Neuroticism affects working memory and training performance in regularly developed school children

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Abstract

There are high individual capacity differences in working memory (WM), a core cognitive ability influencing the development of basic academic skills. Furthermore, the sparse studies investigating the possibility to train WM in children found high individual differences regarding training success. The investigation of the relationship between WM and personality is an important process to find out more about possible reasons for such differences. In Study 1, we examined the performance of 258 school-age children (7 to 12 years) in two WM tasks in relation to their level of neuroticism (emotional instability). Children completed measures of WM (visual n-back task; complex animal span task) and general intellectual abilities (fluid and crystallized intelligence). Our results indicate that high neuroticism scores predict poorer performance in WM tasks, even when controlling for age and general intelligence. In Study 2, we investigated the influence of neuroticism on WM training performance. During four weeks, 34 of the children trained on the same two WM tasks. Even though children with high and low neuroticism, respectively, significantly improved their performance in the WM tasks, there was a detrimental effect of neuroticism on training improvement. We conclude that the level of neuroticism can be considered as a negatively modulating psychological variable on WM capacity and WM training gain. Notwithstanding, higher levels of neuroticism do not prevent training-related improvements in WM performance. The results are discussed in the context of the attentional control theory and implications are made regarding the importance of special support of emotionally instable children with WM-related or non-cognitive interventions.

1. Introduction

A concern of educational research has always been the understanding of the determinants for individual differences of scholastic achievements. Working memory (WM) is one factor which was found to account for such differences. However, research has also shown that ability factors alone are insufficient to fully explain individual differences in academic performance (Chamorro-Premuzic & Furnham, 2006). Non-cognitive factors, first and foremost personality dispositions, were found to play an important part in cognitive abilities related to academic success. Therefore, research on personality and its relationship with cognitive abilities has increased and exerts high influence. In the meanwhile, there is ample evidence for the relationship between some personality traits and intelligence and academic success (see Ackerman & Heggestad, 1997; Poropat, 2011, for reviews), but research regarding the relationship between personality and WM is sparse. Furthermore, most studies investigated samples of young or older adults, whereas investigations of personality and WM capacity in school children are very rare. Considering the high importance of WM capacity for scholastic achievements, we consider it as a need to broaden our understanding of individual factors in personality which are related to WM capacity as well as to WM training performance. On the one hand, such findings may carry important implications for how impairments in WM are characterized and even diagnosed in school. On the other hand, they emphasize the potential that lies in school interventions focussing on cognitive and non-cognitive abilities.

2. Working memory in school

The Working Memory (WM) provides a mental workspace in which we can hold information over short periods of time and simultaneously manipulate it. WM capacity is an effective predictor for a wide range of measures of academic abilities, i.e., literacy and mathematics, as well as learning and scholastic attainment in general (see Alloway, 2006, for a review). This relationship is present even beyond general intelligence (Kane et al., 2004). The importance of WM capacity for scholastic success is not surprising regarding the crucial role of WM in many learning activities in the classroom: While engaging in an effortful activity, children often have to hold rules or other information in mind, as for example the teacher's instructions, or an intended answer. Typical classroom activities often put a strong emphasis on processing or storage or both, and are notorious to place excessive demands on limited resources, making it difficult for children with low WM capacity to complete such tasks. As a result, learning episodes and the process of skill and knowledge acquisition are disrupted and lead to poor academic progress over the school year (Alloway, 2006). Such findings have reinforced the call to find different ways to identify WM impairments as early as possible. An attempt to do so is broadening the understanding of the relationship of WM capacity and personality in children.

