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ORIGINAL RESEARCH

# Child Motivation and Family Environment Influence Outcomes of Working Memory Training in Extremely Preterm Children

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## Abstract

Cognitive training can improve working memory in children at risk of working memory difficulties; however, response to training can vary and doubt exists if working memory improvements can be sustained long- term. This study aimed to explore whether child motivation and family environment are associated with working memory trajectories in children born extremely preterm or extremely low birth weight. Forty-five 7-year-old children completed Cogmed Working Memory Training® at home over 5–7 weeks. Children and their families completed working memory tests and child motivation and family environment questionnaires at baseline, with working memory further tested 2 weeks, 12 months and 24 months post-training. Latent growth modelling was used to explore whether child motivation and family environment factors were associated with working memory trajectories. Children's desire for challenge, training competence, and being from a single-parent household were associated with short-term improvements in verbal short-term memory. Children from poorer functioning families were associated with short-term improvements in working memory. There was little evidence that child motivation or family environment was associated with long-term working memory changes. Child motivation and the training environment may be important for understanding training effects in children born extremely preterm or extremely low birth weight, and warrant closer examination in working memory training studies.

**Keywords** Working memory, cognitive training · Prematurity · Motivation · Family functioning · Individual differences

## Abbreviations

| | |
|---|---|
| STM | Short-term memory |
| WM | Working memory |
| EP | Extremely preterm |
| ELBW | Extremely low birth weight |
| LGM | Latent growth model |

## Introduction

The utility of working memory (WM) training programs has recently come under scrutiny after initial excitement regarding its potential (Simons et al. 2016). While there is evidence for short-term improvements in WM (i.e. weeks to months) following WM training in clinical and typically developing groups of children (Peijnenborgh et al. 2016; Sala and Gobet 2017), some studies report little to no benefit (Chacko et al. 2014). Given the substantial heterogeneity and inconsistent findings (Soderqvist et al. 2014; von Bastian and Oberauer 2014), examination of factors associated with greater

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improvement in outcomes following WM training may help to identify children most likely to benefit from such training. Currently, child factors such as age, ability level and personality have been proposed to influence performance on training activities (Jaeggi et al. 2014; Studer-Luethi et al. 2016); however, few studies have examined the influence of such factors on *near transfer* (the effect of WM training on WM outcomes measures) in children. Furthermore, few studies have examined whether improvements in WM following training are maintained long-term (i.e. years), or if child and family characteristics influence longer-term training effects. Additionally, current understanding of WM outcomes following training is largely based on correlations or group-level change over time (Simons et al. 2016; von Bastian and Oberauer 2014), with little research to date examining whether WM trajectories following training differ based on child and family factors.

Intrinsic motivation, defined as an internally driven interest to engage in an activity and extend one's abilities and knowledge (Deci and Ryan 1985), has been proposed to influence WM training benefits in children (Peijnenborgh et al. 2016), but few studies have examined this association (Soderqvist et al. 2014). Intrinsic motivation is a powerful contributor to academic performance and achievement in children (Gottfried 1990; Taylor et al. 2014) and has previously been associated with WM performance in both typically developing and at-risk children (Lee et al. 2013; Pascoe et al. 2018). For example, in a cohort of children born extremely preterm (EP; < 28 weeks' gestation), desire to master school learning was more strongly associated with verbal short-term memory (STM) processes than WM processes (Pascoe et al. 2018). Within the training literature, initial work has only examined the influence of training-specific motivation on WM training outcomes in children, which remains conflicting. One study reported no correlation between motivation for training and improvements on the training activities (Soderqvist et al. 2012), while others have reported positive associations (Jaeggi et al. 2011; Soderqvist et al. 2014).

The family environment may influence the outcomes of WM training (Chacko et al. 2013), since training is often conducted at home, and the family environment is known to contribute to children's executive functioning (Sarsour et al. 2011). However to date, no study has examined the influence of caregivers or the family environment on WM training outcomes. Known as family functioning, a key component of the family environment is the strength and quality of family relationships and the family's ability to care, support and provide for each other (Miller et al. 2000). Parents and caregivers are often central in training programs for children given they supervise, motivate and support the child through the program, and could influence training compliance and WM outcomes (Nelwan et al. 2018).

