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ABSTRACT

It has been hypothesized that differences in mathematical word problems are the result of differences in spatial skill. Why complex spatial abilities are needed for an individual to represent the relatively simple spatial relations in word problems is not clear. It is possible that a third variable, cognitive strategy preferences, may partially explain the relation between mental rotation and mathematical problem solving. In this study, cognitive strategy was not found to play a role in the relation between mental rotation and math word problem performance. Other variables that might mediate the relationship are discussed, including the effect of gender stereotypes on spatial and mathematical activity levels. (Author)

Cognitive Strategies in Mental Rotation and Mathematical Word Problems

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Abstract

It has been hypothesized that differences in mathematical word problems are the result of differences in spatial skill. Why complex spatial abilities are needed for an individual to represent the relatively simple spatial relations in word problems is not clear. It is possible that a third variable, cognitive strategy preferences, may partially explain the relation between mental rotation and mathematical problem solving.

In this study, cognitive strategy was not found to play a role in the relation between mental rotation and math word problem performance. Other variables that might mediate the relationship are discussed, including the effect of gender stereotypes on spatial and mathematical activity levels.

Introduction

Gender differences, favoring males, have consistently been found in both mental rotation, a type of spatial skill, and mathematical word problem solving (Benbow, 1988; Hyde, Fennema & Lamon, 1990). There appears to be a strong relationship between the two; covarying mental rotation scores out of the equation has been found to eliminate gender differences in mathematical problem solving (Casey, Winner, Brabeck, & Sullivan, 1989). It has been hypothesized that gender differences in mathematical reasoning are the result of differences in spatial skills. However, just because the two are related does not mean that one causes the other. Why the complex spatial ability involved in 3-dimensional mental rotation is needed to perform the relatively easy spatial diagraming used in word problems is not clear. It is possible that a third variable may be partially able to explain both gender differences in mental rotation and mathematical problem solving. A candidate for such a variable is cognitive strategy preferences.

Two possible strategies have been used by study participants to complete mental rotation tasks: a "*key feature*" strategy or a "*spatial*" one (Hoyenga & Hoyenga, 1993). The latter strategy is both more successful and more likely to be used by males. Similarly, "*key feature*" and "*spatial*" strategies have been found to be used by participants in mathematical reasoning, with the spatial strategy appearing to be more effective (McGuinness, 1985). Although gender differences in strategies have not been explored, it has been anecdotally noted that females are less likely to use the spatial strategy. Therefore, it is reasonable to hypothesize that the relationship between mental rotation and mathematical problem solving performance may be related to a third factor, strategy preference, and that different strategy preferences may help explain gender differences in both types of performance.

The purpose of this study was to examine gender differences in mental rotation and mathematical reasoning performance and the relationship between the 2 types of performances. Explore the possibility that cognitive strategy preferences may be an intervening factor related to gender.

Method

Participants were 109 students (61 females, M=15.38 years, SD=.78 and 48 males, M=15.69 years, SD=.88) from a midwestern high school. Students were previously or currently enrolled in Algebra I and Geometry.

Each participant was administered the Vandenberg and Kuse Mental Rotations Test (MRT) (Vandenberg & Kuse, 1978), Spatial Strategies Questionnaire (SSQ) (Shultz, 1991), Math Strategies Questionnaire (MSQ), Word Problems Test (WPT), the Shipley Institute of Living Scales (SILS)

(Shipley, 1986). Based on the results of the Spatial Strategies Questionnaire participants were designated as either spatial (MO) or verbal (KF) strategists.

All participants were tested over a 2 day period in 45 minute sessions. The Word Problems Test, Math Strategies Questionnaire, and Shipley Institute of Living Scales (Shipley, 1986) were administered during the first 45 minutes session. All other measures were administered during the second 45 minute session.

Results

A significant gender difference was found in the math strategies measure (MSQ), with males (M=59.08, SD 50.24) being more likely than females (M=38.25, SD=54.84) to use the more effective spatial strategy to solve math word problems.