2.2. Working memory and personality

According to the well-established WM model of Baddeley (1986), WM is conceptualized as systems of domain specific temporary storage and a domain-general central executive. While the first is mediated by the phonological loop, which specializes in the temporary storage of verbal items, and the visuo-spatial sketchpad, which provides the maintenance of visual-spatial representations, the latter is responsible for attentional and processing control. As Eysenck and his colleagues resume in their attentional control theory (ACT), it is this executive attention which is most sensitive to detrimental effects of anxiety (Derakshan & Eysenck, 2009; Eysenck, Derakshan, Santos, & Calvo, 2007). According to the ACT, the worrisome thoughts result in cognitive interference, which impair the functions of the central executive, including updating, inhibition, and shifting. Latter functions play an important role in complex cognitive tasks involving more than simple retention of material. Hence, it does not astonish that performance in complex WM tasks was found to be negatively associated with anxiety (Derakshan & Eysenck, 1909), with poor emotional regulation (Schmeichel, Volokhov, & Demaree, 2008) as well as with self-reported behavioral inhibition (Shackman et al., 2006). All of these traits are related to neuroticism, suggesting a negative relationship between this trait and WM. Neuroticism is the personality trait of the Five Factor Model (FFM; Eysenck & Eysenck, 1964) expressing the degree of emotional instability and vulnerability to stress. That is, subjects with high neuroticism have easier tendency to experience feelings such as anger, guilt, anxiety and depression.

3. The current studies

While the personality factor most commonly found to be associated with general intelligence has been openness, studies examining the personality-WM relation have primarily focused on trait measures related to neuroticism, as outlined above. Since there is only little evidence demonstrating the predictive validity of neuroticism on WM performance of school-aged children, Study 1 aimed to examine this association in a large sample of children in second or fifth grade.

Even though there is growing evidence of the promising possibility to train WM in children, the examination of the effects of individual differences in personality on the performance in such trainings is very rare. Therefore, Study 2 aimed to examine the effects of neuroticism on the improvement in the WM training task using the same two WM tasks as in study 1.

4. Study 1

Regarding young children, the relationship between neuroticism and WM has not yet been established. However, there has been some evidence for a detrimental effect of trait anxiety on WM performance, even though this effect is less clear than in adults (see Visu-Petra, Ciairano, & Miclea, 2006, for a review).

So far, no differences across different age groups of children have been reported regarding the association between WM capacity and anxiety. Considering the development of WM, there a linear increase in performance which continues to about 12 years and levels off towards 15 years. Considering neuroticism, most researchers reported that it is a stable trait between the age of 7 and 16. Therefore, there is no reason to believe that age modulates the relationship between these two factors. To confirm this assumption, second and fifth graders were included in this study.

In this first investigation, we used two WM tasks that have previously been applied in studies, a visual n-back task, which is often used as a complex WM task, as well as a complex animal span task, a more enjoyable task for children (c.f. Jaeggi, Buschkuehl, Jonides, & Shah, 2011; Loosli, Buschkuehl, Perrig, & Jaeggi, 2010). Both tasks require executive control of the WM, since updating and shifting, as well as inhibition in the n-back task, are crucial processes for a successful performance. To eliminate effects of general intelligence on WM performance, we included proxies for fluid as well as crystallized intelligence as control variables in our analyses. Fluid intelligence (*Gf*) refers to the mainly inherited ability to solve complex problems and was measured with a matrix reasoning test, while crystallized intelligence (*Gc*) involves acquired knowledge and skills and was measured with a vocabulary test (cf. Horn & Cattell, 1966).

Building upon the ACT and some related prior findings, we expected to find a detrimental effect of neuroticism on the WM tasks, and we expected it to be observable in both school-age groups.

4.1. Methods

4.1.1. Participants and procedure

A total of 265 children (147 boys) were recruited from seven different primary schools in Switzerland. Their age ranged from 7 to 13 years (M = 9.35; SD = 1.59) and they attended either the second (N = 161;

mean age = 8.17) or the fifth (*N* = 104; mean age = 11.20) school grade. Beside the written consent of the parents for their children to participate in the study, no exclusion criteria were applied at recruitment. The children provided demographic information including age, gender and mother tongue. 85 % of the children reported Swiss German and 15 % of the children another language to be their first language.

During a regular school lesson with the whole class, the children completed the paper pencil tests first, starting with the matrix reasoning test, followed by the personality questionnaire and the vocabulary test at the end. In the following lesson, participants were tested on the two computer-based WM tasks in groups of up to 15 people on individual computers.