Children born EP are at increased risk of impaired WM compared with their term-born peers (Hutchinson et al. 2013), and current evidence for WM training benefits in this population are mixed (Anderson et al. 2018; Lohaugen et al. 2011). We recently reported little evidence that Cogmed WM training had any benefit for WM outcomes immediately (2 weeks) or 24 months following training compared with a placebo control (IMPRINT trial; Anderson et al. 2018). It is now of interest to examine whether child and family factors are associated with WM trajectories following training in these children to determine whether subgroups of EP children and their families are more or less likely to benefit from this cognitive training method. Such investigations may help clarify the mixed findings regarding the benefits of WM training in children born preterm. Given speculation that WM training may be more beneficial in younger individuals (Sala and Gobet 2017), examining the influence of child motivation and family environment factors on WM performance early in development, such as at early school age, is of particular interest.

This study aimed to explore whether child motivation and family environment factors are associated with WM trajectories from baseline to 2 weeks post-training (short-term), and from 2 weeks post-training to 24 months post-training (long-term), in school-age children born EP or extremely low birth weight (ELBW; < 1000 g). We had no specific expectations that child motivation and family factors would be more strongly associated with improvements in particular WM components following training.

## Methods

### Participants

Participants were 7-year-old children born EP or ELBW in Victoria, Australia, in 2005, enrolled in the IMPRINT trial, a randomised controlled trial of Cogmed Working Memory Training® (Anderson et al. 2018). This study focuses on the 45 children in the trial who were randomised to Cogmed (Anderson et al. 2018). Exclusion criteria for the trial included the child having a severe intellectual, sensory or physical impairment that affected their capacity to complete training, and families considered unable to comply with the training schedule based on the study screening process (Pascoe et al. 2013).

### Procedures

All children completed a comprehensive neuropsychological assessment at baseline including measures of WM. WM training was completed in the home over 5 to 7 weeks. Following the training period, children were followed up for neuropsychological assessment at 2 weeks, 12 months and 24 months post-training. Assessments were conducted by blinded assessors and based on corrected age at assessment to avoid a known bias in cognitive test scores (Wilson-Ching et al.

2014). The study was approved by the Royal Children's Hospital Human Research Ethics Committee in Melbourne, Australia. Written informed consent was obtained from primary caregivers before participation.

## Working Memory Training Program

This trial used Cogmed RM, suitable for children aged 7 years and up. Cogmed is a computerised WM training program that comprises 25 training sessions taking between 35 to 50 minutes to complete, with the recommendation for at least 20 completed sessions. The program comprises eight interactive WM activities, with the difficulty of each activity automatically changing on a trial-by-trial basis according to the child's performance. Consistent with the training program procedures, children and their caregiver/s had an introductory session with a certified Cogmed coach (i.e. team member) prior to training. This session allowed the coach to explain how the program works, discuss with the family how to plan and structure training sessions, explain the role of the caregiver/s as the 'training aides' to maintain and support their child's training, and provide the caregiver/s with information on how to assist their child through the program, e.g. verbal encouragement, a sticker chart, small rewards after every five training sessions. Training compliance and progress was monitored remotely via an online training web by the Cogmed coach. The coach contacted caregivers weekly by phone to enquire about the child's progress, discuss any challenges, and answer any questions regarding the program or trial from caregivers and children (see Pascoe et al. 2013 for further information).

### Clinical and Demographic Characteristics

Child clinical characteristics were documented from medical records. Social risk at baseline was estimated based on six social-demographic domains, with scores $\geq 2$ categorised as higher social risk (range 0–12) (Roberts et al. 2008). Schooling information was collected from a caregiver questionnaire. Duration of formal schooling was based on the number of years spent in the classroom, which may be more closely associated with WM than chronological age (Roberts et al. 2015). To estimate general intelligence, the General Conceptual Ability (GCA) scale was used from the Differential Ability Scales-II (DAS-II) ($M = 100$, $SD = 15$) (Elliott 2007) administered at baseline.

