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BRIEF REPORT

Improving Working Memory Efficiency by Reframing Metacognitive Interpretation of Task Difficulty

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Working memory capacity, our ability to manage incoming information for processing purposes, predicts achievement on a wide range of intellectual abilities. Three randomized experiments ($N = 310$) tested the effectiveness of a brief psychological intervention designed to boost working memory efficiency (i.e., state working memory capacity) by alleviating concerns about incompetence subtly generated by demanding tasks. Sixth graders either received or did not receive a prior 10-min intervention designed to reframe metacognitive interpretation of difficulty as indicative of learning rather than of self-limitation. The intervention improved children's working memory span and reading comprehension and also reduced the accessibility of self-related thoughts of incompetence. These findings demonstrate that constructing a psychologically safe environment through reframing metacognitive interpretation of subjective difficulty can allow children to express their full cognitive potential.

Keywords: working memory, psychological threat, intervention, reading comprehension, working self-concept

There is a limit to how much information we can hold in memory while performing another concurrent task (Cowan, 2010). This cognitive limit, known as working memory capacity (WMC), is assessed with specific memory span tests. Interestingly, how well people do on these tests is highly predictive of their achievement on a wide range of complex activities including language comprehension, problem solving, and learning (Engle, 2001). It is also strongly related to general intelligence (Conway, Kane, & Engle, 2003). In other words, WMC is central to complex cognition. The question of whether working memory can be enhanced therefore constitutes an important challenge.

Except for changes across the life span, WMC has generally been considered a relatively stable trait of the individual. Yet performance on working memory tasks can fluctuate from one context to another. These variations in working memory efficiency have led researchers to propose that WMC should be conceptualized as both a trait and a state (Ilkowska & Engle, 2010). State WMC refers to the temporary changes from the baseline trait WMC. Our capacity to store and process information can then be diminished by situational factors like sleep deprivation or cognitive fatigue (Chee & Choo, 2004). It can also be improved through cognitive training (for reviews see Klingberg, 2010; Morrison & Chein, 2011; Shipstead, Redick, & Engle, 2010). For example, intensive practice of targeted tasks (e.g., 15 min a day for 5 weeks) increases working memory performance (e.g., Bergman Nutley et al., 2011; Klingberg, Forssberg, & Westerberg, 2002). We believe that gains in working memory efficiency (i.e., state WMC) can be more immediate. In this article, we present three studies that tested whether state WMC can be improved without cognitive training by a 10-min social psychological intervention that targets the metacognitive interpretation of difficulty experienced during demanding tasks.

Our approach is based on research that has studied the deleterious impact of situational stress on cognitive performance (DeCaro, Thomas, Albert, & Beilock, 2011). Particularly detrimental are situations where people are pressured to perform at their best (Baumeister, 1984) or are at risk of confirming a stereotype about their group's inability (Steele, 1997). When individuals are taking an important exam, or are participating in a crucial competition, the pressure to excel or the fear of confirming a negative stereotype can generate costly self-regulation that taxes the available resources in working memory (Beilock, Rydell, & McConnell, 2007; Schmader, Johns, & Forbes, 2008).

Here we argue that settings that have the potential to interfere with working memory are not limited to high-stakes performance contexts or situations where negative stereotypes are salient. We propose that state WMC can also be altered by situations that are apparently neutral but in which individuals are confronted with

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demanding tasks. In Western societies, there is a prevalent cultural belief that equates level of achievement with intelligence (Dweck, 1999; Plaut & Markus, 2005). Westerners believe in the entitative nature of human abilities and tend to assume that traits, like intelligence, are immutable, inherent to, and distinctive of the individual (Haslam, Bastian, & Bissett, 2004; Heine et al., 2001). Experiencing difficulty or failure may then constitute a potential psychological threat to self-image because it may be interpreted as revealing intellectual incompetency. These cultural assumptions are pervasive and likely to affect individuals' framing of situations. Thus, even if a performance situation does not pressure individuals to perform at their best, we argue that merely experiencing difficulty spontaneously generates interfering thoughts about incompetence that can tax working memory.