Based on the median split of the personality scale, children were classified as LN (Low neuroticism; *N* = 136, mean N score = 4.89, *SD* = 2.10) and HN (High neuroticism; *N* = 129, mean N score = 12.82, *SD* = 2.61).

4.1.2. Measures

Personality measure: We used part of the form 1 of the „Hamburger Neurotizismus- und Extraversionsskala für Kinder und Jugendliche“ (HANES, KJ; Buggle & Baumgärtel, 1975), which is a self-reported questionnaire for the acquisition of the personality trait neuroticism. The questionnaire is based on Eysencks’ theory (Eysenck & Eysenck, 1964) and is one of the most common German personality questionnaires for children and adolescents (8-16 years). We selected the 20 questions targeted on neuroticism, which the study leader read aloud to the children. Children were allowed to ask when they did not understand a question. They indicated yes or no for each question. In the present sample, cronbach alpha for the neuroticism scale was .79.

Working memory tasks: As a visual-spatial WM task, we chose a s*ingle n-back task* with visual-spatial stimuli as used before (e.g. Jaeggi et al., 2010). However, we applied different colours for the visual stimuli in each level of n in order to help children to distinguish between the different task levels which were adaptive to their individual performance: The program automatically increased the level of n if the child made fewer than 3 mistakes. If the participant made more than 5 mistakes, the level of n was decreased by one and in all other cases, the set size remained unchanged. The average level of *n* reached during five minutes was used as the dependent variable.

As a second WM task which involves verbal rehearsal processes, we chose the *animal span task* as used before (Looslie et al., 2011). In this task, children see a sequence of animals (which names can be pronounced with two syllables) in the centre of the computer screen. Each animal appears either normally or upside-down. The first task of the children is to decide as quickly as possible on the orientation of the animal by pressing the right (for normal orientation) or the left mouse button (for upside down). At the end of each animal sequence, the second task of the children is to reproduce the previous sequence in the correct order by clicking on one animal after the other. In this task too, difficulty level was automatically adapted to the child’s performance after each trial: If the child responded correctly within 3000 ms in orientation decision and made no mistake in the reproduction of the sequence, the next sequence length was increased by one animal. By contrast, the sequence length was reduced by one animal if the child did not correctly reproduce the sequence. In all other cases, the sequence length remained unchanged. The averaged sequence length reached during five minutes served as the dependent variable.

General intelligence tasks: As a proxy for *crystallized intelligence*, we used the “Wortschatztest CFT-WS” (Weiss, 1998) which captures the vocabulary beyond the basic vocabulary of the German language. It measures the stage of development of verbal ability and capacity. According to the Horn-Cattell theory (Horn & Cattell, 1966) it measures an important part of the general crystallized intelligence. We used parallel forms which contained 30 key words each. For each key word, one of 5 sample words needed to be chosen as the most semantically similar word. The dependent variable was the number of correct answers. Split half reliability was r = .83.

As a proxi for *fluid intelligence*, we applied the „Raven’s Standard Progressive Matrices“ (SPM; Raven, 1999). The matrices are appropriate for children and adolescents (6 – 16 years). We used half of the original form as parallel versions (odd and even items) and set a time limit of 10 minutes. Each version contained 24 items which become increasingly difficult. Children were asked to solve as many tasks as possible. The dependent measure was the number of correct solutions. Split half reliability was r = .82.

4.1.3. Results

Zero-order correlations among the personality factors and the WM and general intelligence scores are displayed in Table 1. Considering the whole sample of children, neuroticism was negatively associated with performance in both WM tasks. Neuroticism explained 18% of the variance of the mean score in both WM tasks (β = .42; $F(2, 224)$ = 5.18, $p < .01$, adjusted R^2 = .14; Cohen's f^2 = .23). Furthermore, there was a negative correlation between neuroticism and crystallized intelligence.

