Early childhood working memory forecasts high school dropout risk

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Abstract

Individual differences in cognitive control contribute to academic success, engagement, and persistence toward long-term goal achievement. In a prior study, we found that preschool working memory, a component of cognitive control, predicts kindergarten academic competence and classroom engagement. In the present study, we assess whether preschool working memory contributes to high school dropout risk at age 13. Participants are 1824 children from the Quebec Longitudinal Study of Child Development who were individually assessed at ages 2.5 and 3.5 on working memory using the Imitation Sorting Task. Dropout risk, representing an index, comprised of grade retention history and concurrent school performance and engagement, was measured in spring of grade 7. We used logistic regression to estimate dropout risk from early childhood working memory while controlling for verbal and non-verbal IQ, socioeconomic status, and sex. A one point increase in children's working memory skills predicted a 26% reduction in the odds of being in the high risk group for dropout. Higher socioeconomic status and intellectual skills also predicted lower high school dropout risk. Individual differences in preschool working memory may contribute to early detection of later high school dropout risk. These results suggest the importance of further developing early effective interventions aimed at strengthening cognitive control in children.

1. Introduction

In North America, the proportion of youth who do not finish high school remains high, ranging from 15 to 26% within Canada and the United States (MELS, 2011; Levin, Belfield, Muenig, & Rouse, 2007). As a demographic, high school dropouts pose a tremendous economic and social burden on tax payers because they earn lower salaries, remain unemployed for longer, and spend more time on welfare as adults (Bowlby, 2005; Levin et al., 2007). Youth who do not complete high school also engage in more lifestyle and health risks over their life course (Gase, Kuo, Coller, Guerrero, & Wong, 2014; Hahn et al., 2015). As a result, current dropout rates indicate that many youth are entering adult life at a significant disadvantage.

Being able to identify youth showing precursor signs of dropping out can represent an important step in preventing this social problem before it occurs. Using a composite scale combining academic performance, prior grade retention, and school engagement, researchers have successfully identified 12 year-old students at greater risk of eventually dropping out by age 21 (Archambault, Janosz, Fallu, & Pagani, 2009; Janosz, Le Blanc, Boulérice, & Tremblay, 2000; Janosz, LéBlanc, Boulérice, & Tremblay, 1997). Furthermore, research has examined what characteristics of 7 year old students and their families contribute to dropout risk by the age of 12 (Janosz et al., 2013). Little research has explored how early childhood risk factors might be associated with later dropout risk.

Research suggests that high school dropout represents a gradual process of disengagement that occurs over several years (Archambault et al., 2009; Wang & Fredricks, 2014). There is also evidence that the processes leading to high school disengagement begin as early as kindergarten (Alexander, Entwisle, & Horsey, 1997; Janosz et al., 2013). Specifically, academic difficulties and problems regulating school engagement behaviors in early primary school have been found to forecast not completing high school by age 21 (Alexander et al., 1997). Moreover, persistent attention problems as early as kindergarten predict dropout at age 21 in low risk students. That is, students who do not display the typical risk profile of having previously experienced grade retention, living in a single parent household, and having a mother that did not complete high school (Pagani et al., 2008).

Individual differences in cognitive control among children are likely to play an important role in forecasting later dropout risk since they account for academic performance, engagement behavior, and the ability to pursue long-term goals (Bierman, Nix, Greenberg, Blair, &
Domitrovich, 2008; Fitzpatrick, McKinnon, Blair, & Willoughby, 2014; Mishel, Shoda, & Rodriguez, 1989). Cognitive control refers to a set of functions which allow individuals to exercise willful regulation of their behavior and attentional resources and resist the temptation to give into impulses (Garon, Bryson, & Smith, 2008). As a result, it is plausible that poorly controlled children experience more challenges at school which eventually contribute to their risk of dropout by adolescence.

Cognitive control is related to the broader self-regulatory construct of self-control, a characteristic that is associated with academic performance during adolescence once IQ and socioeconomic status are statistically controlled (Duckworth, 2011; Heckman & Kautz, 2012). In a more recent study, childhood differences in self-control predicted leaving school by age 16 (Moffitt et al., 2011). Finally, poor cognitive control is related to a constellation of maladaptive behaviors with peers and teachers that tend to disrupt academic adjustment (Clark, Prior, & Kinsella, 2002; Jacobson, Williford, & Pianta, 2011; Lee, Lahey, Owens, & Hinshaw, 2008).

