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# The predictive relationships between working memory skills within the spatial and verbal domains and mathematical performance of Grade 2 South African learners

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ABSTRACT

Working memory and mathematical performance have been highly correlated, but the relations among different components of working memory and mathematical performance is unclear. Therefore this study was undertaken to fill this lacuna, especially within the South African context. This study explored the predictive relationships between working memory skills in two different domains (spatial and verbal) and mathematical performance of Grade two learners ($n = 80$) in South Africa. The Automated Working Memory Assessment was administered to these learners to determine if there was a significant difference between visuo-spatial and verbal working memory. In addition, the learners completed the Young Group Mathematics Test to examine which component of working memory, namely: verbal or visuo-spatial, was associated with mathematics achievement. A statistically significant difference between spatial and verbal working memory and mathematical performance was found. Those learners who achieved higher scores in the visuo-spatial recall processing subtest of the Automated Working Memory Assessment attained higher scores in the Group Mathematics Test. The results suggest that for Grade two learners, visuo-spatial working memory plays an important role in mathematical problem solving and advocates the idea that assessing young learners for impaired visuo-spatial skills may help to pinpoint those at risk of developing mathematical difficulties.



## 1. Introduction

According to the World Economic Forum, South Africa's maths and science education remains last out of 148 countries (Schwab, 2014). Indeed, mathematical performance in South Africa is of major concern, resulting in a number of national initiatives to monitor the quality of education in the country. By assessing what pupils know, these tests enable researchers and policy makers to evaluate the level of achievement of different groups of learners. The Annual National Assessments (ANA) is one such initiative and upon the release of the ANA results for 2014, Minister of Basic Education Angie Motshekga reported that learners continued to show unacceptably low performance in mathematics. The ANA results disclosed that in mathematics, 35% of Grade six learners achieved 50% or above, and achievement decreased across grades as only 3% of Grade nine learners achieved above 50% (Department of Basic Education, 2014). Furthermore, Minister Angie Motshekga reported

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that as a diagnostic tool, the ANA results demonstrated that poor performance was a direct result of inadequate teaching and learner's poor grasp of mathematical concepts (Motshekga, 2014).

A well-developed foundation of research (Gathercole & Alloway, 2007) indicates a strong link between working memory (WM) skills and learning. Numerous empirical studies (Bull & Scerif, 2001; Holmes, Adams, & Hamilton, 2008; Passolunghi, Vercelloni, & Schadee, 2007) also indicate that WM is specifically important in the development of children's mathematical abilities. However, as mentioned by Raghubar et al., (2009) the nature of the relationship between WM and mathematics for the understanding of developmental and individual differences in mathematical skills is not well understood. They further argue that evidence connecting mathematical processing and WM is relatively sparse. It is unclear as to how the different mechanisms of WM influence the acquisition and application of knowledge in different areas of mathematics and whether the importance of one or more WM component changes with maturity (Rasmussen & Bisanz, 2005; Swanson & Kim, 2006; Vandierendonck, 2012). Furthermore, research suggests that there are inconsistencies as to which elements of these memory systems are most affected by individual differences in children's mathematical ability, especially in the Grade two learners' population group (Rasmussen & Bisanz, 2005; Swanson & Kim, 2006; Vandierendonck, 2012). The investigation of a relationship between WM and mathematics could lead to an improved understanding of the nature of WM. Furthermore, it would highlight the impact of WM on mathematical success and failure in Grade 2 learners. Identifying the specific source of WM deficits in learners with deficits in mathematical skills may assist educators in the appropriate accommodation and remediation for those learners (Alloway & Alloway, 2010; Dumontheil & Klingberg, 2011; Gathercole & Alloway, 2007; Holmes et al., 2008). For the facilitation of learning, it is important that educators have an understanding of WM development. If classroom demands are not met due to weak WM, this could result in poor academic growth. Alloway (2006) suggests that the learning progress can be enhanced significantly by lessening WM loads in the classroom.

Research suggests that acquiring an understanding for mathematics involves many different cognitive processes (Gathercole & Alloway 2007; Watson & Gable, 2012). Studies such as that of Berg (2008) who investigated mental addition performance and Munro (2003) who examined general mathematical learning have shown that learners engage their WM in a number of ways during problem solving. These ways may include, but are not limited to: when they interpret information using knowledge they retrieve from long-term memory (LTM), when they hold and connect partial mathematics ideas to integrate new knowledge, when they guide their learning and thinking to solve mathematical problems and when they encode their new grasp of mathematical concepts in long-term memory (Berg, 2008; Munro, 2003; Raghubar & Barnes, 2012). The focus of the current study was specifically on mathematical problem solving and as mentioned by Raghubar and Barnes (2012), these activities are expected to engage WM. Research has demonstrated that WM training can transfer to math in kindergarten (Kroesbergen, Van 't Noordende & Kolkman, 2014) and elementary school children (Karbach, Strobach, & Schubert, 2015; Kuhn & Holling, 2014). A recent meta-analysis of 110 studies with 829 effect sizes found a significant medium correlation of mathematics and WM, including moderation analyses that revealed comparable association with mathematics, verbal WM, numerical WM, and visuospatial WM (Peng, Namkung, Barnes, & Sun, 2016).

Mathematical proficiency includes concepts and procedures across many mathematical domains and a number of empirical studies confirm that WM is an important factor in children's mathematical abilities (Alloway & Alloway, 2010; D'Amico & Guarnera, 2005; De Smedt, Janssen, Bouwens, Verschaffel, & Boets, 2009; Holmes et al., 2008; Raghubar & Barnes, 2012; Swanson & Kim, 2006).

Andersson (2008) asserts that individual differences in mathematical problem solving of learners aged 9–10 years are attributed to the phonological system as he found that these learners primarily applied verbal coding tactics during written mathematical tasks. Swanson and Kim (2006) concur that the phonological loop plays an important role in the development of mathematical skills, because it briefly holds inner speech for verbal comprehension and for the rehearsing of verbal information. They found an association between mathematical ability and counting span, with children of greater mathematical aptitude achieving a higher counting span. Because counting span involves some element of maintenance of information in WM, they suggest that this may be reliant on the ability to inhibit previous information held in WM and the use of rehearsal to support recall. When presenting Grade 1 learners with verbal mathematical problems, Rasmussen and Bisanz (2005) also found phonological WM differentiates between poor and good mathematical performance in school-age children. They found that none of the WM measures predicted performance on non-verbal problems, possibly because the Grade 1 learners developed externalising strategies when solving such problems, that they did not use with the solving of verbal problems. It is, however, important to note that discrepancies in findings amongst researchers may be due to the fact that studies have used many different tasks to measure WM and mathematical ability (Raghubar, Barnes, & Hecht, 2009). Additionally, testing conditions differed and for example, in the above study by Rasmussen and Bisanz (2005), learners were tested individually and the assessment was not a pencil and paper group assessment. Understanding the importance of the phonological loop in learning could help educators facilitate learning, especially with learners who perform better on non-verbal mathematical tasks as opposed to verbal activities (Rasmussen & Bisanz 2005).

Although there has been considerable research into the role of the phonological loop, D'Amico and Guarnera (2005) note that the associations between mathematic achievement and the phonological loop have shown inconsistent results. For example, Passolunghi et al. (2007) revealed that the central executive and not the phonological loop, uniquely predicted individual differences in mathematical achievement at the end of first grade. Furthermore, in a study of second and third graders, Meyer et al. (2010) proposed that the central executive and phonological loop assisted functioning during the early stages of learning, whereas visuo-spatial representations played more of an important role during later stages of learning. As