Table 1. Correlations among neuroticism, working memory and fluid as well as crystallized intelligence measures across and within the second and fifth school grade

	General intelligence measures						Working memory measures					
	fluid			crystallized			Complex animal span			Visual n-back		
	all	2nd	5th	all	2nd	5th	all	2nd	5th	all	2nd	5th
Neuroticism	.02	-.03	.11	-.15*	-.11	-.18	-.44**	-.35**	-.41**	-.32**	-.32**	-.21*

Examining the two school-age groups separately, we found that the negative correlations between the WM tasks and neuroticism were present in both age groups.

To further investigate the relationship of interest between neuroticism and WM by controlling for general intelligence and age, analyses with high and low neuroticism groups (HN, LN, respectively) were conducted. The mean WM task scores for the groups are demonstrated in Figure 1. A MANCOVA was conducted with the scores from the two WM tasks as dependent variables and with neuroticism group (HN vs LN) as a between-subject factor. Age and intelligence (*Gf, Gc*) were included as covariates.

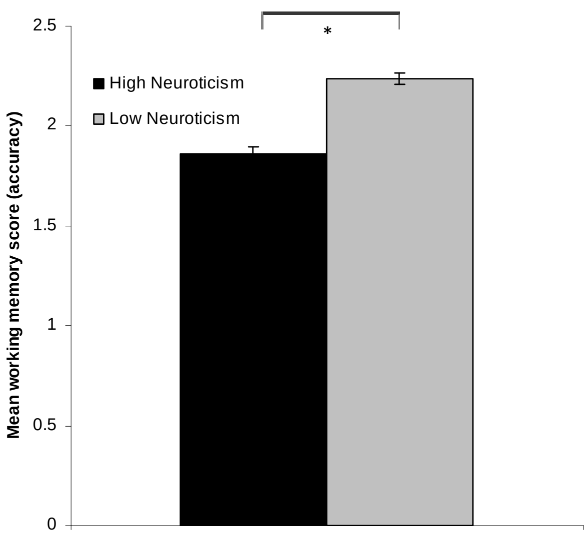

Figure 1. Mean working memory task performance of children with high or low levels of neuroticism

The results indicated a significant effect of Group on the WM tasks, Wilk's lambda = .87, $F(2,124) = 3.4$, $p < .05$, partial $\eta^2 = .09$ In contrast, a MANCOVA with the scores from the intelligence measures (*Gf, Gc*) as dependent variables, with neuroticism group (HN vs LN) as a between-subject factor and age as covariate did not show significance, Wilk's lambda = .99, $F(2, 169) = 1.16$, *n.s.*

4.1.5. Discussion

In our first study we examined the association of neuroticism with WM performance in a group of school children by controlling for age and general intelligence. For a successful performance of the WM tasks used in this study, processes of the central executive, including updating, inhibition, and shifting, are crucial. In line with the attentional control theory (ACT), it was assumed that neuroticism will impair these processes, because neuroticism-related worries and anxiety detract mental resources and interfere with efficient functioning of the executive component of the WM which is crucial for attentional control. Our results supported the hypothesis: We found that the level of neuroticism was a valid predictor for performance in complex WM tasks, in that children with higher levels of neuroticism showed poorer WM capacity compared to children with lower neuroticism levels, even when controlling for age and general intelligence. While some earlier studies are in line with this result, to our knowledge this study is the first one to demonstrate that neuroticism, one of the personality traits of the well established Five Factor Model, affects performance in complex WM tasks in school-aged children. In line with the literature (cf. McVay & Kane, 2009), our results suggest that children with high neuroticism might experience more task-unrelated thoughts (e.g. worry) and negative emotions which might consume or interfere with attentional control processes of the WM and therefore lead to lower WM performance.

From a developmental perspective, our results indicate that neuroticism and WM performance are comparably associated in the two age groups of two- and fifth-graders. The results therefore imply that the neuroticism-WM capacity relationship is stable during brain maturation and WM improvements related to natural development during primary school.

Regarding the crucial role of the WM in school, as e.g. for reading and math, these findings bear important implications about possible underperformance of children with high neuroticism. Even though their general intelligence may be on a similar level as their counterparts' with lower levels of neuroticism, their performance in different school tasks may be lower because of disrupted WM processes.