Working memory is a component of cognitive control which involves manipulation and tracking of incoming information, thus allowing children to retain it on-line during problem solving activities and monitor on-going tasks (Brydges, Reid, Fox, & Anderson, 2012). When measured with an Imitation Sorting Task, working memory predicts kindergarten success and classroom engagement (Fitzpatrick & Pagani, 2012). Similarly, others have found that preschool working memory forecasts achievement by the end of elementary school (Bull, Espy, & Wiebe, 2008). Although environments help enhance the development of these skills, individual differences in cognitive control more generally, and working memory more specifically, tend to remain relatively stable across the lifespan in the absence of formal interventions (Casey et al., 2011; Friedman, Miyake, Robinson, & Hewitt, 2011; Klingberg, 2010; Weintraub et al., 2013). Consequently, we are interested in examining whether this component of cognitive control can help us predict high school dropout before it occurs.

The purpose of the present study is to use longitudinal birth cohort data to examine whether working memory skills from ages 3.5 to 4.5 are prospectively associated with dropout risk at age 13, which corresponds to grade 7. Working memory can be reliably measured as early as 3 years of age (Alp, 1994; Wiebe, Espy, & Charak, 2008). We control for verbal and non-verbal intellectual skills, sex, and socioeconomic disadvantage, to reduce their potential as confounders in the relationship (Battin-Pearson et al., 2000; Bushnik, Barr-Telford, & Bussiere, 2004; MELS, 2011; Moffitt et al., 2011). We expect that children scoring higher on early childhood assessments of working memory will face a lower risk of dropout by the end of their first year of middle school.

2. Methods

2.1. Sample

Participants are 1824 children from the Quebec Longitudinal Study of Child Development (QLSCD) with complete data on an assessment of working memory administered at 29 and 41 months. Our sample originates from a randomly selected, stratified sample of 2837 infants born between 1997 and 1998 in the province of Quebec, Canada. From the inception this longitudinal study, 93 children were ineligible and 172 were untraceable because their coordinates were incorrect. From the remaining 2572 children, 14 were unreachable and 438 refused participation. The sampling procedure resulted in 2120 children once informed parental consent was obtained, representing 82% of the eligible population from the original birth cohort. For the first early childhood phase of this study, 2120 5-month-old infants were consequently eligible for follow-up at age 2.5. Of these children, 39% were firstborn. In the school-aged waves, informed consent was obtained from teachers and from children.

2.2. Measures

2.2.1. Independent variable: working memory at ages 2.5 and 3.5

Children were administered the Imitation Sorting Task (Alp, 1994) by trained examiners. The reliability and validity of this test for measuring early childhood working memory and attention have been published elsewhere (Alp, 1994; Fitzpatrick & Pagani, 2012). During this task, the experimenter first places the objects (e.g., toy animals, puzzle pieces, eating utensils, vehicles) into two canisters. The objective of the task is for children to reproduce the demonstrated sequence by placing the correct toy in the correct canister. Before beginning, the experimenter first ensures that the child is capable of imitating the act of placing a single toy into the correct canister. At the start of each trial, the examiner places each toy in front of the child. The examiner then names each object, attributing the child’s attention before placing the object into one of the canisters. Toys are then removed from the canister and placed in front of the child. Objects are placed in a predetermined manner so that toys that are to be sorted together are not placed directly next to each other. The examiner then asks the child to place the objects in the canisters. At each level of difficulty, the child has one trial to correctly sort the objects into the canisters. At age 2.5, children completed four trials of increasing difficulty. At age 3.5, an additional level of difficulty was added. Successful completion at level 1 involved correctly sorting two toys in one canister, and a third in the other. At level 2, children were asked to sort 2 toys in each canister. At level 3, children sorted 3 objects in one canister and 2 in another. Finally, at level 4 children were asked to sort 3 objects in one canister and 3 in another. Children received full credit (one point) as long as they correctly recreated the demonstrated grouping of toys and placed them into the same canister. Because the objective is for the child to recreate the modeled subsets, children were not required to follow the same order or sort the toys in the same canister as the experimenter to get full credit. Partial credit was not provided for incomplete sequences.

In order to reduce measurement error, we computed a mean score from total scores at 29 and 41 months. Scores ranged from 0 to 3 at age 2.5 and from 0 to 4 at age 3.5. Working memory scores (mean of scores at 29 and 41 months) therefore ranged from 0 to 3.5. The sample mean (standard deviation) working memory score, reflecting the mean of scores at 29 and 41 months, was 1.20 (.74). The mean working memory scores for girls and boys were 1.24 (.72) and 1.15 (.69), respectively.