We predict that an immediate way to elicit higher working memory is to prevent individuals from interpreting their difficulty as a sign of intellectual incompetence. Previous research has shown that changing the way in which people appraise their experience in a threatening testing situation is possible and actually beneficial to performance. When participants face the pressure to excel or the fear of confirming a negative stereotype, informing them that the test "sharpens the mind" (Alter, Aronson, Darley, Rodriguez, & Ruble, 2010), that "feeling anxious might facilitate performance" (Jamieson, Mendes, Blackstock, & Schmader, 2010; Johns, Inzlicht, & Schmader, 2008) or that "intelligence is an expandable capacity" (Good, Aronson, & Inzlicht, 2003) restores cognitive performance to the baseline level (i.e., nonthreatening control condition). However, this research indicates that when participants do not face explicit pressure or threat, that is, when the performance situation is neutral with regard to these social pressures, reframing brings no cognitive benefit. We believe that reframing can nevertheless offer gains beyond the baseline level. Indeed, even if the baseline control condition is conceptualized as neutral, merely experiencing difficulty can already be enough to generate some threat to self-image. Limiting the occurrence of this threat, and therefore its cognitive cost, should therefore elicit higher state WMC relative to the baseline control condition. While previous reframing manipulations aimed to reduce the interference triggered by an explicit pressure to excel or stereotype threat, our goal in the present research was to prevent a threat to self-image from even occurring. We designed a manipulation that reframed subjective difficulty as the normal outcome of learning situations. We predicted that compared with the usual standard situation of WMC assessment, framing difficulty as a part of learning should reduce self-related thoughts of incompetence that tax cognitive resources, therefore improving state WMC.

The present article reports three studies that tested this prediction. The first study investigated whether a situation that leads individuals to dissociate their experience of difficulty from inferences about their intellectual self-worth improves working memory span compared with a standard test of WMC. The second study examined whether this situational context can improve downstream processes beyond working memory, namely, reading comprehension. The third study aimed to provide corroborating evidence that reframing difficulty reduces self-related thoughts of incompetence and their negative association with cognitive performance. To assess the generality of our prediction, all studies were run with children who had just entered junior high school. Working memory predicts academic attainment (e.g., Alloway & Alloway, 2010), and the samples of college students usually targeted in the literature represent the upper end of the normal distribution in WMC. Eleven-year-old children constitute in that respect a more representative sample of the general population.

Study 1

We manipulated what participants did just before taking a standardized working memory test. A third of the participants received a brief psychological intervention developed to reframe children's metacognitive interpretation of difficulty to avoid a spontaneous interpretation of difficulty in terms of intellectual limitation. Children carried out a very difficult anagram task and the experimenter systematically oriented their interpretation of difficulty by explaining that experiencing processing difficulty is the normal outcome of learning situations. This critical condition was compared with two control conditions. The first control condition was similar to the critical condition except that the experimenter did not reframe children's interpretation of difficulty. In the second control condition, participants did not do the prior anagram task. All participants then performed a listening span test. We expected that compared with children in the control groups, children who had learned to dissociate processing difficulty from self-image would display higher working memory span.

Method

Participants. A sample of 111 sixth graders (51 boys, 60 girls, mean age = 11.42 years, *SD* = 0.49) individually participated at their school with the permission of their parents and school authorities. Information about parental occupation was collected from school administration and used to determine participants' socioeconomic status (SES; see Croizet & Claire, 1998). Thirty-one percent of the participants were of high SES, 22% were of intermediate SES, and 46% were of low SES (for 2% of the participants, this information was unavailable). Participants were randomly assigned to one of three conditions: difficulty with reframing, difficulty without reframing, or standard.

Materials and procedure. The tasks administered were presented to the children as a set of laboratory exercises that were not diagnostic of their academic ability and as having no consequences for their academic grades. Participants in the difficulty with reframing and those in the difficulty without reframing conditions completed three series of two difficult anagrams. The difficulty of the anagrams was set to prevent children from finding the correct answer in the time allotted (i.e., 1 min per anagram). As a result, all the participants failed all the items. After each series, participants were questioned about their experience of difficulty. In the difficulty with reframing condition, the experimenter oriented children's interpretation of difficulty: For each series, participants were told that experiencing processing difficulty was normal and only a reflection that learning was occurring. In the difficulty without reframing condition, children performed the anagram task and were questioned about the difficulty they experienced, but the experimenter suggested no alternative interpretation. Instead she discussed that her goal was to study resolution strategies (see Appendix). Overall, the anagram task lasted about 10 min. In the standard condition, participants directly took the working memory test.

State WMC was measured by a listening span task modeled after the reading span task (Daneman & Carpenter, 1980). The task was standardized for French-speaking children (de Ribaupierre & Bailleux, 1995; de Ribaupierre & Lecerf, 2006). It was computerized and followed standard instructions. Participants listened to several series of sentences. For each sentence, they had to indicate as quickly and accurately as possible by pressing a key whether the sentence they heard made sense or not and to memorize the last word. At the end of a series of sentences, children were asked to recall out loud as many last words as possible, in the order of presentation. The cognitive demand of the task varied across series, which included two to five sentences and words to remember. There were four blocks of each set size, totaling 56 sentences. The proportion of the number of correct words recalled constituted the WMC score. All children were then fully debriefed and thanked for their participation. Children's academic level, determined by their score on a national standardized achievement test (Ministère de l'Education Nationale de la Recherche et de l'Enseignement Supérieur [MENRES], 2006), was collected from the school administration.

