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The Influence of Socioeconomic Status, Working Memory and Academic Self-Concept on Academic Achievement

Chevalère J.^{a*}, Cazenave, L.^a, Wollast, R.^a, Berthon, M.^a, Martinez, R.^b, Mazenod, V.^b,
Borion, M.C.^{a,c}, Pailler, D.^c, Rocher, N.^c, Cadet, R.^{d,e}, Lenne, C.^{e,f}, Maïonchi-Pino, N.^a,
& Huguet, P.^a

^a *Université Clermont Auvergne et CNRS, Laboratoire de Psychologie Sociale et Cognitive (LAPSCO), F-63000 Clermont-Ferrand, France*

^b *Université Clermont Auvergne et CNRS, Laboratoire d'Informatique, de Modélisation et d'Optimisation des Systèmes (LIMOS), F-63000 Clermont-Ferrand, France*

^c *Rectorat de Clermont-Ferrand, F-63000 Clermont-Ferrand, France*

^d *Université Clermont Auvergne, Laboratoire Activité, Connaissance, Transmission, Éducation (ACTé), F-63000 Clermont-Ferrand, France*

^e *Université Clermont Auvergne, Maison pour la Science/Auvergne (MPSA), F-63000 Clermont-Ferrand, France*

^f *Université Clermont Auvergne et INRAe, Laboratoire Physique et Physiologie Intégratives de l'Arbre en Environnement Fluctuant (PIAF), F-63000 Clermont-Ferrand, France*

Correspondence concerning this article should be addressed to Johann Chevalère

Email: johann.chevalere@hotmail.fr

Abstract

There is today ample evidence that academic achievement depends on individual disparities in socioeconomic status (SES), working memory (WM) and academic self-concept (ASC). However, because these factors were investigated intensively but in separate fields of research in the past four to six decades, their relationships remain largely unknown. The present study investigated whether SES, WM and ASC interact with each other or represent independent contributions to academic achievement in 2379 adolescents in middle and high schools. The findings confirmed previous results showing that students with lower SES, lower WM, and lower ASC perform less well on academic tests. Above all, they revealed subtle patterns of mediating processes. Specifically, individual differences in WM processing, and to a lesser extent in ASC accounted for most part of the negative impact of low SES on academic achievement. These findings indicate that being a member of disadvantaged groups impair both WM processing and ASC, and provide a clearer picture of the complex involvements of socioeconomic, cognitive and self-perception factors in academic achievement.

Word count: 168 words

Keywords: Socioeconomic status; academic achievement; adolescents; working memory; academic self-concept; structural equation modelling

Main text introduction

The interaction between sociocultural and educational factors represents a major issue in human development which has and continues to stimulate philosophical and scientific debate. In particular, the construction and refinement of knowledge in children and adolescents is thought to result from sociohistorical experiences in situated contexts that shape the development of biological factors and cognitive skills (e.g., Lerner, 1986; Piaget & Inhelder, 1969; Vygotsky, 1978). A way to address the complex influence of contextual factors on human development and education is to consider socioeconomic status (SES) (Farah, 2018, for a review from a neuroscientific perspective). SES refers to the social standing or class of an individual or group (APA, 2020) reflecting by definition social and economic realities, which disparities particularly affect low SES students (Coleman et al., 1966; Reiss, 2013; Sirin, 2005). More precisely, the magnitude and direction of SES effect has been reported about around .25 standard deviation in meta-analytic work (Liu et al., 2019; Sirin, 2005; White, 1982) meaning that the lower the social standing of children's family, the lower their academic achievement. However, perhaps due to disciplinary boundaries, the sociological question of the relationship between SES and academic achievement (e.g., Bourdieu & Passeron, 1990) has left aside other factors, more cognitive and psychological involved in the determination of academic achievement. The present study is an attempt to push disciplinary boundaries for a more integrated view of academic achievement by considering working memory (WM) and academic self-concept (ASC) as explanative factors for the relation between SES and academic achievement.

The multifactorial determinism in between socioeconomic status and academic achievement

The role of working memory

Working memory is thought as a flexible but limited mental capacity that allows temporal maintenance and manipulation of information in an active state for ongoing processing (Camos & Barrouillet, 2018). It is involved in almost any conscious cognitive activity and is a strong predictor of general cognitive abilities (e.g. Engle, 2002) and academic achievement (e.g., Alloway & Alloway, 2010; Daneman & Carpenter, 1980). WM is essential to support complex activities such as language, reading comprehension, problem solving and reasoning (Süß et al., 2002; Unsworth et al, 2009). Past work has shown a relative separability of WM into subcomponents. A first component is devoted to the storage of information in an active and accessible state while a second component processes information (Unsworth et al., 2009). The processing component is mainly attention-based and serves several functions such as long-term memory retrieval and the refreshing of memory traces, to counteract time-based decay (Barrouillet et al., 2004).

WM is thought to be an important factor associated with academic achievement like reading performance (Blankenship et al., 2015). WM plays a central role in the conceptualization and maintenance of words for comprehension through the development of articulatory rehearsal in children (Baddeley, 2003). Besides reading, studies have shown that arithmetic performance involves WM (DeStefano & LeFevre, 2004; Lee & Kang, 2002). In particular, WM capacity supports mathematics achievement because arithmetic operations requires both the maintenance of numerical representations and retrieval of arithmetic facts from long-term memory, which in turn, can be computed in WM (Ecker et al., 2010).

Given the crucial contribution of WM to any type of learning activity, it is reasonable to expect that it might mediate at least partly the SES influence on academic achievement on a range of subjects. Surprisingly, this mediation hypothesis was largely overlooked with few exceptions (Lawson & Farah, 2017, see also Barrouillet et al., 2008). For example, Lawson and Farah (2017) used structural equation modelling among 336 6-to-15 years old middle-class and found two latent factors (verbal memory and executive functions) conceptually close to Unsworth et al.'s two-factor WM model (storage and processing, see Unsworth et al., 2014 for more details). They showed that SES (from lower to higher SES) positively predicted the executive component ($\beta = .39$), more than the verbal memory component ($\beta = .12$). In turn, the processing component significantly predicted changes in calculation ($\beta = .24$) while this path was of smaller magnitude and non-significant for text comprehension ($\beta = .11$). In contrast, the verbal memory component did not significantly predict either indicators of academic achievement¹ (respectively $\beta = .006$ and $\beta = .04$ for calculation and comprehension). Furthermore, the executive factor had a significant indirect effect mediating the path between SES and calculation ($\beta = .11$), suggesting that part of the SES achievement gap is explained in terms of individual differences in executive function, which represents the attentional component of WM, contrary to storage (Barrouillet et al., 2011; Unsworth et al., 2014).

¹ It should be noted this result is inconsistent with previous work (Barrouillet et al., 2008) showing a significant indirect effect by WM storage ($\beta = .12$). This inconsistency is taken into account in the hypothesis formulation in terms of a weaker -rather than an absence of- indirect effect for WM storage compared to WM processing.

The role of academic self-concept

A large body of research has been involved in the understanding of how self-perceptions of one's general ability in school, referred to as ASC (Marsh & Craven, 2006), influence academic achievement. In particular, ASC has proved to account for future academic performance and coursework selection better than prior performance and academic achievement and has been considered as a vehicle for addressing social inequalities in education (Bembenutty, 2009; Marsh & Craven, 2006). Self-concept and academic performance have shown reciprocal effects on each other, meaning that their mutual effects follow a specific causal ordering pattern (Marsh & Martin, 2011).

For example, Marsh and O'Mara (2008) found robust evidence favouring the mutual influence of academic achievement and ASC. They applied a structural equation modelling approach to a large corpus of longitudinal data, including five waves of data (10th, 11th, 12th grades one year and five years after high school graduation). In addition to latent measures of academic ability, ASC, and school grades, the authors provided latent measures of global self-esteem, prior education attainment, and SES. Controlling for SES, academic ability and prior school grades, they found highly consistent associations (from $\beta = .14$ to $.36$) from previous ASC to subsequent ASC, school grades and attainment, and vice versa, with generally stronger paths linking previous academic variables to future ASC. In contrast, they found that self-esteem played a negligible role in predicting future school grades and attainment.

In that study socioeconomic status was used more as a covariate than a variable of interest. It is known however that individuals tend to prioritize elements of their identities that are indicative of their social class more than demographics, community membership or other sociocultural orientations so that SES plays an important role in structuring self-concept

(Easterbrook et al., 2020), and possibly ASC. For example, if individuals perceive socioeconomic success as resulting of hard work and talent, they will be likely to develop self-perceptions congruent with their SES (Jost, 2001), suggesting that ASC may play a role in mediating the relation between SES and academic achievement. A recent study by Li et al. (2020) investigated this question directly. They applied a structural equation modelling approach to a data sample of 345 Chinese high school students in which academic achievement was measured as two separate final exam scores in Chinese literacy and mathematics. In two separate analyses based on the two academic scores, results showed that the three constructs (SES, ASC and academic achievement) significantly correlated with each other. More precisely, SES moderately and positively predicted ASC ($\beta = .22$) which in turn showed a low but significant positive relationship with academic achievement ($\beta = .13$). The indirect effect was small but significant ($\beta = .027$). These authors also investigated the possible role of ASC in moderating the SES – academic achievement relation (whether this relation did interact with ASC) while controlling for gender and age in separate hierarchical regression analyses, but did not find any interaction effect.