2.2.2. Outcome variable (Dropout Prediction Index at age 13)

In spring 2011 when students were in grade 7, students self-reported their academic standing using a 7-item computerized questionnaire which assessed academic performance, grade retention, and school engagement: (1) During this school year, what is your average mark in English Language?; (2) During this school year, what is your average mark in mathematics?; (3) Have you ever repeated an entire school year?; (4) Do you like school?; (5) In terms of your school marks, how would you rate yourself compared with other students of your age at your school?; (6) How important is it for you to get good marks?; and (7) Based on your own wishes, how far do you plan to go in school?. These data generated an index with good validity for predicting school dropout (Archambault & Janosz, 2009). The distribution of this variable was positively skewed (skew = 1.80, SE = .073). The frequency distribution is shown in Fig. 1. We therefore dichotomized this variable to reflect a natural break in the distribution at the 84th percentile. Thus 202 (11.1%) children (58% male) were identified at risk of dropout by grade 7. Our selected cut-off point allowed us to reach a specificity level of 68% and a sensitivity of 76% which means that our dichotomization allowed us to be effective in correctly classifying students at risk of dropout. Furthermore, all alternative cut-offs provided significant results of similar magnitude. Because of sample attrition, 1234 students had
complete data on our composite score of dropout risk, representing a retention rate of 58% from the initial birth cohort.

2.2.3. Measures: control variables

Direct assessments provided data on child characteristics that could potentially confound the relationship between working memory ability and eventual dropout risk. Trained examiners assessed non-verbal intellectual skills in children at age 3.5 using the Block Design subtest from the Wechsler Preschool and Primary Scale of Intelligence—Revised (WPPSI-R, Wechsler, 1991). This subtest, which measures the analysis and reproduction of abstract design with blocks (to assess fluid reasoning, spatial processing, attentiveness to detail, and visual–motor integration) correlates well with general IQ (Sattler, 2008). Children reproduced 14 models using blocks. The first model served as a practice. For the next 6 models, children received 2 points for every model correctly reproduced within the time allotted time (30 s). Children were given 1 point if they correctly produced the design on the second trial. Children received 0 points if they failed to reproduce the design in time on trial 1 or 2. On the last 7 models, children received one trial only. Two points were provided for each correct answer reproduced in time. Raw scores are reported (mean = 6.20 with range between 0 and 24). At age 3.5, trained examiners also assessed children’s receptive vocabulary (mean = 30 with range between 2 and 91) using the most recent version of the Peabody Picture Vocabulary Test, adapted for 3-year-olds (PPVT-French adaptation, Dunn et al., 1993). Parents reported child sex and socioeconomic status when children were 5 months. Socioeconomic status was derived from mother and father reports of income, occupational prestige, and level of education (for details see Willms & Shields, 1996). Scores were standardized to a mean of 0.

2.2.4. Data analytic strategy

Our objective is to model the relationship between early childhood working memory and later high school dropout risk. We conducted logistic regression to estimate the probability of belonging to a high dropout risk category from preschool working memory scores. To reduce omitted variable bias, we generate a model in which we simultaneously estimate the influence of potential confounders of the relationship between our predictor and outcome variables. Descriptive statistics are presented in Table 1.

3. Results

3.1. Incomplete data

This prospective longitudinal study required a substantial amount of data from several sources and ages. T-tests were conducted using SPSS software to compare the 1824 retained cases with working memory data at 29 and 41 months and the 296 unretained cases from the original sample (N = 2120) at age 5 months on the baseline control variables. Children in the retained sample had a higher socioeconomic status (x = .02 vs. -.16(t(2093) = 2.74, p < .01).

As in most follow-up studies, incomplete data was a concern. In total, from the initial 1824 children, 1040 (43% of our sample) had complete dropout risk data at age 13. In order to retain statistical power and reduce bias occasioned by selective attrition, we followed the recommendations of Graham (2009). Incomplete data was imputed for covariates and the outcome variable using the NORM multiple imputations program (Schafer, 1999). The chief advantage of NORM is that it draws values from the conditional distribution of the variables. It does this using an iterative method based on EM algorithm to impute incomplete data. This iterative process depends on the available and valid observations from the original data set.