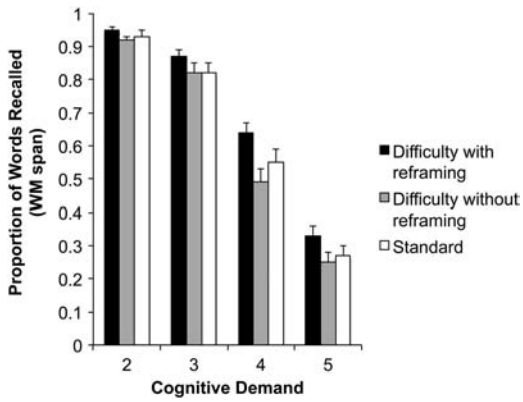

Figure 1. Working memory (WM) span as a function of experimental condition (i.e., experience of performance before the WM test) and cognitive demand of the WM test (2, 3, 4, or 5 words to remember) for Study 1. Error bars represent standard errors.

Results and Discussion

State WMC scores were analyzed using a 3 (condition: difficulty with reframing, difficulty without reframing, standard) × 2 (cognitive demand of the task: low [two and three items to remember] vs. high [four and five items to remember]) mixed analysis of variance (ANOVA) with the last factor as a repeated measure. The analysis yielded main effects of the cognitive demand of the task—working memory score decreased as cognitive demand increased, $F(1, 108) = 1{,}044.99$, $p < .01$, $\eta_p^2 = .90$—and of condition, $F(2, 108) = 3.60$, $p = .03$, $\eta_p^2 = .06$. The effect of the condition factor was further decomposed using two orthogonal contrasts (2, –1, –1 and 0, 1, –1, respectively, for the difficulty with reframing, difficulty without reframing, and standard conditions). Data confirmed that children who had learned during the prior difficult anagram task to attribute their experience of difficulty to the learning situation (difficulty with reframing condition) displayed subsequently higher working memory span ($M = 0.70$) than did those in the difficulty without reframing and standard conditions ($M = 0.63$), $F(1, 108) = 6.73$, $p = .01$, $\eta_p^2 = .06$, which did not differ from one another ($F < 1$). This effect was further qualified by an interaction with the cognitive demand of the task, indicating that the benefit of discounting processing difficulty for self-evaluation was more pronounced when the task demand was high (four or five items to remember) rather than low (two or three items to remember), $F(1, 108) = 4.19$, $p = .04$, $\eta_p^2 = .05$ (see Figure 1). The orthogonal contrast testing the interaction between the condition and task demand was not significant ($F < 1$). The improvement of state WMC limited to high demand series was likely due to a ceiling effect when the task demand is low. However, the important finding remains that reframing the metacognitive interpretation of difficulty brings cognitive gain in situations where available resources are scarce. Interestingly, children's academic level, gender, and SES did not moderate these cognitive gains.[1]

The present findings suggest two important things: First, working memory efficiency can be improved in less than 10 min without intensive cognitive training by an intervention designed to change the metacognitive interpretation of difficulty. Second, the lower performance of children in the standard condition calls into question the neutrality of common assessments of WMC. These assessments rely on procedures that push individuals to their cognitive limit. The interpretation of this experience of difficulty can generate self-related thoughts of incompetence that could interfere with working memory. There are of course many reasons why WMC scores may not reflect individuals' optimal capacity. What our findings suggest is that standard evaluations of working memory may lead to a systematic underestimation of individuals' WMC.

Study 2

To further assess the impact of reframing difficulty as a part of learning on higher cognition, we examined whether our intervention could improve downstream processes that heavily rely on WMC (Daneman & Merikle, 1996). We focused on reading comprehension ability because it is highly relevant for academic success (Daneman & Carpenter, 1980). We predicted that attributing subjective difficulty to learning rather than to one's incompetence would later result in better performance on a difficult reading comprehension task. Another sample of 11-year-old children took part in a second experiment. They were given a very difficult standardized reading comprehension test that was actually designed for older children. Three conditions were replicated from the first study: difficulty with reframing, difficulty without reframing, and standard. To assess the possibility that the benefits observed in Study 1 were caused by a stronger involvement in the task from the participants in the difficulty with reframing condition, we added another control

[1] Initially gender, SES, and academic level were included in the analysis, but because none moderated how conditions or the cognitive demand of the task impacted working memory span, these variables were dropped from the analyses. Including these factors as covariates did not change the results. When gender was included in the analysis, no main effect was found, and gender did not interact with condition or task demand ($ps > .19$; $M_{boys} = 0.65$; $M_{girls} = 0.66$). When SES was included in the analysis, no main effect was found, and SES did not interact with condition or task demand ($ps > .20$; $M_{low\ SES} = 0.62$; $M_{intermediate\ SES} = 0.67$; $M_{high\ SES} = 0.67$). Academic level had a main effect on WMC scores, $F(1, 105) = 4.92$, $p = .03$, but did not interact with condition or task demand ($p = .36$).

condition. In this condition (success), the difficulty of the anagrams was reduced to have participants experience success for each anagram. As a consequence, the anagram task was not perceived as difficult, and no reframing of difficulty was implemented in this condition. Previous research has shown that success has positive motivational and psychological effects (Bandura, 1997; Seery, Blascovich, Weisbuch, & Vick, 2004). Another goal of the second study was therefore to test whether experiencing success on a first task could offer psychological benefits able to improve performance on a difficult comprehension test.