Structural equation modeling (Joreskog & Sorbom, 1996) was utilized to examine the relation between mental rotation and mathematical performance. A 2-group analysis was utilized, using the variable of gender. The analyses used were covariance matrices but are being presented here as correlation matrices (see Table 1 and 2). Estimates of path values were obtained through a procedure called maximum-likelihood model fitting. The set of path estimates that best maximize the fit between the model and the measure data was derived. Below the full model that was tested is pictured in Figure 1. The full model for both males and females was analyzed to determine the best fit model (see Figures 2 and 3).

This study hypothesized that cognitive strategy would explain more of the connection between the mental rotation and math performance than ability *per se*. However, the best fit model in this study did not suggest that cognitive strategies are an important mediator of the relationship between mental rotation performance and math performance. Consistent with a previous study

(Pezaris, Casey, & Nettall, 1993) the direct predictive relation between mental rotation performance and math performance was significant for females only.

Conclusions

A new and interesting finding of this study was a gender difference in the strategy utilized to perform math word problems. Males were more likely than females to use the spatial strategy. This raises the possibility that training in the particular strategy may reduce or alleviate gender differences in math word problem solving.

This study also examined whether the predictive relation between mental rotation performance and math word problems performance may in part be explained by a shared tendency toward either the generally more effective "*spatial*" strategies or the generally less effective "*key feature*" strategies on both tasks. The structural equation model in the present study tested these questions, examining the significance of a direct predictive relationship between mental rotation and math performance when cognitive strategy preferences are also considered as a mediating factor. Cognitive strategy was not a significant mediating factor between mental rotation and math word problem solving skill. A direct relation between the 2 types of performance was found, but only for females. It is especially interesting that this performance relation is found for females but not males. Such a result suggests the possibility that other mediating factors may be operating specifically for females. Some of those possibilities could include gender stereotyping of both spatially-related activities and mathematically-related strategies. Future studies will find it necessary to consider psychosocial variables in an attempt to explain the frequently observed gender difference in math.

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Table 1.

Correlation matrix for females (N = 61)

	Reasoning Ability (SILS)	Mental Rotation Strategy (SSQ)	Math Strategy (MSQ)	Mental Rotation Performance (MRT)	Math Word Problem Performance (WPT)
Reasoning Ability (SILS)	1.00				
Mental Rotation Strategy (SSQ)	.17	1.00			
Math Strategy (MSQ)	.12	-.21	1.00		
Mental Rotation Performance (MRT)	.37**	.22	-.03	1.00	
Math Word Problem Performance (WPT)	.16	-.09	.28*	.31**	1.00

Note. * $p<.05$
** $p<.01$

Table 2.