### Working Memory

WM was assessed using two latent factors previously validated in this group of EP/ELBW children (Pascoe et al. 2018). The first WM factor reflects verbal STM and is comprised of Digit Recall and Word List Recall from the Working Memory Test Battery for Children (WMTB-C) (Pickering and Gathercole 2001). The second WM factor reflects WM more generally and is comprised of Backward Digit Recall, Block Recall and Mazes Recall from the WMTB-C, as well as Mister X from the Automated Working Memory Assessment (AWMA) (Alloway 2007). For this study, we will refer to these two factors as *verbal STM* and *WM.* Although previously validated at baseline (Pascoe et al. 2018), the two factors had not been validated across time. Measurement invariance over time was tested and results indicated that the structure provided a reasonable fit to the data, with metric invariance established at all assessment time-points (Supplementary Table 1). Factor scores for the *verbal STM* and *WM* factors were extracted for each individual and utilised in subsequent latent growth analysis.

### Child Motivation Factors

a) Intrinsic motivation for school learning

Intrinsic motivation towards school learning was assessed using the Intrinsic Motivational Scale at baseline, which estimates children's desire for independent mastery, and preferences for challenge and curiosity (Lepper et al. 2005). This self-report scale has been previously administered to school-age children and comprises 17 items (Lepper et al. 2005). Response options were modified from a 5-point scale to a 3-point scale (*Yes* (3), *Sometimes* (2) and *No* (1)), to improve young children's understanding of response options and increase the reliability of responses. All subscales demonstrated good internal consistency (mastery: $\alpha = 0.76$; challenge: $\alpha = 0.78$; curiosity: $\alpha = 0.71$). Total scores were calculated for each subscale, with higher scores reflecting greater intrinsic motivation.

b) Training-related intrinsic motivation

Training-related intrinsic motivation was assessed 2 weeks post-training using the Intrinsic Motivation Inventory (Ryan et al. 1983). This 22-item, self-report instrument included four subscales consistent with a previous training study in children (Soderqvist et al. 2014): enjoyment, perceived competence, effort and value. Item response options were based on a 3-point scale (*Yes* (3), *Sometimes* (2) and *No* (1)) and internal consistency was acceptable across subscales (enjoyment: $\alpha = 0.88$; perceived competence: $\alpha = 0.84$; effort: $\alpha = 0.74$; value: $\alpha = 0.81$). Subscale scores were averaged across raw item scores for each subscale, with higher scores reflecting greater training-related motivation.

### Family Environment Factors

a) Family functioning

The Family Assessment Device assessed structural and organisational characteristics of the family unit rated by the primary caregiver (Epstein et al. 1983). The 60-item questionnaire comprises six subscales tapping affective involvement, affective responsiveness, behavioural control, communication, roles and problem solving and has a general family functioning scale. Each item is rated on a 4-point scale ranging from Strongly Agree (1) to Strongly Disagree (4), and subscale scores are calculated by averaging across items. Higher scores indicate poorer family functioning.

b) Family structure and composition

Family demographic information was gathered from a questionnaire completed by the primary caregiver. Family structure was assessed and coded into one of three categories based on parental relationships: dual-parent household (0), divided-care household (1) or single-parent household (2). Higher scores for family structure reflect greater environmental risk. Family composition (i.e. household size) was based on the total number of adults and children living in the household.

## Data Analysis

Associations between child motivation and family environment and WM trajectories were explored using latent growth models (LGMs) on the *verbal STM* and *WM* factor scores. First, LGMs were estimated separately for verbal STM and WM without any predictors (unconditional models) comparing linear and piecewise LGMs to select the best fit. Briefly, the linear LGM assumes linear (constant) change across all four assessments, whereas the piecewise model (an extension of LGM) allows for separate linear growth profiles to be modelled reflecting different phases of change (slopes) across time. Specifically, two slopes were modelled representing (a) change from baseline to 2 weeks post-training (slope 1) and (b) change from 2 weeks to 24 months post-training (slope 2) (Supplementary Figure 1). Model fit was assessed using the chi-square test ($\chi^2$), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Room Mean Square Error of Approximation (RMSEA) and the Standardised Root Mean Square Residual (SRMR) (Supplementary Table 2). Thresholds for good fit were defined as $\chi^2$ $p > 0.05$, RMSEA $< 0.06$, SRMR $< 0.05$ and CFI/TLI $\geq 0.95$ (Hu and Bentler 1999). Adequate or acceptable model fit was defined as RMSEA $< 0.08$, SRMR $< 0.08$, CFI/TLI $> 0.90$ (Hu and Bentler 1999).