5. Study 2

Given the well-documented importance of WM for scholastic achievements, there have been some investigations aiming to train WM in children with attentional deficits (Klingberg et al., 2005). In a recent study with typically developing children, Jaeggi et al. (2011) found that some children improved on the WM training task, whereas others did not. They discuss lack of interest or problems coping with the difficulty of the WM task as possible explanations for the fact that some children failed to show improvement in the WM task. However, it is largely unknown if and how individual differences in personality may influence such training gain. Some indications of a detrimental influence of neuroticism (Yesavage, 1989) or related traits, namely depressive symptoms (Bäckman, Hill, & Rosell, 1996) and anxiety (Yesavage & Jacobs, 1984), on memory training outcomes in adults exist. In line with that, a more recent study indicated a detrimental influence of neuroticism on training performance in the challenging dual WM task condition in a sample of university students (Studer-Luethi, Jaeggi, Buschkuehl, & Perrig, submitted). However, to our knowledge such relations have not been examined in young children. To improve interventions which help children to increase their WM capacity, gaining knowledge of personal factors that influence training performance is crucial.

Therefore, in this second study building upon our first analyses confirming the negative association between neuroticism and performance in WM tasks, we aimed to investigate whether the detrimental effect of neuroticism on WM task performance will be observable regarding the progression of training task performance in a WM training. Based on the theoretical assumptions of the ACT, two possible hypotheses could be postulated.

On the one side, children with high neuroticism and related distractions, such as anxiety or worry, may experience difficulties allocating the necessary cognitive resources to the training task in order to increase their performance. In this case, we would expect that children with high levels of neuroticism would show lower training task improvement (difference score between the first and the last training session) in addition to their lower training mean scores compared to their counterparts with low neuroticism.

On the other side, even though the WM training tasks used in this study stay challenging because their difficulty is incessantly adapted to the child's performance, the repetition of the WM task could reduce cognitive load and task-related anxiety. According to the ACT, this would reduce the detrimental effects of neuroticism-related interferences on the executive control of the WM. In this case, we would expect that children with high levels of neuroticism will improve their performance in the WM tasks equally then their counterparts with low neuroticism. Thus, children with high neuroticism could catch up with children with low neuroticism regarding the performance in the WM tasks.

5.1. Method

5.1.1. Participants and procedure

For the WM training, we randomly selected 34 children (21 boys) from the second school grade (*M* = 8.21; *SD* = .43). They participated in a daily 15 minutes long WM training over a period of four week. The training sessions were part of the regular school lessons and the teachers determined the times for the daily training. The children trained in groups of 8 to 13 children on individual computers in the lab rooms of the school.

Based on the median split of the personality scale, children were again classified as LN (Low neuroticism; N = 16, mean N score = 5.94, *SD* = 2.72) and HN (High neuroticism; N = 15, mean N score = 14.27, *SD* = 2.46).

5.1.2. Measures

As WM training tasks, we applied the same tasks used in study 1, namely the *adaptive complex animal span adaptive visual-spatial n-back task* sessions. For each of the two WM tasks, we calculated the training mean and the training gain. Training mean was defined by the mean level achieved in all of the 20 training sessions, and training gain was calculated by subtracting the mean level achieved in the first two training sessions from the mean level achieved in the last two training sessions (cf. Jaeggi et al., 2011).

5.2. Results

Because of the lack of preliminary findings in the literature, we did not postulate a direct hypothesis and conducted two-sided analyses.

To investigate the improvement pattern in the WM training tasks as a function of HN and LN, we conducted a repeated measures ANCOVA with the mean task score achieved in the first two and in the last two training sessions, respectively, as dependent variables and with neuroticism group (HN vs LN) as a between-subject factor. Again, general intelligence measures (*Gf, Gc*) were included as covariates. Regarding the n-back task, we found a significant effect of neuroticism group on task improvement, Wilk's lambda = .89, $F(1,32) = 9.20$, $p < .01$, partial

η^2 = .15. Children in both neuroticism groups showed significant training task gain within the 20 training sessions (HN: $t(14) = 4.09$, LN: $t(15) = 4.29$; both p = .001), but HN children demonstrated significantly lower gain in the training task compared to LN children ($F(1,32) = 2.77$, $p < .05$; see Figure 2).