To assess the robustness of our results, we initially performed the prediction model using only participants with complete data on both the predictor and outcome variables. Such analyses revealed a slightly larger effect size of working memory on dropout risk. Because multiple imputation corrects for selective attrition bias and thus provides more conservative estimates, we only report the results based on the imputed data.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>(SD)</th>
<th>Min</th>
<th>Max</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dropout risk (% high risk)</td>
<td>15.7%</td>
<td>(.70)</td>
<td>0</td>
<td>3.5</td>
<td>1040</td>
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<tr>
<td>Working memory</td>
<td>1.19</td>
<td>(.70)</td>
<td>0</td>
<td>3.5</td>
<td>1824</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>30.18</td>
<td>(14.68)</td>
<td>2</td>
<td>91</td>
<td>1658</td>
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<tr>
<td>Non-verbal IQ</td>
<td>6.21</td>
<td>(3.77)</td>
<td>0</td>
<td>24</td>
<td>1678</td>
</tr>
<tr>
<td>Socio-economic status</td>
<td>.02</td>
<td>(.10)</td>
<td>-2.84</td>
<td>3.66</td>
<td>1805</td>
</tr>
<tr>
<td>Sex (% boys)</td>
<td>50%</td>
<td></td>
<td></td>
<td></td>
<td>1824</td>
</tr>
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</table>

Note: Descriptive data are based on non-imputed data.
Table 2
Correlations between predictor, control and outcome variables.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dropout risk</td>
<td>−.09</td>
<td>−.14</td>
<td>−.12</td>
<td>−.18</td>
<td>−.06</td>
<td></td>
</tr>
<tr>
<td>2. Working memory</td>
<td>−</td>
<td>.11</td>
<td>.27</td>
<td>.13</td>
<td>.05</td>
<td></td>
</tr>
<tr>
<td>3. Verbal intelligence</td>
<td>−</td>
<td>.35</td>
<td>.36</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Non-verbal intelligence</td>
<td>−</td>
<td>.23</td>
<td>.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Socioeconomic status</td>
<td>−</td>
<td>−.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Sex</td>
<td>−</td>
<td>−.06</td>
<td></td>
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</tbody>
</table>

Notes: Bivariate correlations with socioeconomic status reported as Kendall’s rank correlation coefficient. Asterisks indicate significance levels: **p < .001; *p < .01; and *p < .05.

3.2. Logistic regression analysis

Table 2 reports bivariate correlations between independent, control, and outcome variable. Table 3 reports logistic regression results which estimate the odds of being in the high dropout risk group from preschool working memory scores. Results indicate that a one point increase in children’s working memory scores predicted a 26% reduction in the odds of being in the high risk group. One point increases on verbal and non-verbal intelligence also predicted decreased probability of being in the high risk group by 2% and 6%, respectively. Finally, one point increases in socioeconomic status were associated with 37% reductions in the odds of being in the high risk group. In our model, child sex was not significantly associated with dropout risk.

To assess the robustness of these findings, we conducted additional analyses with, 90th, 85th, 80th, 75th, and 70th percentile cut-offs. The results remained significant with these cut off points. When considering students scoring in the 90th, 85th, and 80th percentiles on dropout risk, a one point increase in working memory scores predicted 31, 41, and 43% reductions in the odds of being in the high risk group, respectfully. Additionally, using cut-offs at the 75th, and 70th percentiles, a one point increase in working memory scores predicted 41 and 36% reductions in the odds of being in the high risk group, respectfully.

4. Discussion

In a past prospective-longitudinal study, we found that preschoolers with less effective working memory were less school ready during their transition to the first grade (Fitzpatrick & Pagani, 2012). That study reported a positive association between working memory ability at age 3 and later kindergarten teacher ratings of child classroom engagement, as well as directly measured student number knowledge and receptive vocabulary. Furthermore, it was possible to untangle this association from family socioeconomic status and child baseline IQ. In the present study, the same boys and girls with less effective working memory around the age of 3 subsequently scored higher on a dropout index at age 13. These associations were independent of pre-existing intellectual skills, child sex, and family socioeconomic status. The effect size of working memory compared to that of verbal skills and socioeconomic status was small (1 vs 5.8 and 4.9%, respectively). However, the contribution of preschool working memory was comparable to that of non-verbal intelligence (1.8%) and was greater than that of sex (<1%). To our knowledge this is the first study to examine prospective associations between preschool working memory and high school dropout risk in a large population-based sample.