Once the best model for change over time was identified, child motivation and family environment variables were added to the model as predictors of both the initial (baseline) level of WM (the intercept) and the linear or piecewise slope(s) to explore whether these factors were associated with the change in WM over time (conditional models). Results for baseline WM (intercept) are reported for completeness of our analyses, but results are not interpreted, as they were not the focus of this paper. Given the number of family functioning and training motivation predictor variables, univariable regressions between each predictor and WM outcome at each time-point were conducted prior to building a multivariable model including only family functioning and training motivation variables where there was evidence of a relationship in the univariable models ($p < 0.05$).

Based on the recommended ratio of at least three participants per parameter for structural equation modelling (Kline 2016), a minimum sample size of 36 was required, suggesting our sample size was sufficient. Due to the observed non-linear pattern of change in WM over time (Fig. 1), loadings for slope 2 were freely estimated for the 2 week and 12 month time-points in the piecewise LGM for the WM factor (Supplementary Figure 1), an approach often used for non-linear growth in child development (Grimm et al. 2011). Because random slopes are not defined on two time-points, a fixed slope was used from baseline to 2 weeks post-training in the piecewise LGMs, with the residual variance fixed to zero.

Missing data were addressed using full information maximum likelihood, which allows for the use of all available data and in most cases provides less biased estimates than complete case analysis (Enders and Bandalos 2001). Models were estimated using the robust maximum likelihood estimator, which is robust to non-normality. MPlus version 7 was used to estimate all LGMs (Muthén and Muthén 1998-2012).

**Data Availability** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

# Results

Characteristics of the sample are presented in Table 1. Family functioning for our sample was better than normative means from non-clinical samples (Epstein et al. 1983). Figure 1 displays the mean verbal STM and WM scores over time for the sample and the individual trajectories for each child in the sample. Children completed 19 training sessions on average, with 67% of the sample completing ≥ 20 sessions. Of the 45 children seen at baseline, 2 children had missing data at 2 weeks post-training (non-contactable $n = 1$, declined $n = 1$), 6 had missing data at 12 months post-training (non-contactable $n = 2$, declined $n = 4$) and 4 had missing data at 24 months (non-contactable $n = 1$, declined $n = 3$). Children with missing data were similar to those seen for assessment on

