associations between the Big Five traits and WM performance in our sample, we ran two sets of regression analyses. One set involved squared Big Five traits, and the other, log10 transformed traits. In the analyses, the WM performance variables (verbal, spatial, n-back) were separate dependent variables, the control variables were entered in Step 1 (age, education, childhood wealth, & state anxiety), the untransformed original Big Five trait in Step 2, and the transformed Big Five trait in Step 3. Each Big Five trait was analyzed in a separate model, which resulted in 15 analyses with squared predictors and 15 analyses with log10 predictors. Although Extraversion and Neuroticism showed some minimal signs of a curvilinear (quadratic) association with some WM performance variables, none of the associations remained significant after Bonferroni correction.



Table 1

*Previous associations between working memory performance and the Big Five personality traits (number of statistically significant associations/total number of analyses & effect size)*

Study	Year	N	Age	Personality inventory	WM measure	Ex	Ex ES	Op	Op ES	Co	Co ES	Ag	Ag ES	Ne	Ne ES
*Arbuckle et al.	1992	326	M = 64.8	EPI	Digit span	n.s.	r = -.13							1/1	r = -.26
*Hultsch et al. <sup>1</sup>	1999	431	Range = 55-86	NEO-PI	Latent variable from 2 tasks	n.s.	r = .03	2/2	r = .22 & r = .24	n.s.	?	n.s.	?	n.s.	r = -.12
Lieberman <sup>2</sup>	2000	13	M = 20.3	EPI	Sternberg task RT	1/7 <sup>a</sup>	r = .61								
Lieberman & Rosenthal	2001	23	Undergraduates	EPI	Digit span	n.s.	r = .04								
					N-back RT	2/4 <sup>a</sup>	r = .42								
Süß et al.	2002	128	M = 26.2, Range = 18-46	NEO-FFI	Storage and processing aggregate from 8 tasks					n.s.	r = .00				
					Coordination aggregate from 6 tasks					n.s.	r = -.01				
					Supervision aggregate from 3 tasks					n.s.	r = .01				
*Wetherell et al.	2002	704	M = 63.7-70.3	EPI short form	Digit span									n.s.	r = -.03
Kumari et al.	2004	11	M = 25.4, Range = 21-28	EPQ-R	N-back accuracy	n.s.	?							n.s.	?
					N-back RT	n.s.	?							n.s.	?
					Latent factor from 3 variables									1/1 <sup>b</sup>	r = -.34
Allen et al.	2005	86	M = 45.9, Range = 18-90	NEO-PI-S	Digit span forward	n.s.	?								
Fink et al. <sup>3</sup>	2005	62	M = 30.4, Range = 18-52	NEO-FFI	Modified counting span	n.s.	?								
*Baker &	2006	135	M = 33.9,	Big Five	Composite	n.s.	?	1/1	β = .19	n.s.	?	n.s.	?	n.s.	?