Students with working memory impairments may be likely to dropout of school because they face more difficulty adapting to the learning demands of the classroom. Working memory is responsible for the coordination, manipulation, and short-term storage of information (Ackerman, Beier, & Boyle, 2005; Weintraub et al., 2013). Working memory is therefore important for maintaining crucial information “on-line” during math problem solving or for connecting the information from one paragraph to the next in reading tasks. Furthermore, students with poor working memory are likely to experience difficulties in the classroom because they struggle to remember instructions and to effectively pick up a task where they had left off. Working memory impairments are likely to play an especially important role for students facing learning difficulties. Prior research has found that working memory is an independent predictor of math and reading outcomes in students identified as learning disabled. Furthermore, such associations appear to be independent of prior math and verbal knowledge and IQ (Alloway, 2009).

Working memory is strongly related to other components of cognitive control such as attention and inhibition (Garon et al., 2008; Miyake et al., 2000). Children generally draw upon all these functions to solve complex problems. Consequently, it is likely that developmental continuity in these inter-related skills could explain long-term links between child working memory and dropout risk. Preschool differences in delay of gratification, which highly depend on cognitive control, have been shown to predict achievement as well as the ability to inhibit impulsive behavior by adolescence and adulthood (Casey et al., 2011; Eigsti et al., 2006; Mischel, Shoda, & Peake, 1988; Mischel et al., 1989). Furthermore, Moffitt et al. (2011) found that poor childhood self-control, a concept that encompasses cognitive-control, can undermine youth perseverance and increase the likelihood of making impulsive decisions in the face of difficulty. Their work specifically suggests that poor self-control is likely to influence important life outcomes indirectly through poor decision making.

The brain areas that underlie cognitive control and working memory develop rapidly during the first 5 years of life (Shonkoff, 2011). Because brain development can be most effectively enhanced during the preschool years, the present findings suggest that it may be especially beneficial to include specific neurocognitive training exercises in preschool and elementary school curriculum. In a recent review, Klingberg (2010) concluded that it is feasible to improve working memory in children and adults using computerized training sessions. Such interventions were also found to be effective in children facing specific working memory problems or ADHD. Training on working memory also led to transfer effects on reasoning ability and impulse control, two skills that play an important role in child adaptation to the school environment.

Mindfulness training which involves helping children focus on the moment-to-moment experiences may also have a positive effect on cognitive and working memory processes (Zelazo & Lyons, 2012). In particular, mindfulness training may help children learn to engage top-down processes (cognitive control) and reduce interference by bottom-up influences (emotional reactions, stress). There is some evidence that elementary school students assigned to mindfulness interventions involving breathing exercises and guided meditation show improvements on attention and concentration in the classroom (Flook et al., 2010). Furthermore, there is also some preliminary evidence that a brief mindfulness training may benefit cognitive control in preschool age children.

Another promising strategy for promoting child cognitive control would be to limit child exposure to lifestyle habits and environments that might negatively influence the growth of these skills. Family adversity and stress as well as screen time are detrimental to the development of strong self-regulatory skills (Lillard & Peterson, 2011; Shonkoff, 2011). Policies that protect vulnerable families and that aim to reduce child screen time may therefore be effective strategies for improving working memory in the population.
The early detection of working memory problems may be possible given that such children are likely to show particular functional impairment in the classroom and at home. A child with inadequate working memory might experience difficulty completing tasks in the face of distractors, following sequential instructions, and keeping track of time in order to finish their work in a timely fashion (Fitzpatrick & Pagani, 2012). Poor self-control more generally is likely to result in disorganized living spaces (room, desk, or locker). Providing parents, teachers, and support staff with basic training on cognitive control and working memory may be advantageous for at-risk children.

The present results should be discussed in the context of several limitations. First, sample attrition occurred which reduces the certainty with which we can generalize our conclusions to the population of school-aged children. Furthermore, youth in our retained sample had higher socioeconomic status than non-retained youth. Although selective attrition can increase the uncertainty of estimates, multiple imputation adjustments for associations between socioeconomic status and incomplete-data, thus minimizing the possibility of attrition bias. Furthermore, youth in our retained sample had higher socioeconomic status than non-retained youth. Although selective attrition can increase the uncertainty of estimates, multiple imputation, and dropout risk. In a previous study we found that working memory is a good predictor of kindergarten school readiness. Children who are well

References