The present study

The present study represents a first attempt to clarify the interrelations of the SES-WM-ASC triad. More specifically, the focus is made on whether WM mediates the impact of SES on academic achievement as to describe the contributions of storage and processing as underlying mechanisms of this relation (Unsworth et al., 2009; Lawson & Farah, 2017). In addition, the role of ASC in the relation between SES and academic achievement was examined, as a mediating (i.e., explanative) or moderating (i.e., modulatory) factor (Li et al., 2020). Finally, as the work on WM and ASC have never

been connected, one opportunity in the present study was to connect these two research streams. This connection is especially important given that the two constructs are affected by SES and predict academic achievement.

Research questions and hypotheses

The main questions are whether WM, ASC and academic achievement are different across high and low SES backgrounds, whether the impact of SES on academic achievement is mediated by WM and ASC, and whether WM and ASC represent separate constructs that each contribute to academic achievement. It was expected that:

1. High SES students would show higher academic achievement than low SES students.
2. This effect should be mediated through WM and ASC and the indirect effect should be stronger for WM processing than for WM storage and ASC.
3. WM and ASC should independently contribute to academic achievement.

Method

Participants

The sample is composed of 2379 middle and high school students ($M_{\text{age}} = 14.6$ [11; 20], $SD = 1.52$, n females = 1246 (52.3%), n middle school = 1339 (56.3%)). Of them, 1330 were students from the middle class or from clearly disadvantaged backgrounds (59.9%) and 1049 were students from privileged or highly privileged backgrounds (44.1%). This sample was obtained from a larger sample to which we applied a number of selection criteria (see selection criteria in Text S1). All students were French native speakers enrolled public schools, either in a mainstream curriculum (100% in middle school and 91.6% in high school) or in vocational or technologies curricula (8.4% in high school).

Material & Procedure

The procedure was completed on an online dedicated platform built on purpose. The platform collected different type of data including demographics, test scores, questionnaires, and WM measures.

Academic achievement

In each discipline (Mathematics, Physics-Chemistry, Earth and Life Sciences, Technology, History-Geography, Sciences and Management Technologies, Industrial Sciences and Technologies and Vocational Education), groups of teachers collectively elaborated the academic tests (metrics and content) for the purpose of the present study instead of using GPA scores for two reasons: First, it ensured that all assessments (including academic tests, WM and ASC) were administered close in time. Second, these various tests served as a baseline for a pre /post-test evaluation design in a broader research protocol involving different types of pedagogical interventions. Since our research project took place in authentic school settings, the level of participation of particular schools and referent teachers determined the enrolment of individual or group of students in one or more topics. More precisely, each school referent for the project (either the school principal or a teacher) had the possibility to propose one or more group of students. The number of participating groups (the usual classrooms) was determined by an internal agreement between the school principal and teachers from different disciplines. In case several teachers from one school agreed in participating, the students enrolled in these teachers' usual classrooms received the protocol for the various subjects taught by these teachers, provided that an informed consent was given by the parents or by the student himself when of legal age. All participants responded individually in their

school environment in computer labs comprising approximately 15 computers giving access to the online dedicated platform which automatically standardized the scoring procedure to prevent evaluation biases. The tests consisted of a series of multiple-choice, true /false, and short-answers questions related to topics of the French Educational Programme in the respective subjects taught through the previous year before the study's beginning. In the majority of cases, the procedure was under the supervision of the formal teacher or a school referent, in a computer-lab room equipped with one computer per student. The ASC and WM were first measured (in a counterbalanced order) in one or two sessions of one hour each. About one week later, students took the academic tests in the same room, and the session lasted approximately one hour. When possible, students took more than one academic test related to different subjects depending on the agreements with schools (e.g., in the mainstream curriculum where the same students are taught Physics/Chemistry, Earth and Life sciences and Mathematics in the same school). This situation represented 30.6% and 48.4% of the cases for middle and high school respectively. Academic achievement scores were averaged for students who took more than one test. Ultimately, all performance scores were converted into Z-scores prior to analyses. Unstandardized scores are available in Table S1.

Socioeconomic status

In France, a commonly used indicator of SES (established by the French National Institute for Statistical and Economic Studies or INSEE) is the nomenclature of people's professions and socio-professional categories (PCS) (INSEE, 2018). The PCS index provides a classification of the population based on a synthesis of occupational status, hierarchical position and economic status. This index can be further categorized into four

categories using a previous nomenclature proposed in 1982 (INSEE, 2018) that correspond to increasing levels of social standing, ranging from disadvantaged background (1), middle class (2), privileged background (3) and highly privileged background (4). Students' PCS was derived from their parents' PCS, which was provided by the French Ministry of Education in the form of the 1982's nomenclature. To clarify the role of SES, we collapsed the four 1982's levels into low (1+2) and high SES (3+4). By comparing students with low SES versus high SES, the objective was to simplify analyses and result interpretability by using these two categories as a dummy variable.

Psychological assessments

Working memory storage and processing were assessed as inspired by the work of Unsworth et al. (2009). Shortened versions of three classic complex span tasks (Reading, Operation and Symmetry span tasks) adapted from Oswald et al. (2015) were used in this study. These tasks are available online at the Englelab website (<http://englelab.gatech.edu/taskdownloads>). The complex span tasks were computer-based tasks consisting of lists of to-be-remembered (TBR) items interspersed with to-be-processed (TBP) items. Participants had to memorize lists of TBR items while processing items of the secondary task and to recall the lists of TBR item at the end of each trial. The three complex span tasks have comparable structures and all responses were reported using the mouse. For the Reading and Operation span tasks, TBR items were letters and for the Symmetry span task, TBR items were spatial locations. The secondary tasks were respectively sentence judgment, arithmetic operation judgment and symmetry judgment. For each TBP item, participants had to click on "yes" or "no" response buttons to determine whether the current item was correct or incorrect among an equal number of

correct and incorrect items. Latencies in the secondary task exceeding $\pm 2.5 SD$ of each participant's mean time obtained during a previous practice bloc were automatically considered as outliers and the corresponding trials as errors (Oswald et al., 2015; Unsworth et al., 2009). At the end of a trial, a response screen invited participants to recall the TBR items in serial order by clicking on the right items presented among a number of distractors and then press an "enter" button to validate the response. For each task, the percentage of correct responses to the secondary task represented the processing performance while the number of correctly recalled items in a serial order within a trial corresponded to memory performance. All WM scores were converted into Z-scores prior to analyses. Unstandardized scores for lists of 4, 5 and 6 TBR items for each task are available in Table S1.

Academic self-concept was assessed using the 6-item scale adapted from Huguet et al. (2009) for Maths and French literacy. The scale contained five items and one reversed item, all loading on a single-factor structure, and is associated with high reliability in Maths, $\alpha = .88$, and French literacy, $\alpha = .89$ (Author et al., 2009). Each item responses consisted of a 6 points Likert-type scale ranging from "I strongly disagree" (1) to "I strongly agree" (6) in French language. Originally adapted to assess self-concept in Maths and French, the present study transposed the same scale to different school subjects, in this case, History-Geography, Mathematics, Physics-Chemistry, Earth and Life Sciences, Technology (including Technology, Sciences and Management Technologies and Industrial Sciences and Technologies) and Vocational Education. Each version of the test comprised the same questions except that the wording relevant to a specific assignment changed. For example, item 5 of for Earth and Life Sciences stated in French language: "You quickly understand Earth and Life Sciences" while the same item asked "You

quickly understand Technology” in the Technology version. In case of students being involved in more than one assignment, and therefore, having their academic test scores averaged, the ASC scores tailored to each subject they took were averaged consequently. All ASC scores were converted into Z-scores prior to analyses. Unstandardized scores for each item of the ASC scale are available in Table S1.

Statistical analyses

We used Structural Equation Modelling to examine the relation between SES, WM, ASC and academic achievement. The first step was to conduct confirmatory factor analyses to evaluate the construct validity of WM and ASC. Confirmatory factor analyses were conducted on separate constructs. Values of CFI $> .90$ and RMSEA $< .10$ were considered acceptable model fit, and RMSEA $< .05$ indicated good fit (Browne & Cudeck, 1993; Kenny, 2015). Reliability was assessed using the Composite Reliability Ω index, similar to Cronbach’s alpha, and well suited for SEM (Hayes & Coutts, 2020). The statistical analyses were based on maximum likelihood estimation and were conducted using the Lavaan package (Rosseel, 2012) version 0.6-3 in R software (R Core Team, 2013).

Then, analyses of measurement invariance were conducted prior to investigating structural relationships between WM, ASC, and academic achievement. Measurement invariance allows determining the extent to which each construct is similarly assessed in the two SES groups by comparing levels of measurement invariance (Putnick & Bornstein, 2016; Vandenberg & Lance, 2000). The procedure compared configural invariance (i.e., an unconstrained model), to weak invariance (i.e., factor loadings were constrained to be equal), to strong invariance (i.e., factor loadings, intercepts were constrained to be equal) and to strict invariance (factor loadings, intercepts and residual

variances were constrained to be equal across groups). The measurement invariance procedure was conducted on each measurement model to ensure that high and low SES participants equally interpreted each construct.