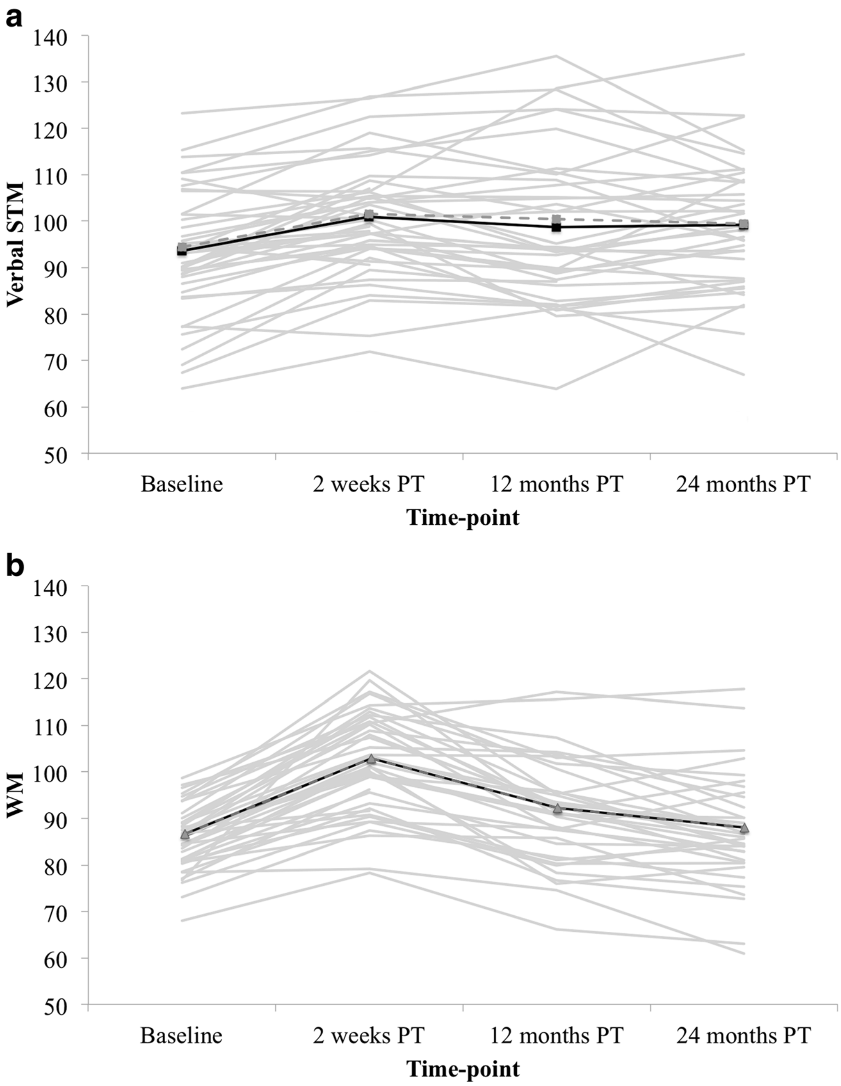

**Fig. 1** Change over time for verbal STM (**a**) and WM (**b**) from baseline to 24 months post-training. Individual trajectories of WM changes over time with mean group WM scores (solid black line = observed scores, dashed grey line = predicted scores from the unconditional models). PT post-training

clinical or demographic characteristics at baseline, suggesting that the data were missing completely at random.

## Building the Model

Prior to adding predictors, LGMs of WM change over time revealed that the linear model for both verbal STM and WM displayed poor fit to the data, while the piecewise models displayed acceptable fit to the data (Supplementary Table 2). Therefore, the piecewise model was selected for modelling WM changes. The piecewise model for WM displayed a slightly better fit to the data than for verbal STM (Fig. 1; Supplementary Table 1).

For verbal STM, short-term improvements (*slope 1* = 7.0, 95% CI [5.0, 9.1], $p < 0.001$) were followed by decreases in verbal STM outcomes (*slope 2* = − 1.04, 95% CI [− 2.59, 0.51], $p = 0.19$). Similarly, for WM, short-term improvements (*slope 1* = 38.3, 95% CI [− 14.4, 91.0], $p = 0.16$) were followed by a decline in WM outcomes (*slope 2* = − 18.5, 95% CI [− 45.5, 8.5], $p = 0.18$).

## Influence of Child Motivation and Family Environment Factors

Univariable analyses revealed evidence that training effort, competence and value, as well as general family functioning were associated with WM outcomes and were included as predictors in the multivariable LGMs along with all intrinsic motivation components. Final LGMs for both verbal STM and WM displayed acceptable fit, but the LGM for WM displayed a better fit to the data (Supplementary Table 2).

Table 2 presents the standardised regression coefficients of the child motivation and family environment variables predicting children's baseline WM performance (intercept) and WM changes (slopes) in the multivariable model. In terms of short-term changes in verbal STM (slope 1), desire for challenge and reduced training competence were associated

