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The influence of juggling on mental rotation performance in children with spina bifida

Jennifer Lehmann *, Petra Jansen

Institute of Sport Science, University of Regensburg, Universitätsstr. 31, 93053 Regensburg, Germany

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ABSTRACT

This study examined the influence of juggling training on mental rotation ability in children with spina bifida. Children between the ages of 8 and 12 solved a chronometric mental rotation test. Half of the children received juggling training (EG) over an 8 week time period; the other half did not receive training (CG). Afterwards, all participants completed the mental rotation test again. Children of the EG showed a significant decrease in reaction time and an increase in mental rotation speed compared to the control group. This indicates that juggling improves the rotation in the mental rotation process in children with spina bifida.

1. Introduction

Spina bifida (SB) is a congenital defect in which the neural tube fails to close in early embryogenesis. The reported prevalence in Europe is one per 1000 births (Masuhr & Neumann, 2005). This malformation can occur at any point along the spine. According to the severity and location of the defect, difficulties can occur with ambulation, bladder and bowel control, and fine motor functions. In 80% of these cases the patients develop hydrocephalus associated with an Arnold-Chiari malformation of the cerebellum and the hindbrain, which blocks the cerebrospinal fluid flow. Girls are more often affected than boys.

The cognitive abilities of children with spina bifida have been a matter of research and it has been shown that these children tend to have a higher risk of cognitive deficits. Children with spina bifida often have a lower than average IQ, which ranges between normal and that of a slight learning disability. Additionally, in nearly all studies it was shown that the performance IQ of these children is lower than the verbal IQ (Jacobs, Northam, & Anderson, 2001; Lindquist, Carlsson, Persson, & Uvebrant, 2005; Wills, Holmbeck, Dillon, & McLone, 1990). However, Jacobs et al. (2001) failed to find this significant discrepancy between verbal and performance IQ in spina bifida children. Due to the impaired abilities concerning the performance IQ, it is assumed that spina bifida children show impairments in spatial abilities. Mammarella, Cornoldi, and Donadello (2003) investigated the visuospatial working memory in children with spina bifida and showed that these children have difficulties in visual discrimination and visual processing. Furthermore, Dennis, Fletcher, Rogers, Hetherington, and Francis (2002) documented that these deficits are more apparent in action-based visual perception tasks than in object-based visual perception tasks. Based on this, they suggest that object based visual perception is a process in which features are detected with regard to an allocentric frame, whereas action based visual perception is a process which uses a more egocentric reference system which allows action that is visually guided and goal directed. Furthermore, this process requires representations of multiple stable states and is therefore coupled to movement. In tasks where only visual perception is required (e.g. face recognition), children with spina bifida performed as well as age-matched controls (Dennis et al., 2002). Additionally, children with spina bifida solved tasks requiring ventral stream visual processing better than those which required dorsal stream visual processing. The intact ventral visual processing stream is also found by Swain, Joy, Bakker, Shores, and West (2009), who compared children with spina bifida to healthy controls and found no significant differences between the two groups. Since the ventral processing stream is intact and the performance of the dorsal processing stream seems to be impaired in children with spina bifida, one can make the assumption that processes that rely on the dorsal processing stream might be impaired in these children.

Most of the studies mentioned above concentrate on one aspect of the visuospatial abilities and, as far as we know, only one study has tried to investigate all aspect of spatial cognition in children with spina bifida. According to Linn and Petersen (1985) the classical visuospatial abilities are comprised of the spatial perception, spatial visualization, and mental rotation. Jansen-Osmann, Wiedenbauer, and Heil (2008) examined the classical visuospatial

* Corresponding author. Fax: +49 (0)941 943 815527.
E-mail addresses: Jennifer.Lehmann@ur.de (J. Lehmann), Petra.Jansen@ur.de (P. Jansen).

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abilities, spatial working memory, spatial behavior, and spatial knowledge in children with spina bifida. They investigated these abilities in connection to the motor abilities with regard to the spina bifida childreńs impaired ability to walk compared to sex-, age-, and verbal IQ-matched healthy controls. Jansen-Osmann et al. (2008) showed that children with spina bifida performed worse in all measured spatial tasks than controls. Furthermore, they found correlations between the age of walking and the Children's Embedded Figures Test, visuospatial memory, and performance in a maze for children with spina bifida. These results indicate that the different motor development in early childhood do have an effect on the performance in the above mentioned tasks. This relationship between motor development and spatial abilities has already been shown in studies with physically disabled children and orientation (Foreman, Stanton, Wilson, & Duffy, 2003) and in children with spina bifida in containment (Simms, 1987). More evidence for the relationship between motor development and spatial abilities is given by studies with children who have developmental coordination disorder (DCD). Wilson et al. (2004) investigated 16 children with DCD (mean age: 10.4 years) and a healthy control-group of 18 children (mean age: 10 years). They showed, using a mental rotation task with pictures of hands as stimuli, that children with DCD solve this task with an atypical reaction-time pattern compared to healthy children. These results suggest that DCD children do not enlist motor imagery processes into their judgment of mental rotation tasks. Loh, Piek, and Barrett (2011) investigated children with DCD, Attention Deficit/Hyperactivity Disorder (ADHD), and children with both DCD and ADHD regarding their cognitive functions. They found significant poorer perceptual reasoning abilities in the groups of children with DCD suggesting that a deficit in visuospatial abilities might be caused by the DCD, which means by the impaired motor performance, and not the ADHD.

