Learning and Individual Differences 57 (2017) 58–64

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

Metacognitive monitoring of working memory performance and its relationship to academic achievement in Grade 4 children

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ARTICLE INFO

Keywords:
Working memory
Metacognitive monitoring
Academic achievement
Confidence
Calibration

ABSTRACT

The relationship between metacognitive monitoring of working memory performance and academic achievement was examined in 73 Grade 4 children. Working memory was assessed using the Working Memory Power Test (WMPT) for children. Metacognitive monitoring was assessed by confidence ratings and two calibration measures, the Bias Index and the Absolute Accuracy Index, calculated from WMPT scores. Children also completed the Wechsler Individual Achievement Test - Australian Abbreviated (WIAT-II). Regression analyses showed the Bias Index was the best metacognitive monitoring calibration measure for predicting academic achievement. These findings extend previous research in two important ways. Firstly, we have shown that Grade 4 children have metacognitive monitoring abilities. Secondly, we have demonstrated that children are able to metacognitively monitor their working memory performance and that the calibration of this monitoring is related to their academic achievement.

1. Introduction

Working memory refers to our ability to hold and manipulate information in our mind over a short period of time (Gathercole & Alloway, 2008). It has often been described as a 'mental workspace' that is used in many aspects of our daily life, including reading comprehension, mental arithmetic and planning a series of actions (Gathercole & Alloway, 2008; Holmes, 2012). Working memory is used to process and store information during complex and demanding activities, such as those activities that children regularly undertake at school. Due to this, the relationship between working memory and academic achievement has been extensively studied. It has previously been shown that students with a poor working memory ability tend to score lower on achievement tests (Alloway, Gathercole, Kirkwood, & Elliott, 2009), and many students with learning difficulties also show problems with working memory (e.g., Siegel & Ryan, 1989; Swanson, Kehler, & Jerman, 2010).

Metacognitive monitoring refers to the ability to monitor one's own cognitive and affective state. It is often examined by calibrating accuracy and confidence ratings on cognitive tasks (Cheng, 2010). Typically, participants are asked to answer a test item and then estimate the accuracy of their answer (i.e., give a confidence rating; Mengelkamp & Bannert, 2010). It has been suggested that accurate knowledge monitoring is the foundation required in order to employ more complex metacognitive processes (e.g., planning and selecting learning strategies, Baker & Fogarty, 2004; Was, 2014). While metacognitive monitoring has often been examined in adult studies, using tasks that tap long-term memory (e.g., Kasperski & Katzir, 2013; Stankov, Morony, & Lee, 2014), in this paper we examine metacognitive monitoring in children performing a working memory task. We also assess the relationship between metacognitive measures of working memory and academic achievement in reading, numeracy and spelling.

1.1. Metacognitive monitoring and academic achievement

Confidence is seen to be a judgement related to one's belief regarding their capability to accomplish a goal that is separate from their actual ability (Bandura, 1986, 1990). The role that confidence, and in turn, metacognitive monitoring play in academic achievement has received increased attention in the last few years (e.g., Kasperski & Katzir, 2013; Stankov et al., 2014). Confidence, as it relates to metacognitive monitoring, is often reported in the literature as self-confidence (e.g., Kleitman, Stankov, Allwood, Young, & Mak, 2012) and is measured via confidence ratings following test-taking or decision-making activities. For example, participants may be asked how confident they are that they have chosen the correct answer on a multiple-choice test. Importantly, in contrast to self-efficacy, which refers to a person's beliefs about how they will perform on a particular task, self-confidence has been shown to be a general factor that remains unaffected across different tasks and experimental manipulations (Kleitman & Moscrop, 2010; Kleitman & Stankov, 2007).

A number of studies have shown moderate to strong associations

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http://dx.doi.org/10.1016/j.lindif.2017.06.003
Received 12 October 2016; Received in revised form 7 June 2017; Accepted 10 June 2017
1041-6080/

between metacognitive monitoring and academic achievement (e.g., Kleitman & Gibson, 2011; Sharma & Bewes, 2011; Stankov & Crawford, 1996; Stankov, Lee, Luo, & Hogan, 2012). The majority of these studies have focussed on adolescent or adult populations. For example, Sharma and Bewes (2011) found that undergraduate physics students with better metacognitive monitoring ability also had higher levels of academic ability as measured using a physics test. More recently, Stankov et al. (2014) showed that metacognitive monitoring (i.e., self-beliefs, or confidence in performance) was a strong predictor of mathematics performance in a group of Chinese secondary school students.

Previously, researchers have thought that although metacognitive awareness develops at around 5 years of age, metacognitive monitoring skills do not develop until 11 years of age (Veenman & Spaans, 2005). As such, relatively few studies have focussed on metacognitive monitoring in children. Allwood, Granhag, and Jonsson (2006) are credited as the first researchers to demonstrate that children as young as 8 years of age are able to use confidence rating scales as well as adults. In the first metacognitive monitoring study using Primary School aged children, Kleitman and Moscrop (2010) showed that children in Grade 4 (aged 9–11 years) had just as advanced metacognitive ability as children in Grade 6 (aged 11–12 years) when confidence was used to predict ability in an achievement task. This is an important finding as it demonstrates that metacognitive ability develops much earlier than formerly proposed.