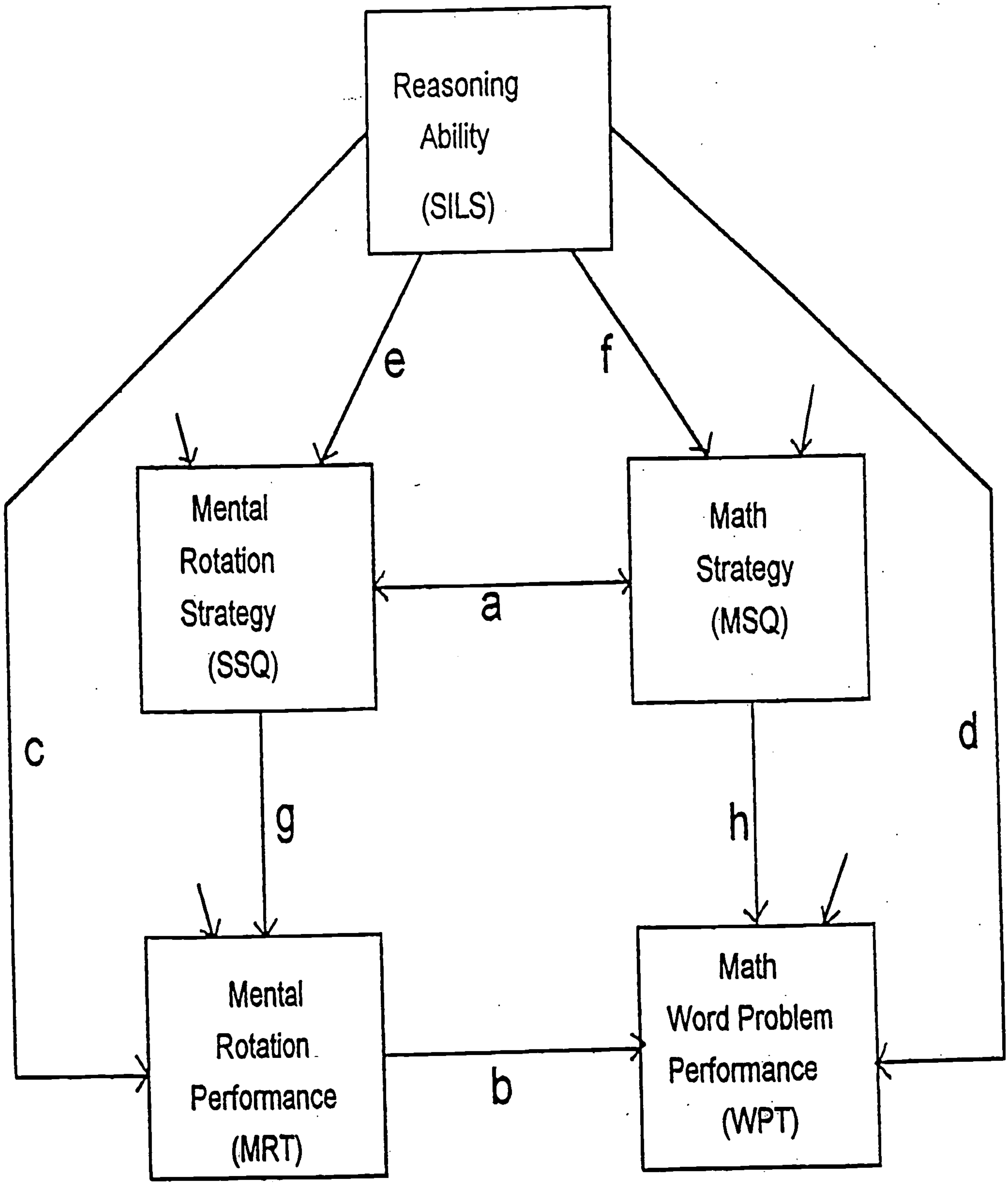
Correlation matrix for males (N = 48)

	Reasoning Ability (SILS)	Mental Rotation Strategy (SSQ)	Math Strategy (MSQ)	Mental Rotation Performance (MRT)	Math Word Problem Performance (WPT)
Reasoning Ability (SILS)	1.00				
Mental Rotation Strategy (SSQ)	-.10	1.00			
Math Strategy (MSQ)	.07	-.06	1.00		
Mental Rotation Performance (MRT)	.31*	.07	.16	1.00	
Math Word Problem Performance (WPT)	.12	.10	.10	.01	1.00