Results

Measurement models and measurement invariance

As shown in Table 1 and Figure S1, a series of confirmatory factor analyses was conducted for WM (a two-factor model, Unsworth et al., 2009) and ASC (a single model, Huguet et al., 2009). For WM, three confirmatory factor analyses were run, one for each WM task. The storage components of WM showed quite low but acceptable reliability (Hinton et al., 2004; Murphy & Davidshofer, 1988). This was possibly due to the experimental procedure where groups of students completed the memory tasks in computer labs, resulting in WM maintenance being highly sensitive to ambient noise. Furthermore, shortened tasks measuring storage component of WM generally show lower reliability than longer versions (Kane et al., 2004; Gonthier et al., 2016; Oswald et al., 2015). Reliability was higher for the processing components of WM as well as for ASC. Measurement invariance tests (Table 1) indicated that all models were strongly invariant across SES groups as shown by Δ_{CFI} and Δ_{RMSEA} below standard thresholds ($\Delta_{CFI} = .01$ and $\Delta_{RMSEA} = .015$, Chen, 2007; Cheung & Rensvold, 2002).

Table 1

Measurement models for working memory and academic self-concept and measurement invariance across high and low socioeconomic status.

	Rspan	Ospan	Span	ASC			
Model fit indices							
χ^2 (df)	775.882 (53)	960.089 (53)	1015.602 (53)	215.709 (18)			
CFI	.956	.958	.957	.980			
RMSEA	.076	.085	.087	.096			
Reliability							
	Storage	Proc	Storage	Proc	Storage	Proc	-
Factor loadings [range]	[.39 ; .50]	[.82 ; .95]	[.47 ; .54]	[.86 ; .96]	[.47 ; .51]	[.86 ; .96]	[.69 ; .86]
Composite reliability (Ω)	.61	.96	.66	.96	.66	.97	.93
Measurement Invariance across SES groups							
	Metric (weak)						
Δ_{CFI}	0	0	0	0			
Δ_{RMSEA}	.003	.004	.003	-.009			
	Scalar (strong)						
Δ_{CFI}	0	0	0	.002			
Δ_{RMSEA}	.004	.003	.004	-.006			
	Residual (strict)						
Δ_{CFI}	.001	.001	0	.004			
Δ_{RMSEA}	.003	.004	.003	-.001			

Note. Proc = working memory processing component. df = degrees of freedom; RMSEA= root mean square error approximation; CFI = comparative fit index; Rspan = reading span task; Ospan = Operation span task; Sspan = symmetry span task.

Full structural mediation model

Next, a series of concurrent models were built (see Figure S2 for graphical representations) with freely estimated parameters testing alternative hypotheses on the

link between SES and academic achievement. These models all included SES as an observed fixed predictor, WM storage and processing, and ASC as latent variables, and academic achievement as an observed dependent variable. Model 1 tested the full mediating role of WM and ASC, Model 2 tested the moderating role of ASC only, and Model 3 tested both the mediating role of WM and the moderating role of ASC. All these models were compared to a model of main effects only (Model 0). Table 2 reports fit statistics. All models showed at least acceptable fit but Model 1 fitted best, as evidenced by highest CFI, and lowest RMSEA, AIC and BIC values.

Table 2

Comparison of hypothesized models

	χ^2 (df)	CFI	RMSEA	AIC	BIC	$\Delta \chi^2$	Δ df	<i>p</i>
Model 0	4072.489 (891)	.957	.039	219624	220439			
Model 1	4001.046 (888)	.958	.038	219559	220391	71.443	3	< .001
Model 2	4689.935 (1161)	.958	.036	249908	250843	617.45	270	< .001
Model 3	4727.013 (1162)	.957	.036	249943	250873	654.52	271	< .001

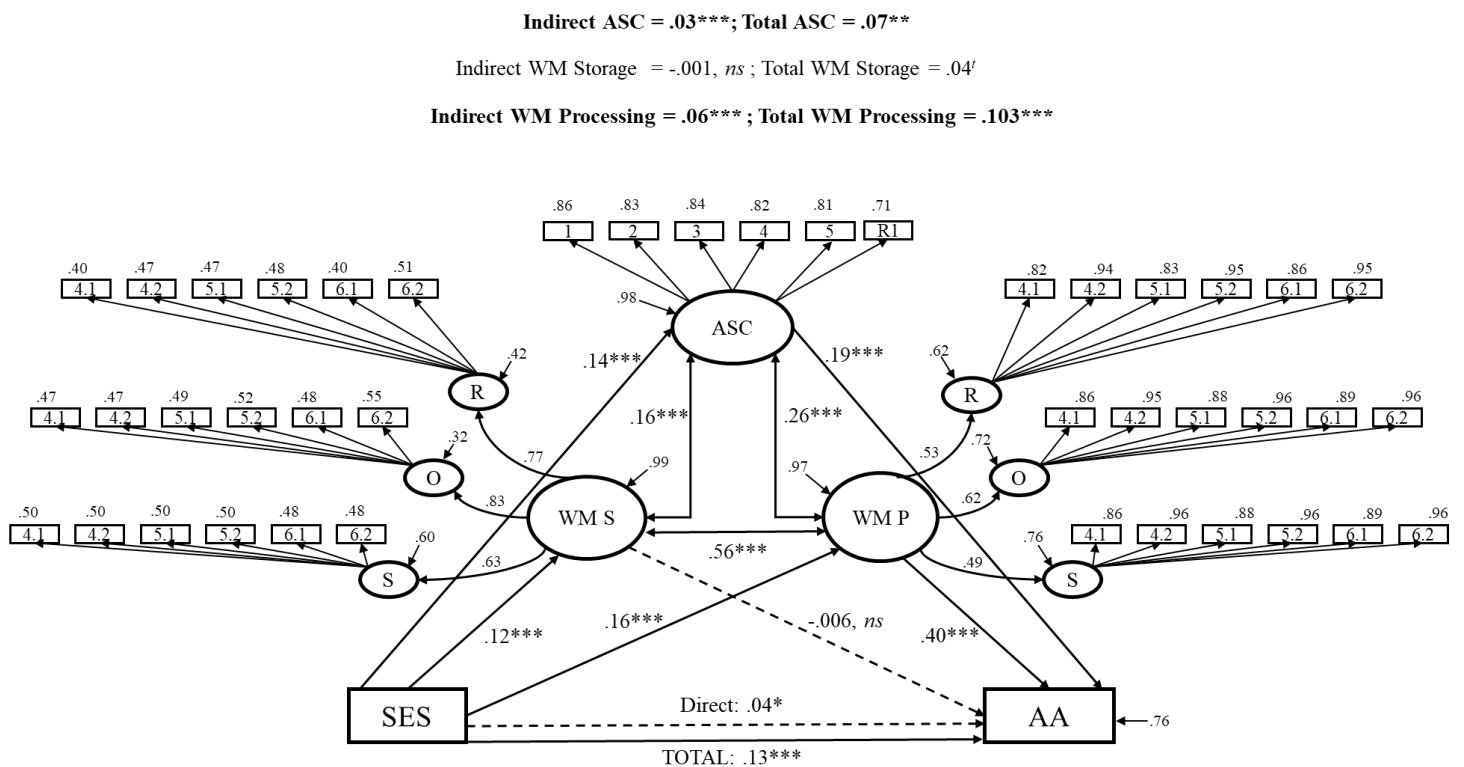
Note. The model in bold is the preferred model. Each model was compared to Model 0. See Figure S2 for graphical representations. df = degrees of freedom; RMSEA = root mean square error approximation; CFI = comparative fit index; AIC = Akaike information criterion; BIC = Bayesian information criterion.

Figure 1 shows the final structural model (Model 1) in which the influence of SES on academic achievement is mediated by WM processing (WMP) and ASC. Factor loadings are displayed in Figure 1. Working memory storage (WMS) capacity showed a non-significant relationship with academic achievement (AA) ($\beta = -.006, p = .87$) and a non-significant indirect effect ($\beta = -.001, p = .87$), which accounted only for 2.6% of the variance of the SES-WMS-AA triad's marginal total effect ($\beta = .038, p = .059$) and 0.8% of variance of the TOTAL effect of SES on academic achievement ($\beta = .129, p < .001$), calculated as the sum of indirect effects and the direct effect. In contrast, the indirect

effect linking SES to academic achievement via WM processing ($\beta = .064, p < .001$) accounted for 62.1% of variance of the total effect of the SES-WMP-AA triad ($\beta = .103, p < .001$), and 49.6% of the TOTAL effect. In smaller but significant proportions, ASC ($\beta = .026, p < .001$), accounted for 40% of the total effect of the SES-ASC-AA triad ($\beta = .065, p = .001$), and 20.2% of the TOTAL effect. The remaining 30% of variance was accounted for by the direct effect between SES and academic achievement ($\beta = .039, p = .049$).