Method

Participants. A sample of 131 sixth graders (65 boys, 66 girls, mean age = 11.84, *SD* = 0.51; 29% were of high SES, 25% were of intermediate SES, 31% were of low SES, and for 8% of the sample this information was not available) participated at their school with the permission of their parents and school authorities. They were randomly assigned to one of four conditions of an experimental design: difficulty with reframing, difficulty without reframing, standard, or success.

Materials and procedure. The difficulty with reframing, difficulty without reframing, and standard conditions were identical to those of Study 1. In the difficulty with reframing and the difficulty without reframing conditions, participants failed an anagram task and were questioned about their experience of difficulty. Only in the reframing condition did the experimenter reframe difficulty as a normal outcome of the learning process. In the standard condition, participants did not complete an anagram task. In the success condition, participants performed a series of less difficult anagrams and achieved success for each anagram. Except for task difficulty, this condition was similar to the difficulty without reframing condition. The reading comprehension test was borrowed from a national standardized test designed for French seventh grade students (MENRES, 2003). Following standard test instructions, participants had 12 min to read a text and to answer questions. Participants were then fully debriefed and thanked for their participation.

Results and Discussion

Children's reading comprehension scores (out of 18) were analyzed using a 4 (condition: difficulty with reframing, difficulty without reframing, standard, success) between-participants ANOVA.[2] In accordance with our hypothesis, the analysis of reading comprehension scores showed that children in the difficulty with reframing condition, that is, children who failed the first task but learned that experiencing difficulty is the normal outcome of learning situations, later demonstrated better comprehension ($M = 12.98$) than did children in the other conditions ($M = 10.57$), $F(1, 127) = 7.30$, $p = .008$, $\eta_p^2 = .05$. Orthogonal contrasts testing the difficulty without reframing condition against the success and standard conditions, as well as the success condition against the standard condition, were not significant (Fs < 1). Further tests revealed that the children in the difficulty with reframing condition performed higher than did those in each of the other conditions (Fisher's least significant difference post hoc test, $p = .05$; see Figure 2). The difficulty without reframing, standard, and success conditions did not differ from one another (Fs < 1).

These results confirmed that orienting metacognitive interpretation of subjective difficulty is beneficial to higher cognition.

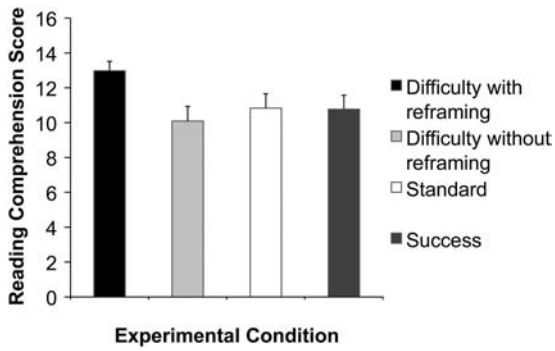

Figure 2. Reading comprehension score as a function of experimental condition (i.e., experience of performance before the reading test) for Study 2 (max = 18). Error bars represent standard errors.

Reframing difficulty as part of the learning process improved reading comprehension, an ability that strongly depends on working memory (Daneman & Merikle, 1996). Interestingly and opposite to lay wisdom, our results also showed that failing with reframing offered more cognitive benefits than succeeding, which actually conferred no advantage for the challenging reading test. Because feedback of success is known to increase motivation and task involvement (Bandura, 1997), this finding is indicative that motivation or involvement alone cannot easily account for the gains observed in the reframing condition. Yet, this interpretation remains suggestive and further research will have to address this issue.

Study 3

Studies 1 and 2 demonstrated that reframing the metacognitive interpretation of difficulty improved state WMC and reading comprehension. We argued that reframing offers cognitive gains because it limits the occurrence of a disruptive threat to self-image. In this third study, our goal was to demonstrate that reframing difficulty reduces self-related thoughts of incompetence. Instead of relying on traditional self-report measures, we measured the differential accessibility of competence and incompetence self-knowledge. Another sample of children were presented with a series of personality traits and had to decide as quickly as possible whether each trait was self-descriptive (Markus & Kunda, 1986). Some of the traits were related to competence, others to incompetence. Previous research with this paradigm has shown that participants often do not differ in the traits they endorse as self-descriptive: They reject most negative traits and endorse most positive ones. Participants also are slower to reject negative traits than to accept positive ones. However, this latency differential is sensitive to temporary changes in self-perception (Markus & Kunda, 1986; Ruvolo & Markus, 1992).