Note. * $p<.05$

Figure 1

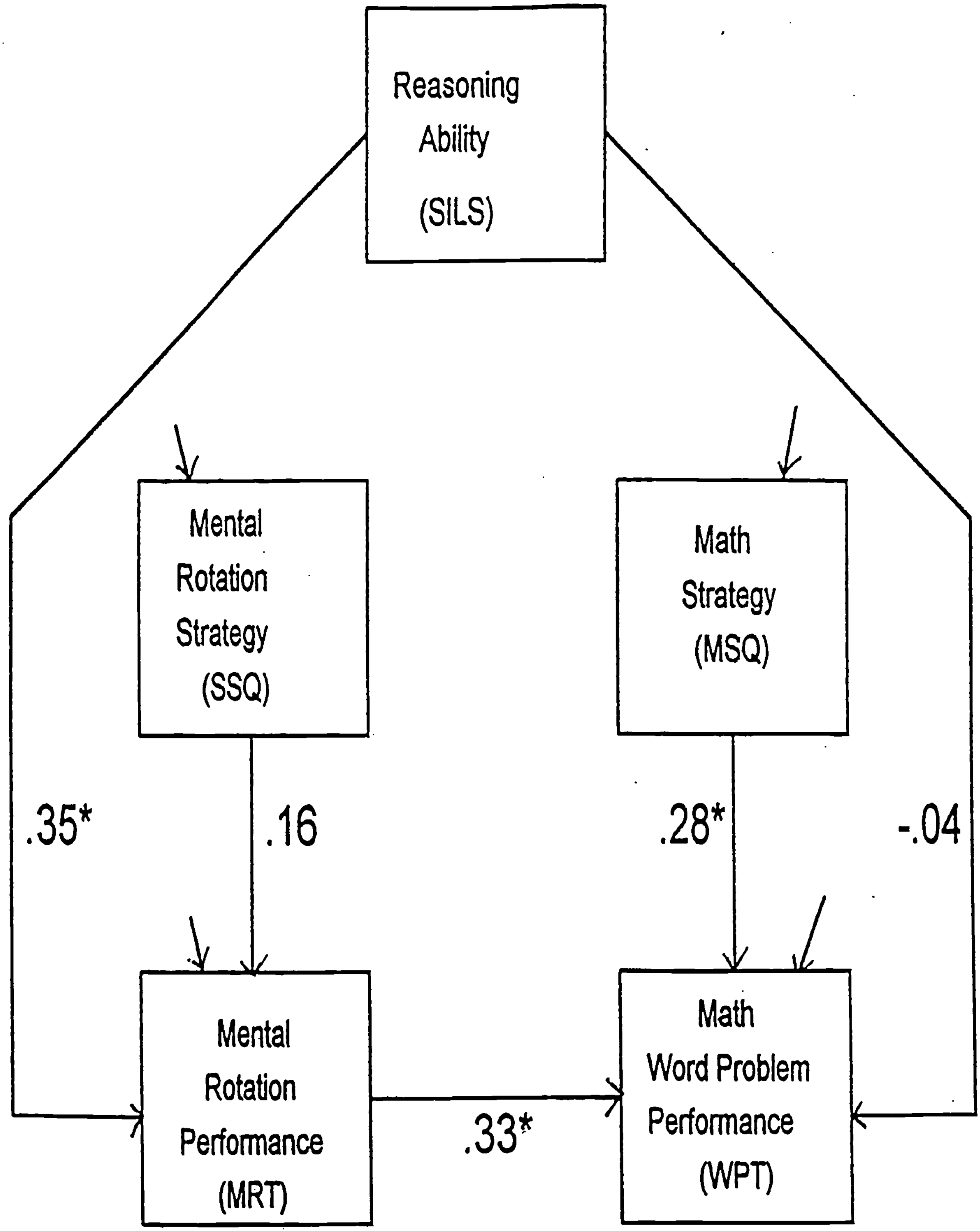
Full structural equation model



Note. SSQ = Spatial Strategies Questionnaire, MSQ = Math Strategies Questionnaire, MRT = Mental Rotations Test, WPT = Word Problems Test.