Not only is the relationship between confidence and ability an interesting theoretical question, but the resulting research may also benefit those children who show poor academic ability. Do they also show low confidence ratings or are they unaware of their actual ability level? This information may help when targeting students for interventions aimed to boost their academic performance. For example, it has been suggested that children's self-assessment of their ability influences their motivation and persistence in regards to learning (Chapman & Tunmer, 2003). Furthermore, confidence based on feedback from others (i.e., teachers, parents, peers etc.) tends to be weaker and less stable than confidence based on one's self-assessments of achievements (Druckman & Bjork, 1994). It is therefore important to determine the accuracy of these self-assessments.

Confidence ratings alone do not provide an indication of one's metacognitive monitoring ability. Metacognitive calibration measures, which combine self-confidence (i.e., confidence ratings) and actual performance (i.e., accuracy) to assess the degree to which a person's self-assessment is calibrated, have therefore been created. A number of metacognitive calibration measures have been proposed and reviewed (e.g., Baranski, 2007; Cheng, 2010; Pieschl, 2009; Schraw, 2009a, 2009b; Schraw, Kuch, & Gutierrez, 2013). It is recommended that, whenever possible, multiple measures should be calculated and reported as they each provide subtly different pieces of information (Boekaerts & Rozendaal, 2010; Schraw, 2009a, 2009b; Schraw, Kuch, Gutierrez, & Richmond, 2014).

Two commonly reported metacognitive calibration measures are the Bias Index and the Absolute Accuracy Index. The Bias Index (Pajares & Miller, 1997) measures the degree to which someone is over- or under-confident in their answers, with positive values indicating overconfidence and negative values indicating under-confidence. The Absolute Accuracy Index measures the discrepancy between confidence judgements and actual performance (Schraw, 2009a). That is, it gives an indication of how well a person is able to monitor their performance on a task. Values close to zero indicate a high level of metacognitive monitoring calibration, whereas large positive values indicate a low level of calibration. It has been shown that better calibrated learners make better decisions regarding their learning compared with non-calibrated learners. For example, well-calibrated learners may make better use of their study time by focussing on areas that they are still having difficulty understanding (e.g., Hacker, Bol, & Keener, 2008; Labuhn, Zimmerman, & Hasselhorn, 2010; Thiede, Anderson, & Therriault, 2003).

1.2. The current study

It has been well established that working memory ability is associated with academic achievement (e.g., Alloway & Alloway, 2010; Dumontheil & Klingberg, 2012; Lee, Ning, & Goh, 2014). Working memory impairments are relatively common during childhood and are typically associated with poor academic learning (Gathercole, 2008). Children with poor working memory capacity have difficulty meeting the heavy working memory demands involved in many classroom activities, including reading, mathematics and spelling. However, although it is clear there is a relationship between working memory and academic achievement, we are not aware of any studies investigating the relationship between metacognitive monitoring in a working memory task and academic achievement.

In the current study, we use a newly developed test of working memory, the Working Memory Power Test (WMPT, ebilities[1]). The WMPT has been specifically designed to measure working memory performance in children. It is unique in that it captures both accuracy and confidence information and thus provides an opportunity to measure metacognitive monitoring ability in children. Given the relationship between working memory and academic achievement, the aim of the study was to examine metacognitive monitoring of working memory performance, as measured by the WMPT, and its relationship to academic achievement in reading, numeracy and spelling, as measured by the Wechsler Individual Achievement Test – Second Edition, Australian Abbreviated Edition (WIAT-II, Wechsler, 2007), in a sample of Australian children. Accuracy and confidence in performance on the WMPT were measured. Confidence ratings were used as a measure of metacognitive monitoring and were combined with accuracy to produce two measures of metacognitive monitoring calibration: the Bias Index and the Absolute Accuracy Index. We extend upon previous studies that have looked at the relationship between accuracy and confidence in children's performance on a single task, by examining whether metacognitive measures based on a working memory task are predictive of academic achievement as measured by a separate standardised test battery.

Based on previous research showing a relationship between metacognitive monitoring and academic achievement in adults (e.g., Kasperski & Katzir, 2013; Kleitman & Moscrop, 2010), we predicted that confidence on the WMPT would be positively correlated with reading, numeracy, and spelling scores. Further, we expected that the metacognitive calibration measures would be negatively correlated with achievement, because larger scores on the Bias and Absolute Accuracy Indexes indicate a poorer level of calibration.

2. Method

2.1. Participants

Seventy-seven Australian children enrolled in Grade 4 of primary school participated in the research. Four children were excluded from the study (one completed only one of the WIAT-II subtests, and three did not complete the WMPT). The mean age of the remaining children (males = 31, females = 42) was 9 years, 10 months (range = 8 years, 8 months to 10 years, 10 months). Ethics approval for this research was granted by the Human Research Ethics Committee of the University of Newcastle.

2.2. Measures

2.2.1. Working Memory Power Test (WMPT)

The WMPT is used to measure children's working memory ability. It

[1] The WMPT has been developed by ebilities, a publisher and supplier of online cognitive ability tests.