Figure 1

Full structural mediation Model 1 between socioeconomic status, working memory storage and processing, academic self-concept and academic achievement.



Note. Values on top of observed variables represent factor loadings. For the sake of simplicity, values for residual variances related to indicators of latent variables are omitted. Residual variances for endogenous latent variables and academic achievement are symbolized with small single-headed arrows; Dotted lines

correspond to non-significant effects; * = significant at $p \leq .05$; ** = significant at $p \leq .01$; *** = significant at $p \leq .001$; *ns* = non-significant at $p \leq .05$; *t* = marginal effect, $p \leq .06$; SES; socioeconomic status; AA: academic achievement; WMS = working memory storage; WMP working memory processing; ASC = academic self-concept. R: reading span task; O: operation span task; S: symmetry span task 4.1 = “Set of 4 to –be-remembered items, first presentation”, etc.; R1 = Reversed item 1. TOTAL = sum of all indirect and direct effects.

The impact of processing task type on working memory processing mediation effects

Next, Model 1 was decomposed to determine the locus of the WM processing mediation effect (see Figure S3 for a graphical representation). If the locus of the mediating processes was mainly explained by academic-related characteristics of WM tasks (i.e., sentence judgment and arithmetic verification), the mediating effect should be explained largely by the Ospan and Rspan processing components and less by the Sspan processing component (symmetry verification). Otherwise, if the locus of the mediation effect resulted from general processing features, effects should be significant in all tasks and more equally distributed across them. To examine this possibility, we restricted Model 1 (i.e., main effects and mediation effect) to contain only one of the three complex span tasks’ processing components. In addition to WM storage and ASC mediating effect, Model 1.1, Model 1.2 and Model 1.3 comprised respectively the Rspan, the Ospan or the Sspan processing component as a mediator. Characteristics were the same as in Model 1 except that the main WM processing effect was restricted to the task relevant for the model. All models showed excellent fit (see Table 3).

Table 3

Fit indexes for Model 1.1 (Reading span task), Model 1.2 (Operation span task) and Model 1.3 (Symmetry span task) and contributions of task-specific processing indirect effects.

	χ^2 (df)	CFI	RMSEA	% variance explained for the indirect Processing effect on the total Processing effect
Model 1.1	1408.488 (453)	.970	.030	32.5%
Model 1.2	1662.746 (453)	.966	.034	15.2%
Model 1.3	1770.319 (453)	.963	.035	10.7%

Note. df = degrees of freedom; RMSEA = root mean square error approximation; CFI = comparative fit index.

While the regression coefficient corresponding to the total effect of SES on academic achievement via WM processing was slightly higher in Model 1 ($\beta = .103$, $p < .001$) compared to subsequent models (from $\beta = .075$ to $\beta = .079$, all $ps < .001$), the indirect effects were much reduced in subsequent models relative to the initial Model 1 ($\beta = .064$, $p < .001$, equal to 62.1% of variance of the total effect). Although all indirect effects were significant, the indirect effect of Rspan processing component was the largest (Model 1.1, $\beta = .025$, $p < .001$), accounting for approximately 32.5% of variance of the total WMP effect ($\beta = .077$, $p = .001$). Then, the Ospan processing component (Model 1.2, $\beta = .012$, $p = .001$) explained approximately 15.2% of variance of the total WMP effect ($\beta = .079$, $p = .001$). Lastly, the Sspan processing component (Model 1.3, $\beta = .008$, $p < .001$), accounted for 10.7% of variance of the total WMP effect ($\beta = .075$, $p = .010$). Interestingly, the common processing factor in Model 1 accounted for a larger proportion of variance (62.1%) than the processing components taken separately (i.e., 32.5%, 15.2% and 10.7% for Rspan, Ospan and Sspan respectively) suggesting that the common factor

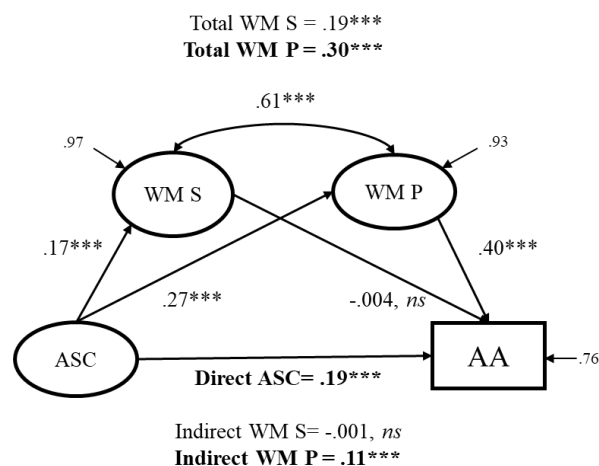
rather than separate tasks better explained the locus of the processing mediation effect on the link between SES and academic achievement.

The relative independence of working memory and academic self-concept

The relative independence of WM and ASC to each other was examined along with their respective contributions in explaining academic achievement. Shown in Figure 2, Model 4 included no SES, ASC as predictor, both WM storage and WM processing as mediators, and academic achievement as observed dependent variable. The structure of the model was inspired by past research exploring whether cognitive abilities explained the effects of self-perceptions on academic achievement (Giofrè et al., 2017). The model showed acceptable fit: $\chi^2 = 3946.934$, $df = 849$, $CFI = .958$, $RMSEA = .039$. It revealed that the indirect effect of processing ($\beta = .11$, $p < .001$), but not storage ($\beta = -.001$, $p = .909$), mediated part of the total ASC effect on academic achievement, accounting for 36.7% of the total effect of ASC on academic achievement ($\beta = .30$, $p < .001$). Consistent with hypothesis 3, the direct effect of ASC on academic achievement was approximately two times larger ($\beta = .19$, $p < .001$), accounting for 63% of the same triad, suggesting that ASC has unique contributions to academic achievement beyond the effects of WM processing.

Figure 2

Structural Model 4 with working memory storage and processing partly mediating the relationship between academic self-concept and academic achievement.



Note. Observed variables are not displayed except for academic achievement. Residual variances for endogenous latent variables and academic achievement are symbolized with small single-headed arrows; * = significant at $p \leq .05$; ** = significant at $p \leq .01$; *** = significant at $p \leq .001$; *ns* = non-significant at $p \leq .05$. AA: academic achievement; WMS = working memory storage; WMP working memory processing; ASC = academic self-concept.

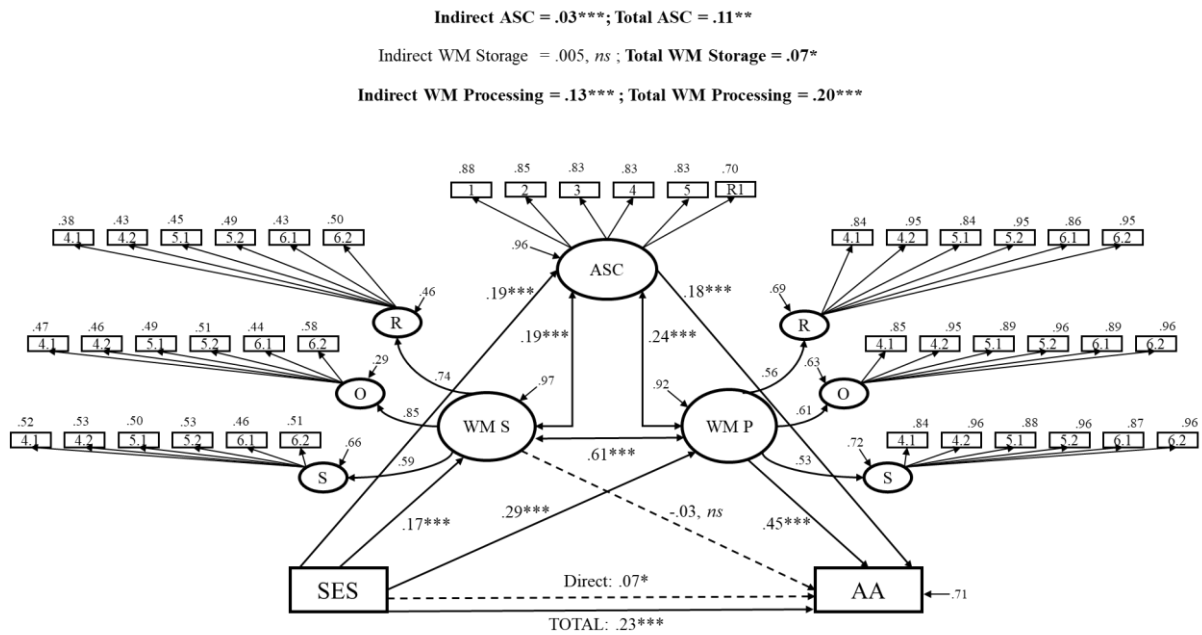
Effects of the proximity of socioeconomic categories

Finally, the extent to which the proximity of SES categories (extreme vs adjacent) impacted SES-related effects sizes was examined. To this end, two additional models were derived from the main mediational model (Model 1). A first model comprising only “Extreme” SES categories (disadvantaged and highly privileged backgrounds, $n = 1017$) was compared to a second model comprising only the “Adjacent” middle categories (middle class and privileged backgrounds, $n = 1362$) and both were examined in light of the whole cohort ($N = 2379$). The two models showed highly similar fit indices compared with one another (respectively, $\chi^2 = 2302.734$, $df = 888$, $CFI = .956$, $RMSEA = .040$, and