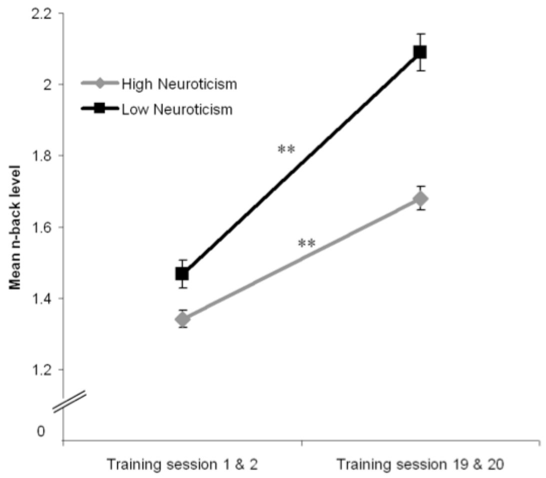

Figure 2. Improvement in the n-back task from the first to the last two training sessions for children with high or low levels neuroticism

Furthermore, analyses regarding the mean level reached in the n-back training task confirmed that children in the HN group trained on a lower mean level compared to children in the LN group ($F(1,32)$ = 3.38, $p < .05$; see Figure 3). Regarding the animal span task, the tendencies were the same, but they failed significance ($F(1,30) = 2.18$, $p = .08$).

5.3. Discussion

The objective of this second investigation was to ascertain whether or not neuroticism presents a significant relation with the WM training gain obtained by a group of young children. With regard to the n-back task, it appears that the training gain is modulated by the personality trait neuroticism, giving rise to a significant interaction between the improvement in the n-back level and the level of neuroticism. That is, children with higher emotional stability had the most WM training benefit. However, it is important to note that not only these children, but also those with high neuroticism demonstrated a significant improvement in the WM task. Furthermore, not only the gain but also the mean n-back level obtained within the 20 training sessions co-varied with the measure of neuroticism, confirming the stability of the negative neuroticism-WM capacity relation.

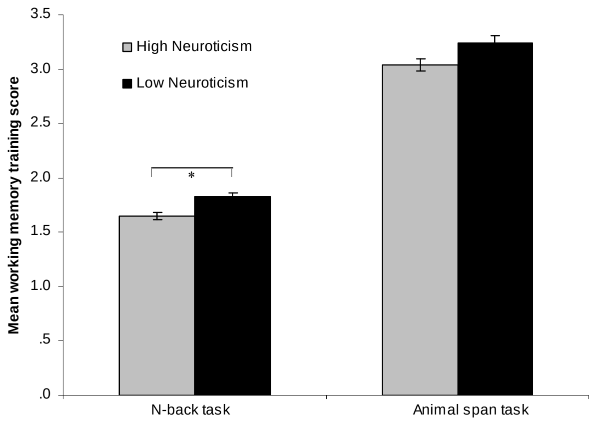

Figure 3. Mean scores in the n-back and the animal span tasks for children with high or low levels of neuroticism

For the complex animal span task, the result pattern was similar, but not statistically significant. A possible reason could be that the animal span task is less wearing and complex compared to the n-back task which is quite challenging for children in this young age. Furthermore, the animal span task does not include inhibitory WM processes to the same extent as does the n-back task. Whereas updating and shifting are shared requirements in both tasks, inhibition is crucial for a successful performance of the n-back task only. Regarding this difference, our results are in line with the suggestion of several researchers that neuroticism-related traits, such as depression, are associated with deficits particularly in inhibition (Joormann, 2005). Therefore, it seems explainable that this decreased ability of subjects high in neuroticism to successfully inhibit negative emotions exerts a negative effect on the trainability of an n-back task that requires strong inhibition processes of the WM.

In sum, the results of this investigation confirm and extend the results of our first investigation by indicating a detrimental effect of neuroticism not only on continuous WM performance, but also on WM improvements within a four-week WM training.