Figure 2

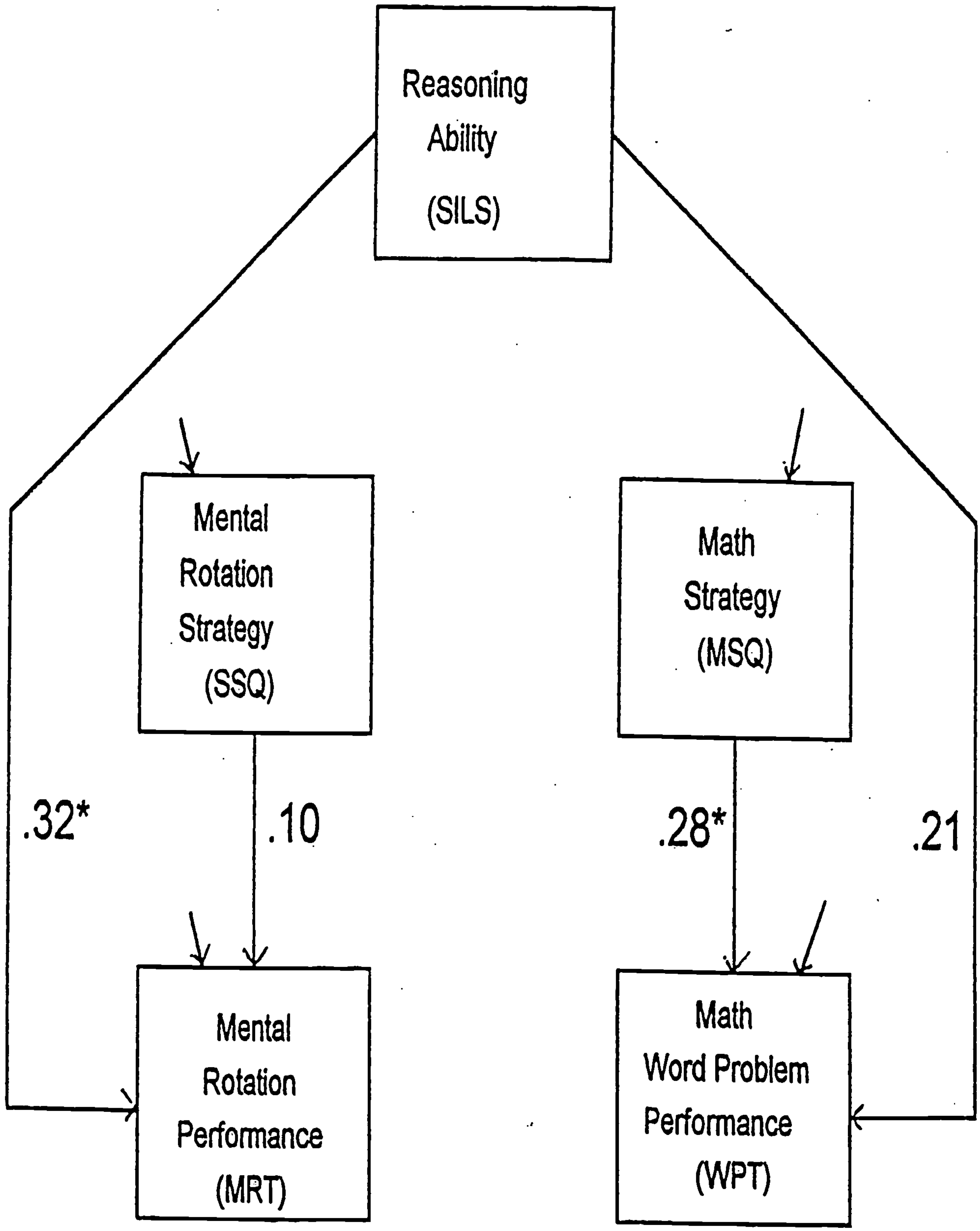
Best fit model for females



Note. * p < .05. SSQ = Spatial Strategies Questionnaire, MSQ = Math Strategies Questionnaire, MRT = Mental Rotations Test, WPT = Word Problems Test.

Figure 3

Best fit model for males



Note. * $p < .05$. SSQ = Spatial Strategies Questionnaire, MSQ = Math Strategies Questionnaire, MRT = Mental Rotations Test, WPT = Word Problems Test.

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