$\chi^2 = 2634.132$, $df = 888$, $CFI = .958$, $RMSEA = .038$) and relatively to the whole model. However, as shown in Figure 3, the model with extreme categories revealed a larger influence of SES on academic achievement (i.e., the TOTAL effect: $\beta = .23$, $p < .001$), compared to the model with adjacent categories ($\beta = .05$, $p = .060$). In the “Extreme” model, the relationship between SES and WM storage ($\beta = .17$, $p < .001$) and processing ($\beta = .29$, $p < .001$) increased compared to the “Adjacent” model ($\beta = .071$, $p = .036$, and $\beta = .068$, $p = .064$). The indirect effects of storage and processing were also larger in the “Extreme” model ($\beta = .005$, $p = .634$, and $\beta = .13$, $p < .001$) compared to the “Adjacent” model, ($\beta = .000$, $p = .923$, and $\beta = .024$, $p = .074$) although only the processing effect was significant in the “Extreme” model. Conversely, the influence of SES on ASC, as well as the indirect effect remained significant both in the “Extreme model” ($\beta = .189$, $p < .001$ indirect effect: $\beta = .034$, $p < .001$) and the “Adjacent” model ($\beta = .090$, $p = .001$ indirect effect: $\beta = .017$, $p = .004$).

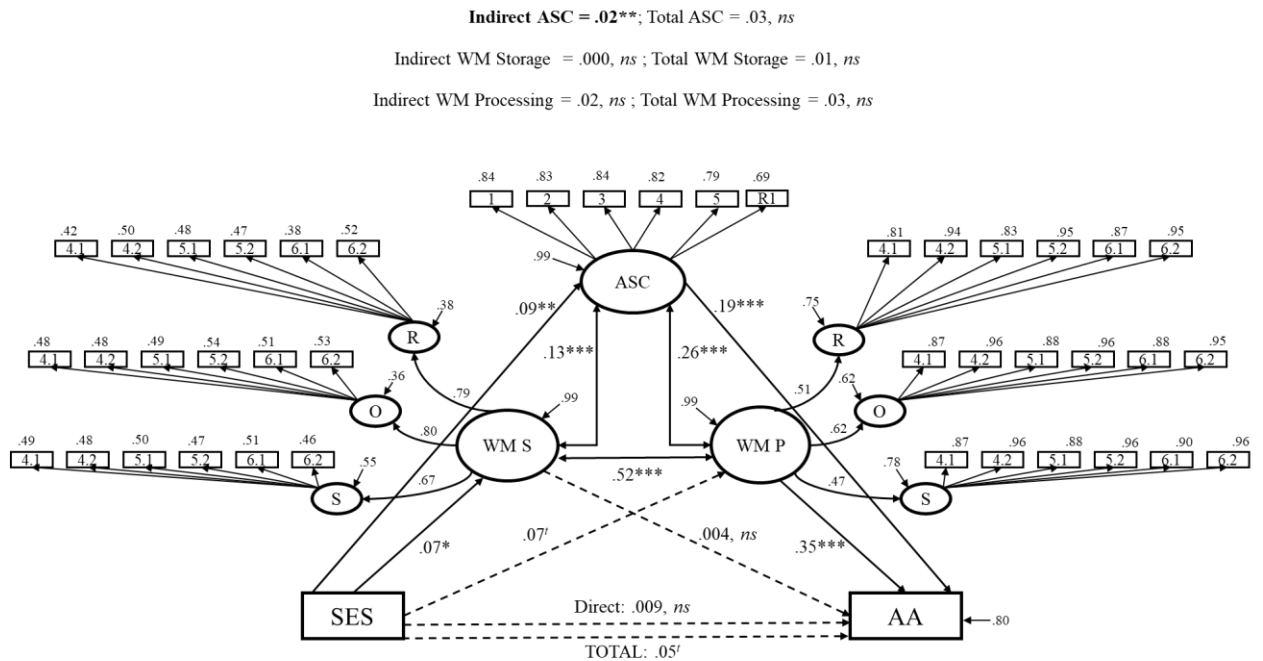
Figure 3

Full structural mediation models comprising “Extreme” (top panel) and “Adjacent” socioeconomic categories (bottom panel).



“Extreme” Model 1, $n = 1017$

Note. The “Extreme” model comprises PCS categories 1 (disadvantaged background) and 4 (highly privileged background) as low and high SES. $M_{age} = 14.54$ [11; 19], $SD = 1.51$, n females = 540 (53.1%), n middle school = 597 (58.7%), n low SES = 562 (55.2%).



“Adjacent” Model 1, $n = 1362$

Note. The “Adjacent” model comprises PCS categories 2 (middle class) and 3 (privileged background) as low and high SES. $M_{age} = 14.63$ [11; 20], $SD = 1.53$, n females = 706 (51.8%), n middle school = 742

(54.5%), n low SES = 875 (64.2%); Values on top of observed variables represent factor loadings. For the sake of simplicity, values for residual variances related to indicators of latent variables are omitted. Residual variances for endogenous latent variables and academic achievement are symbolized with small single-headed arrows; Dotted lines correspond to non-significant effects; * = significant at $p \leq .05$; ** = significant at $p \leq .01$; *** = significant at $p \leq .001$; *ns* = non-significant at $p \leq .05$; *t* = marginal effect, $p \leq .06$; SES: socioeconomic status; AA: academic achievement; WMS = working memory storage; WMP working memory processing; ASC = academic self-concept. R: reading span task; O: operation span task; S: symmetry span task 4.1 = “Set of 4 to be-remembered items, first presentation”, etc...; R1 = Reversed item 1; TOTAL = sum of all indirect and direct effects.

Discussion

To fuel the debate on the interaction between sociocultural and educational factors in the course of human development, the present study has investigated the influence of SES on academic achievement while considering WM and ASC jointly as explanatory variables for that relationship. The main findings point to small effect of SES on academic achievement that confirms previous studies in terms of direction of effects (Barrouillet et al., 2008; Lawson & Farah, 2017; Liu et al., 2019; Sirin, 2005), that is, students with lower SES showed lower academic achievement. Globally, the structural associations between WM, ASC and academic achievement were comparable in low and high SES students. WM and ASC were shown to independently contribute to academic achievement, and ASC related more strongly with WM processing than with WM storage. Finally, the locus of the WM processing component mediation effect on the relation between SES and academic achievement was distributed across the three complex span tasks, but with greater contribution of the reading span task. Hereafter these results are discussed in more details.

The impact of socioeconomic status on academic achievement

How SES relates to academic achievement is still a matter of debate since the pioneer works on equality of educational opportunity (Coleman et al., 1966), unravelling the

strong determinism of parent's education level and social origin over children's school performance. Ever since, the magnitude of the influence of SES has been found around .25 standard deviation in meta-analytic work (Liu et al., 2019; Sirin, 2005) although substantial variation exists when considering a number of moderators (Liu et al., 2019; White, 1982). In the present study, where SES was assessed with a 4-category indicator, the coefficient is about $\beta = .13$ ($N = 2379$) confirming our first hypothesis. This smaller coefficient, however, might be related to several factors including the diversity of school subjects, the heterogeneity of the student population, the possible specificities of the French educational system or the specificity of the SES indicator used here. Further research is needed to clarify this slight magnitude. Interestingly, the SES-academic achievement relationship increased (as well as the links from SES to WM and ASC) when the cohort comprised only extreme SES categories (i.e., disadvantaged and highly privileged backgrounds, $\beta = .23$), and decreased to a marginal trend when the cohort comprised only middle adjacent SES categories (i.e., middle class and privileged backgrounds, $\beta = .05$). This is consistent with previous work showing a weaker SES impact on academic achievement as SES is restricted in range (White, 1982). Clearly, differences in academic achievement between middle class and privileged students were minimal. However, these analyses only inform on how similar students are across adjacent SES categories relative to extreme ones. Because this study did not use a continuous indicator of SES, it leaves open the question of possible variations of the SES effects on academic achievement *within* different SES populations.

At the conceptual level, the negative influence of low SES on academic achievement has been traditionally explained in two ways. One explanation concerns the disproportionate access to culture in disadvantaged and highly privileged backgrounds and its consequence

for learning (Bourdieu & Passeron, 1990; Damon et al., 2007). Several factors may contribute to this disproportionate access, some of them being situational, including reduced time spent by parents in support of their children's learning, as parent's low education level impede support; other being contextual, as families perceive low incomes and live in areas of deprivation, decreasing the possibility of affording cultural resources at home or outside (Banerjee, 2015; Chen et al., 2018). Another explanation proposes that the socioeconomic environment would shape the development of cognitive abilities and self-perceptions of own competences (Croizet & Dutrevis, 2004; Régner et al., 2002; Wiederkehr et al., 2015). Either way, the intertwinement of socio-cognitive factors contributing to SES effects is consistent with the fact that the SES impact on academic achievement decreases when a few variables are taken into account (Marks, 2017; Sirin, 2005). Accordingly, the SES effect size in the present study decreased after controlling for WM and ASC due to their mediating role.