Since Jansen-Osmann et al. (2008) found an impairment of the classic visuospatial abilities, which include mental rotation, research on this specific aspect has particularly be done because during the process of mental rotation the dorsal processing stream is activated (e.g. Podzebenko, Egan, & Watson, 2002). According to Dennis et al. (2002) children with spina bifida show decreased abilities in tasks requiring the dorsal stream. Based on this, one can assume that the mental rotation ability in these children is impaired.

Wiedenbauer's and Jansen-Osman's (2007) study concerning mental rotation ability showed that manual rotation training could improve this ability. Therefore, 19 children with spina bifida and 19 matched controls were assessed with a chronometric mental rotation test before and after manual rotation training. The entire testing procedure, comprised of the pre- and post-test and the training, was conducted in 60 min for each participant. Children with spina bifida showed impaired mental rotation abilities compared to controls demonstrated by slower reaction times in the pretest. Both groups improved their mental rotation abilities after the manual training, although children with spina bifida benefited more than controls. The reduction of reaction times was twice as high for the children with spina bifida, indicating that children with poor mental rotation abilities benefit more from rotation training than children with normal mental rotation abilities (Rizzo et al., 2001). Due to the kind of manual training used, the question of suitability for daily use comes up and the need for a more appropriate training for these children, one that could be carried out at home, is apparent. Preliminary considerations for choosing the training were the practicability at home, the suitability for different disability levels, and the effectiveness for training the spatial abilities. So far there are only few studies that have investigated the influence of motor or coordination training on spatial abilities in children with spina bifida (Wiedenbauer & Jansen-Osmann, 2008). To choose a suitable training we assessed the research of motor training and its effect on spatial abilities in healthy children. Since juggling training has already been found to improve mental rotation performance (Jansen, Lange, & Heil, 2011; Jansen, Titze, & Heil, 2009), it also is considered to be suitable for children with spina bifida. The suitability of this task was judged based on the versatility of items that can be juggled and the number of items that can be used to juggle. Because of these aspects juggling can be adapted to the individual skills of the children.

Jansen, Titze et al. (2009) showed that juggling improved the mental rotation performance in students. In this study, two groups (23 per group) solved a chronometric mental rotation task at the beginning and at the end of a 3 month time period. In between the tests the experimental group received one and a half hour of juggling training once a week according to a specifically developed program. Although a test effect for the second test was found in the control group, the results of the study clearly indicate that the experimental group's improvement in reaction time was above the repetition effect. Jansen, Titze et al. (2009) found this effect only for the angular disparity 90° and 180°, but not for 0°. But since 0° does not need any rotation, this might explain the missing effect for this condition. However, juggling showed no effect on error rate. These results were expanded by the study of Jansen, Lange et al. (2011), who showed that this effect is also found in school-aged children and that the training effect is specific for juggling.

Taken together, on one hand the studies mentioned above show that children with different motor impairments, e.g. children with DCD and also children with spina bifida, show an impaired mental rotation performance. On the other side, neuroscientific studies suggest that juggling leads to an increasing plasticity (Draganski et al., 2004) in one area which is also involved in mental rotation (Jordan, Heinze, Lutz, Kanowski, & Jäncke, 2001). On a behavioral level it has been demonstrated that juggling enhances mental rotation performance (Jansen, Lange et al., 2011; Jansen, Titze et al., 2009). Due to the fact that children with spina bifida benefit from mental rotation training and due to the positive "juggling" studies, the main goal of this paper is to investigate the influence of juggling training on the mental rotation ability in children with spina bifida.

2. Method

2.1. Participants

Nineteen children with spina bifida (15 girls and four boys) aged between 8 and 12 ($M = 9.74$, $SD = 1.45$) years old took part in the study. Children were recruited by means of advertisement in local newspapers and in the journal of the *German Society of Spina bifida and Hydrocephalus* and with the cooperation of social pediatric centers in Bavaria, Baden-Württemberg, and North Rhine-Westphalia. Prior to testing, all parents gave their written consent for their children's participation. The ethical review committee was informed.

In addition to general information, the medical condition and infantile motor development were assessed by a questionnaire. All children had myelomeningocele and, apart from one child, all suffered from a shunted hydrocephalus. The localization of the lesion was lumbal in 15 children, thoracic and sacral in two children respectively. None of the children suffered from epilepsy, uncontrolled seizure disorder, perception disorder, or behavioral occurrences. Thirteen of the children learned to walk with or without assistance (6 in the intervention group, 7 in the control group). The other six children are not able to walk and sit in a wheelchair (4 in the intervention group, 2 in the control group). All children had normal or corrected to normal vision.