Cognitive Development 28 (2013) 51–62

Contents lists available at SciVerse ScienceDirect

Cognitive Development

Mental rotation performance in primary school age children: Are there gender differences in chronometric tests?

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ARTICLE INFO

Keywords:
Mental rotation
Pre-adolescence
Gender differences
Stimulus type

ABSTRACT

In contrast to the well documented male advantage in psychometric mental rotation tests, gender differences in chronometric experimental designs are still under dispute. Therefore, a systematic investigation of gender differences in mental rotation performance in primary-school children is presented in this paper. A chronometric mental rotation task was used to test 449 second and fourth graders. The children were tested in three separate groups each with different stimulus material (animal drawings, letters, or cube figures). The results show that chronometric mental rotation tasks with cube figures – even rotated in picture plane only – were too difficult for children in both age groups. Further analyses with animal drawings and letters as stimuli revealed an overall gender difference in response time (RT) favoring males, an increasing RT with increasing angular disparity for all children, and faster RTs for fourth graders compared to second graders. This is the first study which has shown consistent gender differences in chronometric mental rotation with primary school aged children regarding reaction time and accuracy while considering appropriate stimuli.

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http://dx.doi.org/10.1016/j.cogdev.2012.08.005

1. Introduction

Mental rotation is the ability to rotate two- or three-dimensional stimuli in the mind (Shepard & Metzler, 1971). The main goal of this study is to investigate gender differences in the chronometric mental rotation performance of school age children when using different types of stimuli. This is a combination of topics which has not been systematically investigated until now.

1.1. Mental rotation performance measured with psychometric and chronometric tests in children

Psychometric mental rotation tests, where participants have to solve time-limited mental rotation tasks on a paper sheet, can be used to test children as young as 5 years old (Quaiser-Pohl, Rohe, & Amberger, 2010) when using age appropriate stimuli (Quaiser-Pohl, 2003). With the most widely used paper–pencil mental rotation test, the MRT (Peters et al., 1995; Vandenberg & Kuse, 1978), psychometric mental rotation performance can be reliably measured in primary school-aged children (9–11 years) (Titze, Jansen, & Heil, 2010). In the MRT, each of the 24 items consists of one target on the left side and four comparison items on the right side. Two of the four comparisons are "correct" (identical to the left item) and two are "incorrect". Participants must choose both of the correct stimuli within a time limit of three minutes for 12 items. Accuracy is measured.

In addition to psychometric tests there are chronometric mental rotation tests. In these tests, participants sit in front of a computer screen and are shown pairs of mental rotation objects. They must decide as fast and as accurately as possible if the objects are the same or are mirror images of each other by pressing a key. Accuracy and reaction time are measured. It has been demonstrated that children are able to solve chronometric mental rotation tasks even before entering school. Marmor (1975) showed that 5-year-old children can mentally rotate two-dimensional figures in the picture plane. However, they were twice as slow as 8-year-old children. These results were confirmed in other studies (e.g. Kosslyn, Margolis, Barrett, & Goldknopf, 1990), but they are also still controversially discussed (Newcombe, 2002). Results from additional studies have revealed a high individual variability and some studies have failed to replicate Marmor's result (compare Newcombe & Frick, 2010). Kail, Pellegrino, and Carter (1980) investigated the development of mental rotation performance after the age of eight. They found a linear mental-rotation function using alphanumeric and abstract symbols and showed that mental-rotation speed nearly doubled from 8 years old to adulthood. Concerning the influence of stimulus type, Courbois (2000) showed that the ability to rotate unfamiliar stimuli with no salient axis improves from five to 8 years of age. Furthermore, Perrucci, Agnoli, and Albiero (2008) demonstrated that children at the age of 6 years old are already able to compare two stimuli at different orientations dependent on orientation-free features, such as the color of some part of the stimuli. In this case they are able to respond without using mental rotation.

1.2. The importance of gender differences in children measured with psychometric and chronometric tests

Gender differences in mental-rotation tasks are widely discussed and well investigated in psychometric, paper–pencil tests (Peters & Battista, 2008). Using psychometric tests with three different stimulus conditions (animal pictures, letters, and cube figures) it was shown that fourth graders, but not second graders, showed a small, significant, stimulus-independent gender difference favoring males (Neuburger, Jansen, Heil, & Quaiser-Pohl, 2011). This is in line with another study showing a large gender difference favoring males only in older (mean age: 10.3 years) but not in younger fourth graders (mean age: 9.3 years) (Titze et al., 2010). These gender differences are often discussed on a psycho-social or biological–neuronal basis. Psycho-social theories often argue that gender differences are based on the influence of attitudes or stereotypes (Moè & Pazzaglia, 2006; Steele, 1997) or on different experiences based on gender. For example, Levine, Ratliff, Huttenlocher, and Cannon 2012) showed that the quality, but not the frequency, of puzzle play was higher for boys than for girls (between 2 and 4 years old) and that this variation predicts performance on spatial transformation tasks. Biological theories stress the importance of brain organization and hormonal (organizational and activational) influences. Both psycho-social and biological approaches are empirically supported