The impact of socioeconomic status on working memory and academic self-concept

Separate works have documented the impact of SES on cognitive factors and self-perceptions. On self-perceptions, previous work showed small to moderate magnitude of the SES effect on ASC (from $\beta = .13$ to $.22$, Li et al. 2020; Maqsd & Rouhani, 1991). Here, a standardized coefficient of $\beta = .14$ was found, which closely aligns with these values. On cognitive factors, the magnitude of the SES effect has been shown to vary depending on specific components. Lawson and Farah (2017) found executive functions and verbal memory as being differentially affected by SES. In their study, while the executive factor received the strongest effect of SES ($\beta = .39$), the verbal memory factor, composed of short- and long-term memory tasks, showed more independence ($\beta = .12$).

Because WM processing and executive functions tasks both tap into attention (Barrouillet et al., 2011; Engle, 2002) and short-term storage capacity is relatively independent from attentional control (Unsworth et al., 2009; 2014), we can assume some overlap between the WM two-factor model and the two factors identified in Lawson and Farah. Consistent with their findings, WM storage was found to be less affected by SES ($\beta = .12$) than WM processing in the present study ($\beta = .16$), although this gap becomes more apparent ($\beta = .17$ and $.29$, respectively) when considering extreme SES categories (see Figure 3). This difference in the status of the two WM components may be explained in the light of the two complementary explanations proposed above. The first explanation emphasizes the the impact of SES on cerebral maturation hence reduced cognitive functions (Lawson & Farah, 2017). Accordingly, we may interpret SES effects as resulting from an attentional diminution rather than substantial changes in storage capacity.

The second explanation emphasizes the reduced exposition to learning resources that would impede the automatization of literacy and numeracy. In this perspective, the reduced access to culture, inherent to disadvantaged backgrounds, that keep students away from the required resources to successful academic learning, may also reduce the automaticity with which to process distractor items of the present complex span tasks (Noble et al., 2006). Indeed, these items imply respectively sentence judgments, arithmetic operation verifications, and symmetry judgments. Although students' access to cultural resources at home was not directly measured, part of this cultural knowledge could be somehow involved in the complex span processing tasks. While both verbal processing tasks (i.e., reading judgment and operation verification) may comport a true part of variance associated with attentional control (Shipstead et al., 2014), they might also depend on cultural factors. For instance, the assimilation of critical notions in

arithmetic and reading might be helped by social contexts where parents or substitutes can themselves understand the notions taught in class, and go into more details with verbally interacting with the learner (Caro, 2011; Harju-Luukkainen et al., 2020). To perform the WM tasks quickly and accurately, students must show efficient reading and arithmetic skills, that home cultural resources like books, videogames and parent support may enhance, suggesting that lowered automaticity in processing the complex span distractors is a by-product of the influence of SES through reduced cultural resources, not through reduced cognitive ability *per se*.

The mediating role of key psychological factors (working memory and academic self-concept)

In addition to the differential impact of SES on the two components of WM, there was a disproportionate mediation effect of WM processing, accounting for 50% of the SES impact on academic achievement, relative to WM storage. The latter only accounted for less than 1% of this link. These findings confirmed our second hypothesis. The huge disproportion of storage and processing contributions to the SES impact on academic achievement might again be explained in light of the two previous arguments. Just like SES may have a greater impact on executive/attentional than storage processes (Lawson & Farah, 2017, Unsworth et al., 2009), academic achievement might in turn be more affected by individual differences in executive/attentional than storage functions. Alternatively, the disproportionate contributions of storage and processing could also be the consequence of reduced automaticity of the essential skills both needed to perform the processing items of the WM tasks and the most basic requirements for all kind of school learning activities (like reading and arithmetic), as a result of reduced home

support that more cultural resources help affording (Caro, 2011; Harju-Luukkainen et al., 2020; Noble et al., 2006).

Focusing on the status of the symmetry span may help to clarify the heuristic value of the two approaches. Verbal WM is related to both crystallized and fluid cognition while spatial WM is almost exclusively related with fluid cognition (Haavisto & Lehto, 2005). Consequently, the symmetry judgment task should minimize the knowledge which can be transmitted by the means of social contexts and hence should be less dependent from disparities in cultural capital. If cultural capital mainly explained the locus of the WM processing mediation effect, there should be little contribution of the symmetry judgment processing task along with a large contribution of the reading judgment and the operation verification tasks. On the contrary, if an attention-based account prevailed in the explanation of SES influence on academic achievement, processing indirect effects should distribute more equitably across tasks. The findings support both accounts. Ruling out the strict account of a unique involvement of cultural factors, all three tasks significantly contributed to the WM processing mediation effect. Consistent with the attentional account, this suggests that the locus of the WM processing mediation effect was the result of a common source of variance distributed across the 3 tasks (i.e., attention driven). In support for this hypothesis, the common processing factors explained more variance of the total effect (62.1%) of the SES-WMS-AA triad than any task taken separately. On the contrary, in favour of the cultural-account, the three tasks contributed differentially to the total WM processing effect in subsequent models, from reading judgment (32.5%) to operation verification (15.2%), to symmetry judgment (10.7%). This finding is consistent with the view that some task-specific elements are maybe more influential than others in determining the disadvantage of low SES students in academic

achievement. These crucial elements may reflect the degree of sophistication of the to-be-learned material (e.g., arithmetic strategies, reading fluency), calling for higher culturally-acquired abilities, that are more easily transmitted to students in social contexts that afford high quality education. Therefore, both the cognitive account, thought as reduced attentional capacities in disadvantageous students, and the cultural account, though as a reduced exposition and training on basic literacy skills, especially reading, may contribute to disproportionate mediating contribution of WM processing over storage in the negative impact of SES on academic achievement.

The data also point to interesting results regarding ASC and its relation with the other constructs examined here. Confirming the findings of Marsh and O'Mara, we further found that ASC moderately predicted academic achievement ($\beta = .19$) which coefficient lies within the range reported by Marsh and O'Mara ($\beta = .14$ to $.36$). We were also very close to Li et al.'s (2020) findings showing that ASC partially mediated the effects of SES on academic achievement ($\beta = .027$ and $\beta = .026$ in Li et al. and in the present study, respectively). It should be noted that although we adopted a correlational approach, the causality of the relation is non-reversible due to the temporal impossibility of ASC to reciprocally influence SES, which strengthens the idea that SES is a powerful causal determinant of self-perceptions. Furthermore, we found that ASC was more strongly related to WM processing ($\beta = .27$) than to WM storage ($\beta = .17$), therefore offering new insights on the relations between cognitive factors and self-perceptions that are usually examined separately. These results offer a first indication of distinct relations that might exist between self-perceptions and maintenance mechanisms in WM. The newly evidenced and particularly strong relation between ASC and WM processing is consistent with the proposed cultural account, in which performing items of the processing task may

be particularly sensitive to exposition to cultural resources and literacy / numeracy training (which is less likely for maintaining items in the storage task). However, the contribution of ASC alone to academic achievement ($\beta = .19$) -meaning that students with lower ASC underperform academically their more self-confident counterparts- was nevertheless much larger than this partially mediated effect via WM processing ($\beta = .11$), approximately two times more pronounced. These findings confirmed our third hypothesis by showing partially independent contributions of self-perceptions and cognitive abilities to academic achievement (Griofrè et al., 2017). Previous studies have stressed that the meritocratic ideology conveyed in western societies and the comparison of social status has consequences in the manner individual develop self-perceptions about their social class (Croizet & Dutrévis, 2004; Easterbrook et al., 2020; O'Brien & Major, 2009). Accordingly, it may be that the larger influence of ASC reflects a process of internalization discussed in Wiederkehr et al. (2015), transforming social norms of success and failure (such as those associated with high and low SES backgrounds) into personal factors, which relates more to cultural beliefs than to student's efficiency *per se* in performing cognitive or academic tasks.

Limitations

The most crucial limitation of the present study concerns the nature of the SES indicator. The categorical variable used here (the PCS, INSEE, 2018) may have limited the variability in SES which could have affected the magnitude of the SES coefficient, therefore, findings regarding the magnitude of effect (more than the direction of effect) should be interpreted with caution. Furthermore, despite the indicator in a synthesis of the parents' occupational status, hierarchical position and economic status, the PCS does not consider other important SES aspects such as home environment (i.e., familial

atmosphere, home library equipment, frequency of exposure to cultural events), school characteristics or neighbourhood influence (Aikens & Barbarin, 2008). A second important limitation concerns the nature of field experimentation. Although the collection of data in real school settings brings ecological validity, some parameters lie outside the experimenter's control. For instance, the fact that all measures were administered in the computer labs, in which students responded individually but in presence of other classmates, may have induced distraction while completing the WM tasks. After all, however, the presence of others and related distraction is the rule rather than the exception at least in the school setting. There is ample evidence that examining cognition in its social context is necessary to predict academic achievement (for a review, see Huguet et al., 2017). Nevertheless, one may argue that providing ecological validity may undermine psychometric validity as maintaining a list of items is very sensitive to distraction inherent to noisy environments thus possibly underestimating the contribution of WM storage in its structural relationships with other variables.