**Table 1** Study sample characteristics at baseline

| | Sample $n = 45$ |
|---|---|
| Clinical characteristics | |
| Gestational age (weeks), M (SD) | 27 (2) |
| Birth weight (g), M (SD) | 842 (147) |
| Males, *n* (%) | 22 (49) |
| Multiple birth, *n* (%) | 11 (24) |
| BPD, *n* (%) | 23 (51) |
| IVH, grade III/IV, *n* (%) | 3 (7) |
| Corrected age at assessment (years), M (SD) | 8 (0) |
| High social risk, *n* (%) | 30 (67) |
| General intelligence, M (SD) | 97 (11) |
| Duration of formal schooling in years, M (SD) | 3 (1) |
| Child motivation variables | |
| Intrinsic motivation, M (SD) | |
| Mastery | 11 (3) |
| Challenge | 14 (3) |
| Curiosity | 15 (3) |
| Training-related motivation, M (SD) | |
| Enjoyment | 2 (1) |
| Perceived competence | 2 (1) |
| Effort | 3 (0) |
| Value | 2 (1) |
| Family environment variables | |
| Family functioning, M (SD) | |
| Affective involvement | 2 (0) |
| Affective responsiveness | 2 (1) |
| Behavioural control | 2 (0) |
| Communication | 2 (0) |
| Roles | 2 (0) |
| Problem solving | 2 (0) |
| General functioning | 2 (0) |
| Household size, M (SD) | 4 (1) |
| Family structure, *n* (%) | |
| Dual-parent care | 36 (80) |
| Divided care | 2 (4) |
| Single-parent care | 7 (16) |

*M* mean, *SD* standard deviation, *BPD* bronchopulmonary dysplasia, *IVH* intraventricular haemorrhage

**Table 2** Standardised regression coefficient (β) estimates for each included predictor in the multivariable conditional models

| Predictor | | Verbal STM | | | | | | WM | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Baseline | | Short-term changes from baseline to 2 weeks PT (*slope 1*) | | Sustained long-term changes from 2 weeks to 12 months PT (*slope 2*) | | Baseline | | Short-term changes from baseline to 2 weeks PT (*slope 1*) | | Sustained long-term changes from 2 weeks to 12 months PT (*slope 2*) | |
| | | $\beta$ (95% CI) | $p$ | $\beta$ (95% CI) | $p$ | $\beta$ (95% CI) | $p$ | $\beta$ (95% CI) | $p$ | $\beta$ (95% CI) | $p$ | $\beta$ (95% CI) | $p$ |
| Child motivation variables | | | | | | | | | | | | | |
| Intrinsic motivation | Mastery | 0.27 (−0.03, 0.57) | 0.08 | −0.17 (−0.69, 0.36) | 0.54 | −0.41 (−1.25, 0.44) | 0.34 | −0.07 (−0.43, 0.30) | 0.72 | 0.45 (−0.46, 1.37) | 0.33 | −0.61 (−1.28, 0.06) | 0.07 |
| | Challenge | −0.17 (−0.54, 0.21) | 0.39 | *0.60 (0.05, 1.15)* | *0.03* | 0.23 (−0.64, 1.10) | 0.60 | 0.15 (−0.26, 0.56) | 0.47 | 0.06 (−0.97, 1.10) | 0.90 | 0.36 (−0.41, 1.12) | 0.36 |
| | Curiosity | −0.23 (−0.49, 0.04) | 0.10 | −0.03 (−0.46, 0.39) | 0.88 | −0.05 (−0.73, 0.63) | 0.88 | −0.04 (−0.35, 0.27) | 0.81 | 0.10 (−0.66, 0.87) | 0.79 | −0.25 (−0.90, 0.41) | 0.46 |
| Training motivation | Competence | – | – | *−0.79 (−1.54, −0.04)* | *0.04* | 0.29 (−1.04, 1.61) | 0.67 | – | – | −0.42 (−1.94, 1.09) | 0.59 | −0.03 (−1.29, 1.24) | 0.97 |
| | Effort | – | – | 0.14 (−0.53, 0.81) | 0.69 | 0.12 (−1.31, 1.54) | 0.87 | – | – | −0.18 (−1.70, 1.33) | 0.81 | 0.24 (−1.11, 1.58) | 0.73 |
| | Value | – | – | 0.23 (−0.14, 0.60) | 0.22 | 0.65 (−1.13, 2.43) | 0.48 | – | – | 0.38 (−0.60, 1.36) | 0.45 | −0.08 (−0.79, 0.62) | 0.82 |
| Family environment variables | | | | | | | | | | | | | |
| | General family functioning | 0.26 (−0.01, 0.53) | 0.06 | 0.38 (−0.05, 0.81) | 0.08 | −0.28 (−1.14, 0.58) | 0.52 | 0.24 (−0.02, 0.51) | 0.07 | *0.74 (0.22, 1.26)* | *0.005* | −0.44 (−1.11, 0.23) | 0.20 |
| | Family structure | *−0.70 (−1.04, −0.37)* | *< 0.001* | *0.51 (0.01, 1.01)* | *< 0.05* | 0.65 (−1.22, 2.52) | 0.50 | *−0.55 (−0.88, −0.22)* | *0.001* | −0.76 (−1.57, 0.06) | 0.07 | 0.57 (−0.31, 1.44) | 0.20 |
| | Household size | *−0.45 (−0.77, −0.13)* | *0.005* | 0.05 (−0.46, 0.55) | 0.86 | 0.57 (−0.98, 2.12) | 0.47 | −0.29 (−0.66, 0.09) | 0.13 | −0.41 (−1.28, 0.45) | 0.35 | 0.24 (−0.45, 0.93) | 0.49 |