[2] Gender, SES, and academic level did not moderate the results and were dropped from the analyses. Gender had a main effect on reading comprehension scores, $F(1, 123) = 4.18$, $p = .04$ ($M_{boys} = 10.37$; $M_{girls} = 11.94$), but did not interact with condition ($F < 1$). SES had a main effect on scores, $F(1, 116) = 4.53$, $p < .01$ ($M_{low\ SES} = 9.91$; $M_{intermediate\ SES} = 11.40$; $M_{high\ SES} = 13.11$), but did not interact with condition, $F(1, 116) = 1.54$, $p = .14$. Academic level had a main effect on scores, $F(1, 123) = 92.40$, $p < .01$, but did not interact with condition, $F(1, 123) = 1.31$, $p = .25$.

Threat to self-image should translate into an imbalance of accessible self-knowledge about incompetence. Therefore, individuals experiencing concerns of intellectual inadequacy should have more trouble rejecting incompetence traits, resulting in a stronger latency differential between rejection of incompetence-related traits and acceptance of competence-related traits. If reframing difficulty as a part of learning reduces doubts of incompetence, the imbalance of accessible self-knowledge should be reduced and it should be easier for participants to decide that incompetence traits do not describe them. As a consequence, we expected a smaller latency differential between incompetence and competence trait decisions when difficulty was reframed as a part of learning.

Participants were assigned to either the difficulty with reframing or the difficulty without reframing conditions, since no difference between the various control conditions emerged in the previous studies. After the anagram task, children took a difficult reading comprehension test and completed the self-description task to assess balance in the accessibility of self-knowledge related to the competence domain.

Method

Participants. A sample of 68 sixth graders (38 girls, 30 boys, mean age = 11.64, *SD* = 0.56; 32% were of high SES, 21% were of intermediate SES, 25% were of low SES, and for 22% of the sample this information was not available) participated at their school with the permission of their parents and school authorities. They were randomly assigned to one of two conditions of an experimental design: difficulty with reframing or difficulty without reframing.

Materials and procedure. The difficulty with reframing and difficulty without reframing conditions were identical to those of Studies 1 and 2 and operationalized with the same anagram task. After performing the anagrams, participants took a difficult reading comprehension task borrowed from the same standardized test used in Study 2 (MENRES, 2003). Participants had 10 min to read a text and to answer several questions.

After the comprehension test, participants completed a computerized self-description task (adapted from Markus & Kunda, 1986). Sixty traits were successively and randomly presented for 2 s in the center of the screen. Children had to decide as quickly and accurately as possible by pressing a key whether each trait described them. From a pretest involving 25 sixth graders, we selected five positive traits related to competence that were judged as highly descriptive of a high achiever (on a 5-point scale from 1 = *not descriptive* to 5 = *very descriptive*; e.g., intelligent) and five negative traits related to incompetence that were judged as highly descriptive of a low achiever (e.g., stupid). We also selected 10 control traits related to warmth, a dimension orthogonal to the competence dimension (Fiske, Cuddy, Glick, & Xu, 2002): the five positive traits that were the most descriptive of a good friend (e.g., nice) and the five negative traits that were the most descriptive of a person children did not want as friend (e.g., mean). The 10 critical and the 10 control traits were presented among positive and negative filler traits (e.g., athletic). Participants' self-description decisions and response times were recorded. Children were then fully debriefed and thanked for their participation.

Results and Discussion

Reading comprehension test. Reading comprehension scores (out of 17) were analyzed using a 2 (condition: difficulty with reframing, difficulty without reframing) between-participants ANOVA.[3] In a replication of Study 2, children whose experience of difficulty was reframed as a normal outcome of learning situations achieved better reading comprehension ($M = 13.12$) than did children in the difficulty without reframing condition ($M = 11.53$), $F(1, 65) = 4.10$, $p = .05$, $\eta_p^2 = .06$.

Self-description task. We first analyzed participants' choice of traits using a 2 (condition) × 2 (trait dimension: competence vs. warmth) × 2 (trait valence: positive vs. negative) mixed ANOVA with the two last factors as repeated measures. The analysis yielded no effect of condition, alone or in interaction with other factors; the usual effect of valence, in that positive traits were more endorsed than negative traits, $F(1, 66) = 472.58$, $p < .001$, $\eta_p^2 = .87$; and, nonrelevant to our predictions, an interaction between trait valence and trait dimension, $F(1, 66) = 17.01$, $p < .001$, $\eta_p^2 = .21$. The endorsement differential between positive and negative traits was smaller for the competence dimension ($M_{competence} = 4.16$ out of 5 and $M_{incompetence} = 1.21$) than for the warmth dimension ($M_{warmth} = 4.51$ and $M_{nonwarmth} = 0.71$). Thus, in a replication of previous research, the experimental manipulation did not affect the traits, in terms of competence or warmth, that the participants chose as self-descriptive.