Theoretical and practical implications and future directions

The results of the present research call for caution when examining SES effects on the ability to process essential information related to basic literacy and numeracy operations, that are both inherent to WM complex span tasks (as processing distractors, therefore important to measure WM) and at the root of any academic learning activity. Students struggling with decoding these essential elements as a result of unfavourable socioeconomic contexts for their acquisition and development may encounter great difficulties in learning since the time spent in decoding these basic elements may mobilize attention at the detriment of relevant parts of the lessons taught in class. It seems that SES

influences these factors more than the capacity to store information in WM and also determines partly how students develop self-perceptions of competence.

At the practical level, the findings are good news. If the results indeed showed a lack of any mediation effects by WM processing and ASC, this would mean that the only way to reduce the SES achievement gap is by restructuring society, which is obviously not within the reach of the teacher. The teacher may nevertheless act effectively at the level of his/her students by developing their information processing capacity and enhance their ASC using appropriate techniques. However, this rationale only makes sense in the case of accessible leverages for the teacher that would mediate at least partially the effect of SES on academic achievement. This is exactly what the results support by revealing the critical role of WM processing and ASC in this SES effect. This is why educational systems should increase their attention about how to train low SES students' automaticity in decoding and processing basic elements while ensuring that the classroom setting minimizes evaluative pressures and related social comparisons that may damage their ASC (Author et al. 2009). Combining these two conditions might help reduce the SES achievement gap.

Conclusion

The present study found that the psychological factors working memory and academic self-concept accounted for a significant portion of the SES influence on academic achievement. In particular, the role of reduced processing abilities in working memory for the less advantaged students explains their poorer academic performance. However, we caution against a straightforward interpretation in terms of inferior cognitive skills *per se*.

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Declarations

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Conflicts of interest/Competing interests. The authors declare no competing interests.

Availability of data and material. The dataset SEM_EP3C supporting the findings of this study is available in the OSF repository [<https://doi.org/10.17605/OSF.IO/M5V2H>].

Authors' contribution. *Project concept and management:* P. Huguet, M.C. Borion, L. Pailler, N. Rocher, R. Cadet, N. Maïonchi-Pino, C. Lenne, D. Cazenave & J. Chevalère. *Study site lead investigators:* M.C. Borion, D. Pailler & N. Rocher. *Data collection:* M. Berthon, R. Martinez, V. Mazenod, L. Cazenave & J. Chevalère. *Data analysis:* J. Chevalère, R. Wollast & P. Huguet. *Paper writing:* J. Chevalère & P. Huguet. All authors provided critical revisions, approved the final version of the paper for submission, and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

Ethics approval. The study is part of a larger research project which received an approval from the Clermont Auvergne University Ethics Committee (number IRBO0011540-2018-08) in conformity with the French bioethical law (covering Psychology).

Consent to participate. All participants were recruited in their usual school by the referent teacher participating in the study, which was observed by an individual established collaboration between a school and Clermont Auvergne University. For underaged participants, the parents or legal guardian received a written informed consent form several weeks before the study that they had to read and sign to allow their child to participate.

Consent for publication. Consent for publication was obtained for this study.

Supplementary Information

For

The Influence of Socioeconomic Status, Working Memory and Academic Self-Concept on Academic Achievement

(Including: Text S1, Table S1, Figures S1, S2, S3)

Text S1: Selection criteria

This study was part of a larger multicentric research project conducted among 3328 students, which served different research purposes. For the needs of the present study, participants had to meet several criteria to be included in the final sample. First, participants had to take all three WM tasks and show a minimum average of 50% processing accuracy (chance level) and above 0% in memory performance on the 3 WM tasks taken separately. Approximately 8.6% of the initial sample did not meet this criterion, therefore, they were excluded from analyses. This ensured to keep only students who paid sufficient attention to the WM tasks and completed them cautiously. Within the remaining 3041 participants, the PCS was unavailable for approximately 3.9% of the sample, resulting in 2924 participants. Only after this selection, we identified participants who did not complete all six items of the ASC. Out to 2924 participants, approximately 11.8% were in such cases ($n = 346$). Given such a high percentage, we conducted a missing value analysis using Little's MCAR test, which was significant, ($\chi^2 = 4522.41$, $df = 1472$, $p < .001$). A visual inspection of the missing patterns revealed that in a majority of cases, students associated with missing values on ASC did not complete all six items

of the scale as a block, and this seemed to occur for many participants at the same time in relation to specific disciplines, strongly suggesting that a number of classrooms did not comply well with the protocol. These were consequently excluded. Finally, out to the remaining 2578 participants, an additional 7% ($n = 199$) of the sample did not complete at least one academic test and therefore, was also discarded. After the selection procedure, the final sample comprised 2379 students ($M_{\text{age}} = 14.6$ [11, 20], $SD = 1.52$, n females = 1246 (52.3%), n middle school = 1339 (56.3%)) who had completed all psychological measures and at least one academic test.

Table S1

Descriptive statistics of the unstandardized scores for academic achievement tests, working memory and academic self-concept assessments

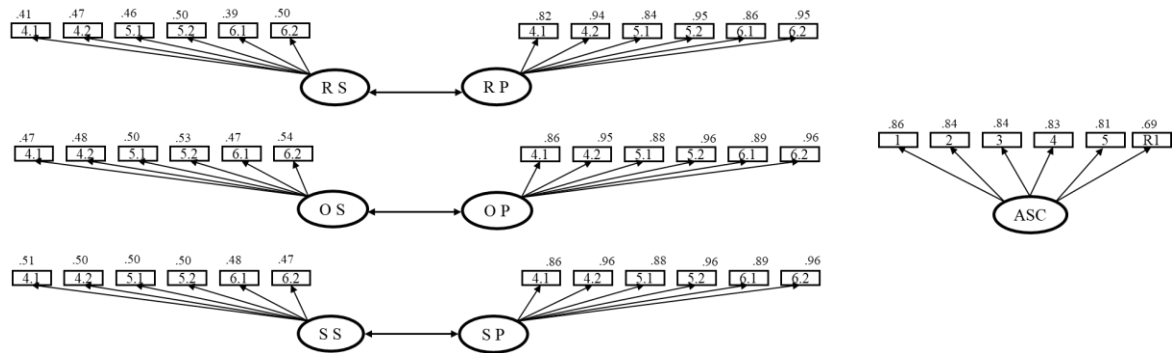
Name	N	Mean	SD	Med	Min	Max	Range	Skew	Kurtosis	SE
Middle school knowledge tests										
History-Geography	230	6.17	2.32	6	0	10	10	-0.52	-0.21	0.15
Mathematics	376	5.80	1.63	6	0	10	10	-0.11	0.00	0.08
Physics-Chemistry	438	6.88	1.78	7	0	10	10	-0.54	-0.20	0.09
Earth and Life Sciences	496	7.42	1.82	7.5	0	10	10	-0.84	0.93	0.08
Technology	457	6.63	2.60	7.5	0	10	10	-1.06	-0.23	0.12
High school knowledge tests										
History-Geography	501	6.60	2.26	7	0	10	10	-0.63	-0.32	0.10
Mathematics	162	5.15	2.17	5	0	10	10	0.34	-0.49	0.17
Physics-Chemistry	600	4.53	1.60	4.5	0	10	10	-0.11	-0.05	0.07
Earth and Life Sciences	473	6.63	2.06	7	0	10	10	-0.45	-0.06	0.09
Vocational	37	5.07	2.53	5	0	10	10	0.01	-0.81	0.42
STM	83	4.64	2.61	4.5	0	10	10	-0.06	-1.24	0.29
IST	79	5.56	2.12	6	0	10	10	-0.25	-0.53	0.24
Working memory - storage - number of recalled consonants in serial order										
Ospan, length 4, trial 1	2379	3.04	1.36	4	0	4	4	-1.19	0.01	0.03
Ospan, length 4, trial 2	2379	3.00	1.41	4	0	4	4	-1.13	-0.18	0.03
Ospan, length 5, trial 1	2379	3.37	1.78	4	0	5	5	-0.74	-0.84	0.04
Ospan, length 5, trial 2	2379	3.30	1.84	4	0	5	5	-0.66	-1.04	0.04
Ospan, length 6, trial 1	2379	3.43	2.10	4	0	6	6	-0.29	-1.24	0.04
Ospan, length 6, trial 2	2379	3.28	2.16	4	0	6	6	-0.22	-1.34	0.04
Rspan, length 4, trial 1	2379	2.96	1.32	4	0	4	4	-1.00	-0.28	0.03