Italic figures indicate significant associations where $p < 0.05$. -Data not shown as child variables were collected 2 weeks post-training. *PT*, post-training

with greater verbal STM improvements (Table 2). These aspects of motivation were not found to be important predictors of short-term WM improvements. Children of single-parent families demonstrated greater short-term verbal STM improvements, while children of families reporting poorer family functioning demonstrated greater short-term WM improvements (Table 2).

In terms of long-term WM changes following training (slope 2), there was little evidence that child motivation or family environment variables predicted either verbal STM or WM performance when the other predictors were accounted for (Table 2). However, there was some evidence that children who reported greater mastery at baseline displayed greater declines in WM performance.

## Discussion

This study found that increased child motivation, less optimal parenting structures and poorer family functioning were associated with short-term, but not long-term improvements in WM following Cogmed training for early school-age children born EP/ELBW.

Our novel finding that children's desire to be challenged in school learning was associated with greater short-term improvements in verbal STM highlights that children's prior enjoyment of challenges may be a key factor in facilitating training effects following WM training. A desire to be challenged may enable children to engage and comply better with training, and apply themselves on training activities, which may then have flow-on effects to their performance on WM measures following training. Interestingly, our results indicated that EP/ELBW children who reported feeling more competent at training demonstrated less improvement in verbal STM over the short-term. While this finding contrasts previous studies in children and young adults (aged 7 to 19 years; Soderqvist et al. 2014) and older adults (Guye et al. 2017), previous work focused on associations between training-related motivation and improvements in performance on the training task itself, rather than performance on more general WM measures following training as in the current study. Further investigations are required to better understand the driving forces of performance in EP/ELBW children.

Our results indicated that EP/ELBW children from single-parent households experienced greater short-term improvements in the verbal STM component of WM following training compared with children from dual-parent households. This finding is in line with a previous study of preterm children showing differential effects of an early intervention program based on social risk factors, where preterm children from higher social risk environments demonstrated greater gains in cognitive outcomes compared with children from families with lower social risk (Spittle et al. 2018). This association may partly be explained by the tendency for children from single-parent households to have lower WM capacity to begin with. For example, previous studies have suggested greatest training gains in individuals with lower baseline abilities, given these individuals have more room for improvement (referred to as the *compensation effect*; Titz and Karbach 2014).

Contrary to our expectations, poorer general family functioning was associated with greater short-term improvements in WM following training. While the reasons for this association are unclear, it is important to note the homogeneity in family functioning in our sample, with most families (95%) classified as 'well functioning'. While this association was not driven by the *compensation effect* (i.e. poorer family functioning was not associated with poorer baseline child WM performance), it requires further clarification using larger samples. Future studies should consider the bi-directional relationship between family functioning and training outcomes in children.

We found little evidence that child motivation or family environment factors were associated with longer-term WM improvements following Cogmed. Results illustrated that training gains achieved in association with child motivation or family environment factors in the short-term, diminished over time, with the greatest declines seen in WM. While there is increasing evidence to suggest that Cogmed can improve children's WM (Peijnenborgh et al. 2016; Sala and Gobet 2017), it remains unclear if these improvements are maintained over time. Indeed results from recent larger, randomised controlled trials provide little support for long-term benefits of Cogmed for WM outcomes in children with low WM (Roberts et al. 2016) or children born EP/ELBW (Anderson et al. 2018).