Because we hypothesized that reframing would create an imbalance in accessible self-knowledge about incompetence, we analyzed the latencies of both the positive traits that were endorsed as self-descriptive and the negative traits that were rejected for both the competence and warmth dimensions (89% of the latencies; see Ruvolo & Markus, 1992).[4] Response times (RTs) greater than 3 interquartile range lengths for a given trait were excluded (1% of the latencies). Mean RTs were analyzed using a 2 (condition) × 2 (trait dimension) × 2 (trait valence) mixed ANOVA with the two last factors as repeated measures.[5] The analysis yielded a main effect of valence—participants endorsed positive traits faster ($M = 1{,}354$ ms) than they rejected negative traits ($M = 1{,}556$ ms), $F(1, 59) = 41.17$, $p < .001$, $\eta_p^2 = .40$—and of trait dimension—participants judged warmth-related traits faster ($M = 1{,}416$ ms) than competence-related traits ($M = 1{,}495$ ms), $F(1, 59) = 6.49$, $p = .01$, $\eta_p^2 = .10$. A marginal unexpected two-way interaction

[3] Gender, SES, and academic level did not moderate the results and were dropped from analyses. Gender had no main effect on comprehension scores and did not interact with condition (Fs < 1; $M_{boys} = 12.29$; $M_{girls} = 12.09$). SES had no main effect on scores and did not interact with condition (ps > .43; $M_{low\ SES} = 12.59$; $M_{intermediate\ SES} = 12.70$; $M_{high\ SES} = 13.66$). Academic level had a main effect on scores, $F(1, 64) = 10.94$, $p < .01$, but did not interact with condition ($F < 1$). One outlier was excluded from the analysis due to an uncommon Cook's distance and deleted studentized residual. Including this datum did not significantly alter the findings.

[4] Including the data for rejected positive traits and accepted negative traits did not change the results.

[5] Four participants were dropped from the analysis due to one or more missing values, and three others were dropped because of an uncommon Cook's distance and deleted studentized residual. Including these data did not significantly affect the findings.

between condition and trait dimension emerged, suggesting that the gap in reaction time between competence and warmth traits tended to be reduced in the difficulty with reframing condition, $F(1, 59) = 3.21$, $p = .08$. More important, the expected three-way interaction reached significance, $F(1, 59) = 6.84$, $p = .01$, $\eta_p^2 = .10$ (see Figure 3). This interaction was decomposed by examining how condition affected both the endorsement of positive trait and rejection of negative traits separately for each trait dimension. This analysis revealed that the latency differential between positive and negative traits was moderated by condition for the competence-related traits, $F(1, 59) = 3.95$, $p = .05$, $\eta_p^2 = .06$, but not for the warmth-related traits, $F(1, 59) = 1.04$, $p = .31$. Participants were faster to accept competence-related traits than to reject incompetence-related traits, but as expected, this difference was less pronounced for the participants whose interpretation of difficulty had been reframed. Actually, participants in the difficulty with reframing condition took less time to reject traits of incompetence than did participants in the difficulty without reframing condition, $F(1, 59) = 4.69$, $p = .03$, $\eta_p^2 = .07$. This finding is congruent with the hypothesis that in the standard situation, participants experienced higher accessibility of incompetence-related thoughts.

We then examined whether the imbalance in accessible self-knowledge about incompetence was related to performance on the reading comprehension task. For children in the difficulty without reframing condition, we predicted that this imbalance in self-related thoughts would be associated with lower cognitive performance. In accordance with this hypothesis, a higher imbalance (i.e., the longer participants took to reject incompetence traits compared with the time they took to endorse competence traits) was related to poorer reading comprehension ($r = -.38$, $p = .04$). For children in the difficulty with reframing condition, we expected that reframing would prevent the occurrence of a disruptive threat to self-image. Accordingly, we found no relationship between imbalance in accessible self-knowledge about incompetence and reading comprehension scores ($r = .09$, $p = .62$). Further analysis revealed that the two correlation coefficients were significantly different ($Z = 1.83$, $p = .03$, one-tailed).

These findings again demonstrate that reframing subjective difficulty as a part of learning is beneficial for complex cognition.