Rspan, length 4, trial 2	2379	2.87	1.40	4	0	4	4	-0.90	-0.60	0.03
Rspan, length 5, trial 1	2379	3.16	1.73	3	0	5	5	-0.47	-1.08	0.04
Rspan, length 5, trial 2	2379	3.00	1.81	3	0	5	5	-0.37	-1.26	0.04
Rspan, length 6, trial 1	2379	3.24	1.96	3	0	6	6	-0.10	-1.15	0.04
Rspan, length 6, trial 2	2379	3.00	2.05	3	0	6	6	0.00	-1.26	0.04
Sspan, length 4, trial 1	2379	2.74	1.41	3	0	4	4	-0.73	-0.85	0.03
Sspan, length 4, trial 2	2379	2.59	1.49	3	0	4	4	-0.56	-1.15	0.03
Sspan, length 5, trial 1	2379	2.70	1.74	3	0	5	5	-0.08	-1.28	0.04
Sspan, length 5, trial 2	2379	2.55	1.78	2	0	5	5	0.02	-1.33	0.04
Sspan, length 6, trial 1	2379	2.42	1.84	2	0	6	6	0.43	-0.82	0.04
Sspan, length 6, trial 2	2379	2.21	1.86	2	0	6	6	0.53	-0.76	0.04
Working memory - processing percentage accuracy										
Ospan, length 4, trial 1	2379	83.29	13.54	87	37	100	63	-0.69	-0.15	0.28
Ospan, length 4, trial 2	2379	81.61	12.40	83	43	100	57	-0.63	-0.26	0.25
Ospan, length 5, trial 1	2379	82.46	13.55	84	33	100	67	-0.65	-0.07	0.28
Ospan, length 5, trial 2	2379	81.38	12.65	83	42	100	58	-0.65	-0.24	0.26
Ospan, length 6, trial 1	2379	82.42	13.33	85	30	100	70	-0.66	-0.15	0.27
Ospan, length 6, trial 2	2379	81.27	12.57	84	36	100	64	-0.64	-0.27	0.26
Rspan, length 4, trial 1	2379	75.75	13.92	76	37	100	63	-0.18	-0.65	0.29
Rspan, length 4, trial 2	2379	73.70	12.60	75	41	100	59	-0.21	-0.69	0.26
Rspan, length 5, trial 1	2379	74.92	13.80	77	33	100	67	-0.20	-0.58	0.28
Rspan, length 5, trial 2	2379	73.56	12.48	75	40	100	60	-0.24	-0.68	0.26
Rspan, length 6, trial 1	2379	74.87	13.54	78	30	100	70	-0.27	-0.51	0.28
Rspan, length 6, trial 2	2379	73.39	12.30	75	40	100	60	-0.23	-0.67	0.25
Sspan, length 4, trial 1	2379	83.60	13.91	87	25	100	75	-0.87	0.33	0.29
Sspan, length 4, trial 2	2379	83.49	12.34	86	41	100	59	-0.78	-0.06	0.25
Sspan, length 5, trial 1	2379	83.60	13.86	88	22	100	78	-0.81	0.20	0.28
Sspan, length 5, trial 2	2379	83.62	12.11	85	41	100	59	-0.71	-0.21	0.25
Sspan, length 6, trial 1	2379	83.94	13.28	86	30	100	70	-0.78	0.01	0.27
Sspan, length 6, trial 2	2379	83.59	12.13	86	44	100	56	-0.75	-0.17	0.25
Academic self-concept										
Item 1	2379	2.82	1.15	3	0	5	5	-0.30	-0.21	0.02
Item 2	2379	2.62	1.11	2.67	0	5	5	-0.05	-0.28	0.02
Item 3	2379	3.03	1.07	3	0	5	5	-0.45	0.14	0.02
Item 4	2379	2.93	1.18	3	0	5	5	-0.35	-0.14	0.02
Item 5	2379	2.71	1.06	3	0	5	5	-0.18	0.05	0.02
Reversed item 1	2379	3.27	1.19	3.33	0	5	5	-0.56	-0.11	0.02

Note. SD = standard deviation; Med = Median; SE = standard error; Ospan = Operations pan task; Rspan = Reading span task; Sspan = Symmetry span task; SMT: Sciences and Management Technologies; IST: Industrial Sciences and Technologies.

Figure S1

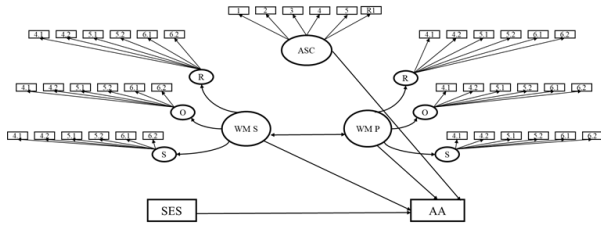
Measurement models for working memory (the two-component model for each complex span task, left) and academic self-concept (single-component model, right)



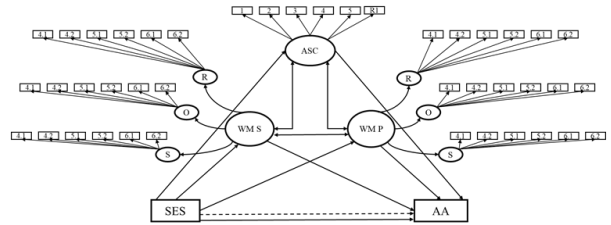
Note. Values on top of observed variables represent factor loadings. For the sake of simplicity, values for residual variances related to indicators of latent variables are omitted; R S/P: Reading span task, storage/processing; O S/P: Operation span task, storage/processing, S S/P Symmetry span task, storage/processing; ASC: academic self-concept; 4.1 = “Set of 4 to –be-remembered items, first presentation”, etc.; R1 = Reversed item 1

Figure S2

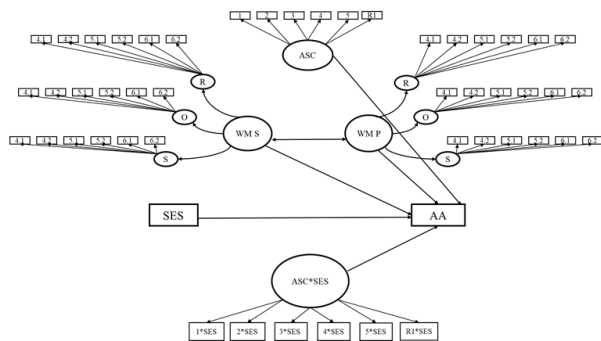
Description of each hypothesized model.



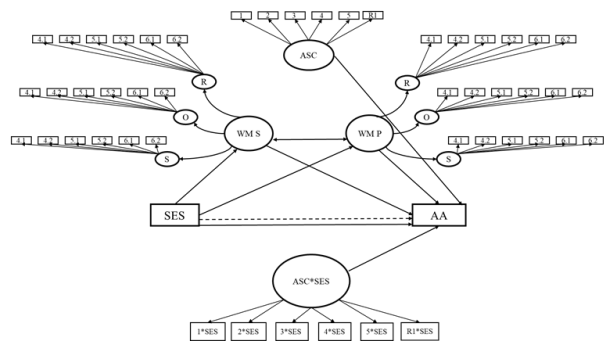
Model 0 : Main effects SES, WM, ASC



Model 1 : Main effects SES, WM, ASC + mediation WM, ASC



Model 2 : Main effects SES, WM, ASC + moderation ASC

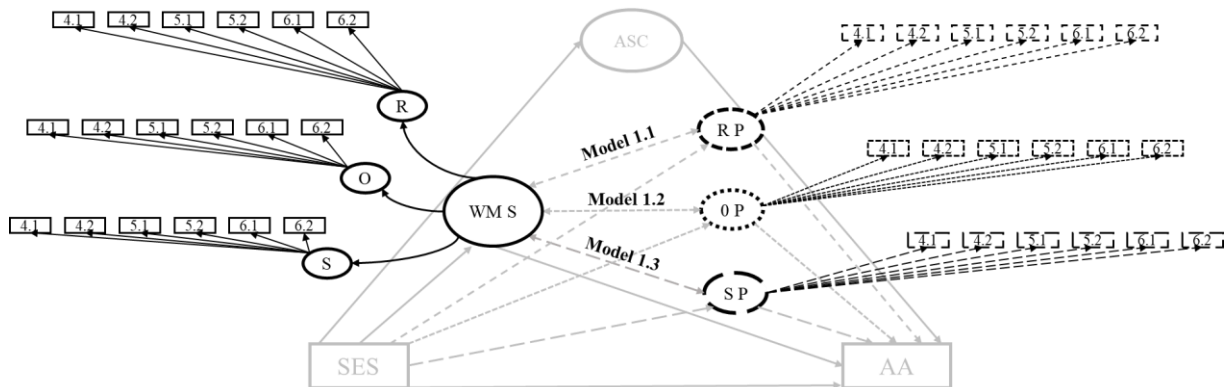


Model 3 : Main effects SES, WM, ASC + mediation WM + moderation ASC

Note. SES: socioeconomic status; AA: academic achievement; WMS = working memory storage; WMP working memory processing; ASC = academic self-concept; 4.1 = “Set of 4 to –be-remembered items, first presentation”, etc.

Figure S3

Description of Model 1.1 (Rspan), Model 1.2 (Ospan) and Model 1.3 (Sspan) manipulating the processing indirect effects.



Note. SES: socioeconomic status; AA: academic achievement; WMS = working memory storage; R P: Reading span task, processing; O P: Operation span task, processing, S P Symmetry span task, processing; ASC = academic self-concept; 4.1 = “Set of 4 to –be-remembered items, first presentation”, etc.