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														34			
Bischel <sup>4</sup>			Range = 19-60	Inventory	from 2 tasks												
		123	M = 69.2, Range = 61-89			n.s.	?	n.s.	?	n.s.	?	n.s.	?	n.s.	?		
		123	M = 70.1, Range = 61-89			n.s.	?	n.s.	?	1/1	$\beta = .19$	n.s.	?	n.s.	?		
Matthews et al.	2006	50	Range = 18-47	NEO-FFI	Operation span	n.s.	?	1/1	$r = .37$	n.s.	?	n.s.	?	n.s.	?		
Wilson et al. <sup>5</sup>	2007a	920	M = 73.5-80	NEO-FFI	Composite from 4 tasks							n.s.	E = 0.002 (SE = 0.004)				
*Wilson et al. <sup>6</sup>	2007b	1256	M = 76.8	NEO-FFI	Composite from 3 tasks									1/1	E = -0.013 (SE = 0.003)		
Ayotte et al. <sup>7</sup>	2009	103	M = 70.4, Range = 58-73	NEO-PI-R	Digit span	n.s.	$r = -.14$	n.s.	$r = .08$					n.s.	$r = -.19$	n.s.	$r = -.05$
De Young et al. <sup>8</sup>	2009	104	M = 22.7, Range = 18-40	NEO PI-R	N-back accuracy	n.s.	$r = -.08$	n.s.	$r = .14$	n.s.	$r = -.15$	n.s.	$r = .01$	n.s.	$r = -.05$		
					Average from 4 tasks	n.s.	$r = -.03$	n.s.	$r = .01$	n.s.	$r = .06$	n.s.	$r = .09$	n.s.	$r = -.05$		
Konig et al.	2009	122	M = 23.3, Range = 19-36	Big Five questionnaire	Latent variable from 3 tasks	n.s.	$r = .05$										
Unsworth et al.	2009	138	M = 19.1	NEO PI-R	Latent variable from 2 variables	n.s.	$r = -.19$	n.s.	$r = -.04$	n.s.	$r = -.16$	n.s.	$r = -.18$	n.s.	$r = .00$		
Gregory et al. <sup>9</sup>	2010	70	Range = 74-90	NEO PI-R	Sum score from 2 tasks							n.s.	$r = .15$				
Matthews & Campbell	2010	112	M = 21.2	EPQ-R	Operation span	n.s.	?									n.s.	?
Soubelet <sup>10</sup>	2011	164	M = 49.8, Range = 19-96	Big-Five 5 Broad Domains	Letter-number sequencing							1/1	$r_{part} = -.21$				
Tharp & Pickering	2011	48	M = 19.8, Range = 18-28	EPQ-R	Operation span	n.s.	?									n.s.	?
Aiken-Morgan et al. <sup>11</sup>	2012	291	M = 67.2, Range = 49-90	NEO PI-R	Factor weight composite from 3 tasks	n.s.	$\beta = -.02$	n.s.	$\beta = .11$	n.s.	$\beta = -.08$	1/1	$\beta = .16$	n.s.	$\beta = -.02$		
*Graham & Lachman	2012	4974	M = 55, Range = 32-84	MIDUS survey	Digit span	n.s.	$\beta = -.04$	1/1	$\beta = .06$	n.s.	$\beta = -.02$	n.s.	$\beta = .02$	1/1	$\beta = -.05$		
Studer-Luethi et al.	2012	99	M = 19.5	Mini-Marker Set	N-back accuracy							n.s.	$r = -.06$	n.s.	$r = -.07$		

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					Dual n-back accuracy					n.s.	r = -.03			n.s.	r = -.01
Wang <sup>12</sup>	2012	222	Undergraduates	IPIP	Operation span			1/1	r = .17	n.s.	r = -.06 - .08				
Boyd & Oswald	2013	102	M = 19.1	IPIP	Composite from 2 tasks					n.s.	r = -.15				
Steinberg et al.	2013	125	M = 77 Range = 65-95	NEO-FFI	N-back	n.s.	?	n.s.	?	n.s.	?	n.s.	?	n.s.	?
Benedek et al.	2014	230	M = 23, Range = 18-45	NEO-FFI	N-back accuracy			n.s.	r = .02 - .11						
Costantini et al. <sup>13</sup>	2015	141	M = 22.6	64 markers	Operation span					1/3 <sup>c</sup>	-.22 - -.26				
Buchanan Study 3 <sup>14</sup>	2016	103	M = 20.2 Range = 18-41	NEO-FFI & IPIP	Composite from 2 tasks	n.s.	β = .02	n.s.	β = .09	n.s.	β = -.04	n.s.	β = .02	n.s.	β = .18
Fleming et al.	2016	420	M = 22.5, Range = 21-30	NEO-FFI	Latent factor from 3 tasks	n.s.	β = -.06	n.s.	β = .06	n.s.	β = -.04	n.s.	β = .00	n.s.	β = .06
Smeeckens & Kane Exp 2 <sup>15</sup>	2016	115	M = 18.8, Range = 18-28	NEO PI-3	Composite from 2 tasks			n.s.	r = -.16						
Smillie et al. Exp 1 <sup>16</sup>	2016	79	Range = 18-45	BFAS & NEO IPIP	Interleaved dual task			1/2	r = -.24 & r = .08						
Smillie et al. Exp 2 <sup>17</sup>	2016	81	Range = 18-48	BFAS & NEO IPIP	Interleaved dual task			n.s.	r = -.11 & r = -.19	n.s.	r = -.06				
					N-back accuracy			n.s.	r = -.01 & r = .01	n.s.	r = -.03				
Chapman et al.	2017	179	M = 82.1	NEO-FFI	Digit span	n.s.	?	n.s.	?	n.s.	?	n.s.	?	n.s.	?
Kane et al.	2017	271	M = 18.7, Range = 18-35	NEO FFI-3	Factor score from 6 tasks	n.s.	r = -.07	1/1	r = .18	n.s.	r = -.01	n.s.	r = .04	n.s.	r = -.04
Mulligan et al.	2017	29	M = 70.8, Range = 65-79	Big Five Inventory	N-back accuracy									n.s.	?
Peltier & Becker	2017	144	Range = 18-24	Mini IPIP	Change detection task	n.s.	r = .01	n.s.	r = -.09	n.s.	r = -.07	n.s.	r = .01	n.s.	r = .07
Robison et al.	2017	201	M = 19.4	44-item Big Five Inventory	Latent factor from 3 tasks									1/1 <sup>b</sup>	-.29
Chuderski & Jastrzębski	2018	305	M = 24.5, Range = 18-46	NEO-FFI	Storage aggregate from 3 tasks	n.s.	r = .03	n.s.	r = .02			n.s.	r = -.01	n.s.	r = -.07
					Storage & Processing aggregate from 3 tasks	n.s.	r = .06	n.s.	r = .03			n.s.	r = .06	n.s.	r = -.07