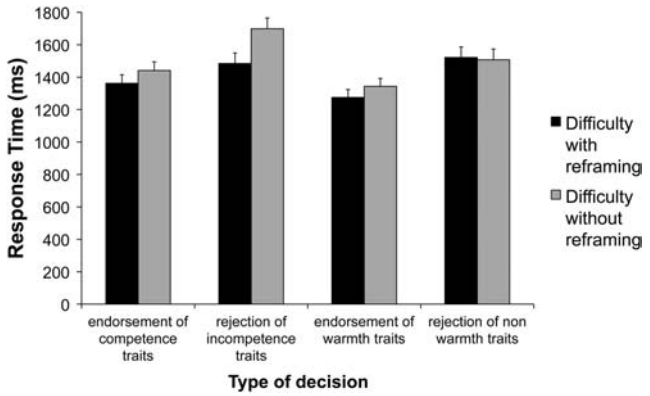

Figure 3. Mean response times for endorsement of competence- and warmth-related traits (i.e., positive traits) and rejection of incompetence- and non-warmth-related traits (i.e., negative traits) as a function of experimental condition (i.e., experience of performance before the test). Error bars represent standard errors.

More important, we showed that changing the metacognitive interpretation of difficulty reduces the imbalance in accessible self-thoughts about incompetence. We argued that in neutral situations (e.g., our control condition), spontaneous metacognitive interpretation of difficulty trigger concerns about self-image, which can tax working memory. Accordingly, our findings indicate that participants confronted with a difficult task experienced higher accessibility of incompetence-related thoughts and that those concerns were associated with lower cognitive performance. This was not observed when difficulty was interpreted as the normal outcome of learning experiences.

General Discussion

In this article we sought to examine whether state WMC can be improved without cognitive training by orienting the metacognitive interpretation of difficulty. We argued that a hidden cause to the limitation of state WMC stems from disruptive thoughts of incompetence that individuals spontaneously experience when they are confronted with a demanding task. We predicted that preventing interpretation of difficulty as a sign of intellectual limitation relieves working memory from the burden of a threat to self-image and temporarily improves individuals' ability to efficiently store and process information. To test this hypothesis, we designed a brief intervention through which children learned to reframe their experience of difficulty as an expected outcome of learning situations. Our findings showed that this 10-min reframing intervention was successful in improving children's working memory span. We also found that these cognitive gains were especially observed when the cognitive demand of the task was high, that is, when difficulty was at its maximum. A second study demonstrated that these cognitive gains extended to reading comprehension, an ability known to rely heavily on working memory (Daneman & Merikle, 1996). This study also indicated that reframing difficulty was more beneficial for cognitive performance than a prior experience of success. Finally, a third study showed that orienting the metacognitive interpretation of difficulty reduces self-related thoughts of incompetence and suppresses their negative association with reading comprehension. Altogether, our results plead for the generality of the beneficial impact of reframing phenomenal difficulty on state WMC, as children's academic level, gender, and socioeconomic background did not moderate the gains in cognitive performance across the three studies.

The present research confirms that threats to self-image are an important limiting factor of human cognition. It is well established that individuals prone to such worries (e.g., persons high in trait anxiety) show diminished working memory (Ashcraft & Kirk, 2001). However, situations can also generate threat-based working memory deficits (DeCaro et al., 2011; Schmader et al., 2008). In a situation where individuals are pressured to excel or are at risk of confirming a stereotype about their group's inferiority, they indeed show reduced state WMC. These settings activate a sense of uncertainty about competence, which triggers additional control and cognitive effort that hijack working memory and lead to suboptimal performance (Schmader & Beilock, 2011). In this article we have proposed that a higher cognition deficit can also occur in apparently neutral situations because individuals associate intellectual success with competence and failure with lower ability (Dweck, 1999; Plaut & Markus, 2005). We have argued that

outside of high-stakes settings, tasks that are very demanding have the potential to trigger concerns about incompetence. Our results confirmed that preventing individuals from linking their subjective experience of difficulty to a negative self-evaluation improves their working memory efficiency in regular performance situations. Previous research has shown that reframing phenomenal experiences during a test restores cognitive performance hampered by stereotype threat or the pressure to excel. Nevertheless, no benefits to reframing occurred when participants were not under an explicit threat (Alter et al., 2010; Jamieson et al., 2010; Johns et al., 2008). Our findings extend this literature by demonstrating that appropriate reframing of metacognition—a reframing that prevents a threat from occurring in the first place rather than helping individuals to cope with it—can also improve state WMC in low-pressure, yet demanding, situations.