6. General discussion

As a solid body of literature demonstrates, poor WM capacity is a risk factor for learning difficulties and derogated long-term academic success. Yet, poor WM is not generally associated with low cognitive abilities, implicating that children with undiagnosed poor WM are at risk of missing the chance to exploit their full academic potential. On these grounds it seems crucial to identify affected children as early as possible and to give them the specific support they need. Better insight into the processes leading to poor WM capacity is very important for this aim. The findings of the present study demonstrate the relevance of neuroticism, i.e., the degree to which a child can be described as emotionally instable and prone to stress or anxiety, when seeking to explain the individual differences in WM performance as well as in WM training performance achieved by a population of school-aged children.

The first study demonstrated decreased performance in two complex WM tasks in second and fifth graders with higher levels of neuroticism.

The second study, investigating the effects of neuroticism on performance in a four-week WM training, on the one hand, demonstrated that performance in WM tasks can be trained and significantly improved in both children with low levels of neuroticism as well as in children with higher levels of neuroticism. On the other hand, even though neuroticism does not completely prevent WM improvements, it was found to have a debilitating effect on WM training gain. Taken together, children with high neuroticism, associated with emotional and cognitive distractions and hence impaired WM capacity, are able to significantly improve their WM performance, albeit training-related progresses can be expected to be weaker and slower than in emotionally stable children.

Among the potential limitations of the present study, an important point is the reliance on the self-reported personality data. Even though self-reports in children after 7 years were shown to be reliable and the test proved satisfying reliability in the present data, the possibility of a lack of young children's understanding of the questionnaire still exists. To control for this tentativeness, we conducted a parent-assessed personality measure for the children in the second study, namely the questionnaire HiPIC (Bleidorn, & Ostendorf, 2009). Parents were asked to assess the level of their child's neuroticism by answering several questions. Comparisons between the parent- and child-assessed scores in neuroticism were highly intercorrelated (r = .42, p < .001). The self-assessed measure used to capture neuroticism scores in this study can thus be assumed to be reliable.

Another limitation is the question about the generalizability of the results regarding WM performance, since we chose two complex and often used WM tasks, but there are many other tasks yielding to measure WM capacity.

7. Implications

By identifying school children who are likely to underperform because of week WM, different ways to improve cognitive as well as personal determinants can be found to help these children to tap their full academic potential. Our results hold some important implications for such processes.

The results help to understand why children with high general intelligence may have problems in school by demonstrating the strength of association between neuroticism, WM and learning. From this perspective it seems important to identify anxious behaviour, e.g. fearful responses to novel situations (e.g. a new toy or task) or withdrawn behaviour from an unfamiliar person, since it might indicate learning difficulties and thus need for specific support.

Beside the neuroticism-WM link, our results demonstrate that WM performance can be efficiently trained even in children with high neuroticism. This underlines the potential which lies in cognitive interventions that help anxious and emotionally unstable children to improve their WM capacity, and with it, their school achievements (see Owens et al, 2008, for a discussion of moderating effects). Another method described in the literature is to decrease the negative effects of WM-related deficits through effective classroom management (Alloway, 2006).

In addition, this further evidence of a moderating effect of neuroticism on WM performance confirms the need for non-cognitive interventions which help children to reduce their anxiety, shyness and worrisome thoughts. Such attempts have been successfully made (Keogh, Bond, & Flayman, 2007). In their study, the authors applied cognitive-behavioral stress management in typically developing children to reduce anxiety. They found increased grades for the children in the intervention group. In line with this finding, another study with clinically anxious children implemented a similar intervention and demonstrated improved parent-rated school performance (Wood, 2006). Such findings encourage the attempts to positively influence children's personal dysfunctional dispositions to help them to become more stable and

To conclude, the results of the current study have supported the ACT predictions that neuroticism- related traits affect WM functions and the capability to concentrate. Considering the importance of WM in school, this could thus be the primary cause of poor academic achievements. The findings bear important implications for special support of emotionally instable, anxious children. In further research, effects of cognitive and non-cognitive interventions on WM and academic performance should be examined and validated in children with high levels of neuroticism.

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