Updating aggregate from 1 task	n.s.	r = .07	n.s.	r = .04	n.s.	r = -.11	1/1	r = -.18
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Note. \* Found in Table 1 of Curtis et al. (2015), not in the present systematic search. WM = Working memory, ES = Effect size, EPI = Eysenck Personality Inventory, NEO-FFI = NEO Five-Factor Inventory, EPQ-R = Eysenck Personality Questionnaire-Revised, NEO-PI = NEO Personality Inventory, IPIP = International Personality Item Pool, BFAS = Big Five Aspects Scales, Ex = Extraversion, Op = Openness, Co = Conscientiousness, Ag = Agreeableness, Ne = Neuroticism, gray cell = positive association (higher personality trait score = better WM performance), black cell = negative association, n.s. = non-significant association, empty cell = not assessed or analyzed, r = Pearson correlation coefficient,  $\beta$  = standardized beta coefficient, ? = effect size not reported.

For this Table, mainly trait-level associations are reported. Facet-level associations have been included in the table if a study has only included facets. If both trait and facet-level associations have been included, then the table includes traits while the facet-level associations are mentioned below.

<sup>1</sup>For this Table, cross-sectional data from Time 1 has been included. Agreeableness and Conscientiousness had no significant zero-order correlations, and were therefore not analyzed further. For the other traits, latent trait scores were derived from facet scores. Extraversion included the facets Warmth, Gregariousness, Positive Emotions, and Feelings (a facet of Openness). Neuroticism included the facets Anxiety, Depression, and Vulnerability. Openness was divided into Openness to Experience (including the facets Fantasy, Aesthetics, Feelings, Values, and Positive Emotions from Extraversion) and Openness to Ideas (only the Ideas facet).

<sup>2</sup>Extreme groups comparison (Extraverts/Introverts). The direction of the correlation has been reversed in this table for the sake of consistency.

<sup>3</sup>Group comparison according to median split of Extraversion.

<sup>4</sup>Participants split into three samples: Young adults, older adults who were cognitively comparable to the young adults, and cognitively superior older adults. Short-term memory (derived from the Woodcock-Johnson Tests of Cognitive Abilities) was evaluated to reflect working memory.

<sup>5</sup>Mixed-effects models adjusted for age, sex, and education.

<sup>6</sup> Mixed-effects models adjusted for age, sex, and education. Six items from the 12-item NEO-FFI Neuroticism scale was used to measure Neuroticism.

<sup>7</sup>Only the bivariate correlations for the non-depressed participants have been included.

<sup>8</sup>Openness was not significantly correlated with either n-back or working memory capacity, but the Ideas facet of Openness was significantly correlated with n-back performance ( $r = .23$ ) and working memory capacity ( $r = .19$ ), while the Values facet was significantly correlated with n-back performance ( $r = .23$ ) but not working memory capacity.

<sup>9</sup>The working memory – Openness correlation was non-significant, but the Values facet of Openness was significantly correlated with working memory ( $r = .28$ ).

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<sup>10</sup>Partial correlation where age has been partialled out.

<sup>11</sup>Agreeableness was significantly associated with working memory performance, while the other traits were not. The facets Assertiveness (Extraversion) ( $\beta = .12$ ), Straightforwardness (Agreeableness) ( $\beta = .12$ ), Tender-mindedness (Agreeableness) ( $\beta = .13$ ), and Self-Discipline (Conscientiousness) ( $\beta = -.14$ ) were significantly associated with working memory performance while controlling for age, education, and sex.