The effectiveness of our manipulation is contingent on the dissemination of a widespread cultural assumption that equates experiencing difficulty with lower cognitive ability (Plaut & Markus, 2005). In other cultures where this default framing of difficulty is less prevalent, reframing difficulty as learning may offer no benefit for cognition. Research shows that Japanese, for example, view intellectual performance as flexible and determined by effort and incremental abilities, whereas North Americans tend to attribute performance to fixed abilities (Heine et al., 2001; Holloway, 1988; Plaut & Markus, 2005). It is therefore possible that in East Asian cultures, people are less threatened by subjective difficulty because they interpret it more as a lack of mastery and less as a sign of lower ability. Though to our knowledge there is no evidence that culture moderates the link between metacognition and intellectual performance, available evidence is congruent with our reasoning. Heine et al. (2001) showed that North Americans who failed on a test persisted less on a follow-up test than did those who succeeded. In contrast, Japanese confronted with failure persisted more than did the ones who succeeded. In brief, reframing difficulty as learning can elicit higher state WMC, but, we believe, only in situational contexts where individuals make the default assumption that lower performance is a sign of intellectual inferiority. Future research will have to investigate the cross-cultural generality of our results.

The finding that orienting the metacognitive interpretation of difficulty improves state WMC and reading comprehension fits with recent research attributing a key role in complex cognition to mind wandering (McVay & Kane, 2009). According to this approach, WMC predicts reading comprehension because individuals with lower WMC have more difficulty controlling off-task thoughts that compete for attentional control (McVay & Kane, 2011). This line of work points out that individuals differ in the ways in which they apprehend complex task-resolution situations. Some are more susceptible than others to task-unrelated thoughts. The current research suggests that beyond individual differences, situations can also induce interpretational frameworks that favor or limit the emergence of disruptive off-task thoughts (e.g., self-related thoughts of incompetence).

The present research constitutes an important contribution to the ongoing debate on the possibility of improving working memory efficiency (Ilkowska & Engle, 2010). There is growing evidence that intensive practice of certain memory tasks (e.g., 60 min per day for a hundred sessions) can offer benefits to working memory (see Diamond & Lee, 2011; Schmiedek, Lövdén, & Lindenberger, 2010). Here we showed that benefits to state WMC may also be more immediate. Whereas training aims to ease the very processes of working memory (but see Shipstead et al., 2010), reframing aims to improve working memory efficiency by reducing a psychological threat insidiously generated by task demand. We do not contend that the gains observed in our studies are permanent or that we expanded WMC as a trait (Ilkowska & Engle, 2010). Our goal was to highlight the impact of metacognition on state WMC. Though distinct, the effects of cognitive training and of reframing of difficulty could nevertheless be combined. As practice of working memory increases, the perceived difficulty of the task indeed diminishes, which likely reduces disruptive concerns of incompetence. An interesting venue for future research would be to disentangle such gains and also to examine whether cognitive training and reframing could capitalize on one another.

The finding that a short psychological intervention can improve working memory efficiency is also important because working memory predicts achievement on a wide range of complex activities. The fact that academic level never moderated the cognitive gains observed across the studies suggests that reframing difficulty as the normal outcome of learning situations does not alter the predictive validity of WMC; it also indicates that reframing metacognition offers general benefits. Being able to increase, at virtually no cost, children's ability to retain and manipulate information therefore offers promising prospects for application in education.

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(*Appendix follows*)

Appendix

Detailed Instructions for the Difficulty With Framing and Difficulty Without Framing Conditions

For each anagram, all participants were instructed to write down all the letter combinations as they searched for the answer. After each set of anagrams, participants were questioned about the difficulty they experienced:

> So how did you find this exercise? Difficult or easy? . . . Why do you think it was difficult? How do you explain this difficulty?

In the difficulty with reframing conditions, the experimenter oriented participants' interpretation of difficulty:

> If you have some difficulty it's because these exercises are new and you have not learned how to solve them yet. It is like when you were a kid and learned how to ride a bike. Do you remember when you did not know how to ride a bike? Was it easy or difficult to ride the first time? . . . Yes, it was difficult and it is normal that children find it difficult precisely because they have not yet learned how to do it. Well it is the same thing for these exercises. When you're in a situation like you are in right now, what you need to do is to practice, to learn little by little how to solve them. While practicing you'll keep trying things that do not work out, but it's fine because that is actually how you learn. You cannot get it right immediately. It takes time to learn. These exercises work just like the bicycle; you can learn how to do it but it takes time and at the beginning it's hard, it's normal.

In the difficulty without reframing conditions, the experimenter stated the following:

> If we are working on these exercises it is because I want to know what kind of strategy you use to solve these exercises. It's like when you were a kid and learned how to ride a bike. Do you remember when you did not know how to ride a bike? Well, when children learn how to ride a bike, they use different strategies: Some pedal very slowly, others pedal right away very quickly, some look straight ahead, some look at their feet, it depends. It's the same for exercises; there are different ways to solve them and here I would like to understand the strategy you are using. That is why I want you to write down the letter combination you're thinking about. The ideal would be to write right away every combination you are trying in your head. In fact, it's like when you learned how to ride a bike you proceeded in a certain way. This is what I am studying.

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