We found larger short-term and long-term changes in WM compared with verbal STM following training. Given most of the Cogmed training activities involve manipulation of information (rather than simply storage or maintenance of information) and visuo-spatial information, this finding was not surprising. This finding is also consistent with results of a previous meta-analysis that showed large effect sizes for visuo-spatial WM following training, particularly for Cogmed training (Melby-Lervag and Hulme 2013). Despite this, we found little evidence for child motivation or family environment factors to be associated with WM performance following Cogmed. This lack of evidence may reflect our measurement model of WM. While our two-factor WM structure is in line with previous studies of the structure of WM in young children (Gathercole and Pickering 2000), in our model, our WM factor is comprised of both verbal and visuo-spatial maintenance and manipulation tasks, while our verbal STM factor reflected only maintenance-based verbal short-term memory tasks. Additionally, constraints were placed on our piecewise LGMs that made assumptions about how WM was changing over the short-term (i.e. the inclusion of a fixed slope from baseline to 2 weeks post-training). This may have affected WM more than verbal STM, given there was more variability in baseline verbal STM compared with WM.

The results have important implications for WM training studies, particularly in at-risk groups of children. Greater consideration of children's motivational drives, self-efficacy and competence are needed in training studies, given evidence of some effect of these characteristics on WM outcomes following training, particularly shortly after training which the majority of training studies report on. Our findings suggest that the WM processes examined in training studies, such as maintenance (STM) and/or manipulation of information, likely affects whether improvements on WM outcomes are observed following training. Furthermore, particular child factors such as motivation may be more closely related to certain WM processes (e.g. verbal STM) than others, but further investigation is needed. Our initial work suggests that the family environment may be important for cognitive training approaches conducted in the home. Increased facilitation and support from family during training may benefit a child's training progress. However, intensive cognitive training programs, like Cogmed, may place burden on family units, which may have a negative influence on training outcomes. We suggest that evaluating the 'benefit-cost ratio' of cognitive training at home is of interest.

There are some limitations that should be noted. Our sample was derived from a larger randomised controlled trial of WM training in EP/ELBW children and was not powered to investigate factors associated with WM training outcomes, and hence, our findings should be treated as exploratory. Furthermore, no typically developing control group was included in the study, which limits the generalisability of these results. In this study, two family environmental factors were examined but we acknowledge that there are other factors that are important to consider, such as social risk and family income, which need to be further explored to understand if these associations vary by social risk. We considered child and family factors at single time-points, but did not examine bi-directional associations as well as changes in these variables over time. Our piecewise LGMs were fitted to just four time-points, which required constraints to be placed on model parameters that further restricted our interpretation of associations and made assumptions about individuals' change over time. These constraints did not allow for the correlation between baseline WM (intercept) and verbal WM changes (slope 1). It is of interest for future WM training studies to conduct more than four waves of observation to better assess change over time with LGMs. While measurement invariance testing was able to establish that factor loadings from our measurement model of WM were not different at different time-points, it was more challenging to establish that the means were invariant over time. Our limited number of measurement items made it difficult to identify and remove potentially problematic items without compromising the integrity of the overall model. Furthermore, our measurement model of WM was based on a WM structure evident early in development in children born EP/ELBW, which may not apply to other populations or be apparent at later ages (Gathercole et al. 2004).

In conclusion, child motivation and higher-risk family environments appear to influence short-term improvements in WM following Cogmed training in EP/ELBW children. Initial evidence from this study suggests that child motivation and engagement may be important when trying to maximise WM improvements, at least in the short term, following Cogmed training. While further investigation is warranted, fostering and developing these qualities in children may benefit child WM outcomes. Future studies should carefully assess and consider the appropriateness of such training paradigms for higher risk EP/ELBW families, given the challenge of committing additional time and resources for training.

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**Compliance with Ethical Standards** The study was approved by the Royal Children's Hospital Human Research Ethics Committee in Melbourne, Australia. Written informed consent was obtained from primary caregivers before participation.

**Conflict of Interest** The authors declare that they have no conflicts of interest.

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