<sup>12</sup>Conscientiousness measured only on the facet level. None of the six tested Conscientiousness facets were significantly associated with working memory.

<sup>13</sup>Working memory significantly associated with the Orderliness facet of Conscientiousness. Conscientiousness measured only on the facet level (the authors derived a three-facet structure of Conscientiousness: Impulse Control, Industriousness, and Orderliness).

<sup>14</sup>For this table, the regression model in Table 9 containing the Webexec questionnaire (not the DEX) was chosen at random.

<sup>15</sup>Working memory capacity non-significantly correlated with Openness, but significantly negatively with the Actions facet of Openness ( $r = -.28$ ).

<sup>16</sup>Only the associations involving the Secondary task under high load has been included from the Interleaved dual task. Working memory was significantly negatively associated with Openness, but not with Intellect (two facet model of Openness/Intellect).

<sup>17</sup>Only the associations involving the Secondary task under high load has been included from the Interleaved dual task. Working memory was non-significantly associated with Openness, Intellect (two facet model of Openness/Intellect), and the Industriousness facet of Conscientiousness. Conscientiousness measured on the facet level with only the facet Industriousness.

<sup>a</sup>Correlations chosen before t-test results.

<sup>b</sup>Correlation between latent factors chosen before bivariate correlations.

<sup>c</sup>Bivariate correlations between principal components and Operation span chosen instead of bivariate correlations separately for all personality measures.

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Table 2

*Demographic information of the study sample*


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Age in years	$M = 34.15$ ( $SD\ 10.57$ ), range = 18-71
Gender	56.5% female, 43.3% male, 0.2% other
Educational attainment	$M = 5.03$ ( $SD\ 1.35$ ), range = 1-7, 53.7% report having a Bachelor's or Master's degree
Estimated household wealth during childhood <sup>a</sup>	$M = 3.88$ ( $SD\ 1.26$ ), range = 1-7

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*Note.* Educational attainment classification: 1 = Primary education, 2 = Lower Secondary education, 3 = Higher Secondary education, 4 = Basic vocational education, 5 = Vocational university / Other upper vocational education, 6 = University: Bachelor's or Master's degree, 7 = University: Doctoral degree. Household wealth during childhood subjectively estimated on a scale from 1 (very poor) to 7 (very wealthy). <sup>a</sup> Data missing for 3 participants.

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Table 3

*Correlations between the working memory composites and the Big Five personality traits*

	Verbal	Spatial	N-	Ex	Ag	Co	Ne	Op
Verba	1							
Spatia	.556**	1						
N-	.414**	.562**	1					
Ex	.021	-.040	-.090*	1				
Ag	-.020	-.060	-.048	.040	1			
Co	-.039	-.085	-.103*	.073	.091**	1		
Ne	-.057	-.018	-.011	-.139**	-.316**	-.302**	1	
Op	.028	.002	-.096*	.273**	.203**	.045	-	1

*Note.* WM = working memory, Ex = Extraversion, Ag = Agreeableness, Co =

Conscientiousness, Ne = Neuroticism, Op = Openness. \*\*  $p < .01$ , \*  $p < .05$ .  $N = 503$ .

## Appendix.

### Systematic literature search: Methods and Results

#### Systematic search

A systematic search was performed using Google Scholar and the PubMed and PsycINFO databases. For Google Scholar, the search string ““big five" OR neuroticism OR agreeableness OR conscientiousness OR openness OR intellect OR extroversion OR extraversion "working memory" –child” yielded about 19700 hits (search performed 8<sup>th</sup> Sep 2017) of which the first 150 as sorted by relevance were evaluated for inclusion. For PubMed, the search string ““working memory” AND (“big five” OR neuroticism OR agreeableness OR conscientiousness OR openness OR intellect OR extroversion OR extraversion) NOT child” yielded 86 hits (search performed 29<sup>th</sup> Aug 2017) that were all evaluated for inclusion. For PsycINFO, the search string “(("working memory" and ("big five" or neuroticism or agreeableness or conscientiousness or openness or intellect or extroversion or extraversion)) not child).af.” yielded 2385 hits (search performed 13<sup>th</sup> Sep 2017). The search was therefore further restricted to the abstract which yielded 106 hits that were all evaluated for inclusion.

A second literature search was performed in February 2018 where the keywords were expanded to include executive functions. For Google Scholar, the search string “((personality OR "big five" OR neuroticism OR agreeableness OR conscientiousness OR openness OR intellect OR extroversion OR extraversion) AND ("working memory" OR "executive function" OR "executive task")) –child” yielded about 23 600 hits (search



performed 8<sup>th</sup> Feb 2018) of which the first 200 as sorted by relevance were evaluated for inclusion (147 novel articles). For PubMed, the search string “(“working memory” AND (“big five” OR neuroticism OR agreeableness OR conscientiousness OR openness OR intellect OR extroversion OR extraversion)) OR (“executive function” AND (“big five” OR neuroticism OR agreeableness OR conscientiousness OR openness OR intellect OR extroversion OR extraversion)) OR (“executive task” AND (“big five” OR neuroticism OR agreeableness OR conscientiousness OR openness OR intellect OR extroversion OR extraversion)) NOT child)” yielded 183 hits (search performed 1<sup>st</sup> Feb 2018) that were all evaluated for inclusion (97 novel articles). For PsycINFO, the search string “(((“working memory” and (“big five” or neuroticism or agreeableness or conscientiousness or openness or intellect or extroversion or extraversion)) or (“executive function” and (“big five” or neuroticism or agreeableness or conscientiousness or openness or intellect or extroversion or extraversion)) or (“executive task” and (“big five” or neuroticism or agreeableness or conscientiousness or openness or intellect or extroversion or extraversion))) not child).ab.” yielded 167 hits (search performed 1<sup>st</sup> Feb 2018) that were all evaluated for inclusion (26 novel articles).

### **Inclusion criteria**

To be included, a study had to be written in English. As we were interested in WM-Big Five associations, we restricted ourselves to studies that reported constructs that were clearly indicative of WM function. We did not include studies that investigated, for example, more broadly executive functions or dorsolateral prefrontal function, inhibition, or fluid intelligence, unless WM was clearly separated. The study also had to report direct associations between at least one of the Big Five traits or facets and WM. Studies with

extreme group comparisons, such as studies comparing participants with highest versus lowest Extraversion scores, were included. Hence, studies reporting associations between only, for example, State-Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) or Behavioral Inhibition System and/or Behavioral Activation System (Carver & White, 1994) and WM were excluded. Likewise, studies reporting the association between interacting personality traits (e.g., participants high in Neuroticism and low in Extraversion) and WM were excluded. As we focused on healthy adult participants, studies reporting associations in clinical samples or samples with participants under 18 years of age were not included. We excluded a study if only an abstract was available and the abstract contained no mention of WM and personality, Big Five, or any of the Big Five traits. We also excluded one study (Pearman, 2009) whose sample was included in a much larger one (Graham & Lachman, 2012). Following these criteria, 33 studies were included. Finally, the articles included in the review by Curtis et al. (2015) were assessed for inclusion using the same criteria that are detailed above. This resulted in six additional studies being included in the present review, adding up to a total of 39 studies.

## Results

A detailed presentation of the results is given in Table 1, and here we shortly summarize the findings. For Table 1 and this summary, we have focused on trait-level associations. This means that we have included trait-level associations when available, and facet-level associations only when trait-level associations are not available or have not been reported. Facet-level associations are reported in the Notes of Table 1. *Extraversion*. The relationship between Extraversion and WM performance was investigated in 25 of the

included samples. Two (8%) of them showed statistically significant associations that were all positive, indicating that higher Extraversion was related to better WM performance. *Openness*. The relationship between Openness (or a facet of Openness, see General Discussion) and WM performance was examined in 23 samples. The results from six (26.1%) of them revealed statistically significant positive relationships, with higher Openness being associated with better WM performance. A negative relationship between Openness and WM performance was seen in one (4.3%) sample.

*Conscientiousness*. Out of the 23 samples investigating the relationship between Conscientiousness and WM performance, two (8.7%) found statistically significant negative associations. Thus, in these two samples, lower Conscientiousness was associated with better WM performance. A negative association between Conscientiousness and WM was seen in one (4.3%) sample. *Agreeableness*. One (5.9%) out of 17 samples reporting associations between Agreeableness and WM performance showed a statistically significant positive relationship, with higher Agreeableness being associated with better WM performance. *Neuroticism*. The relationship between Neuroticism and WM performance was investigated in 27 samples. Six (22.2%) of them showed a statistically significant negative relationship, so that lower Neuroticism was related to better WM performance.