Gender, mental rotations, and introductory physics

Jessica Watkins
UMd PERG seminar
April 1, 2010

The Science of Gender and Science

Pinker vs. Spelke

Mind/Brain/Behavior
Interfaculty Initiative

Harvard University
May 16, 2005

“The male advantage in physics may be partly due to the spatial and visualization demands common to physics problems.”

Taasoobshirazi & Carr, 2008

How does performance on an assessment of mental rotation abilities relate to performance in introductory physics courses?

Are mental rotations necessary for introductory physics problem-solving?

background	quantitative	qualitative

sex differences in spatial ability

$$\text{effect size } (d) = \frac{\bar{x}_M - \bar{x}_F}{s}$$

Voyer, Voyer, & Bryden, 1995

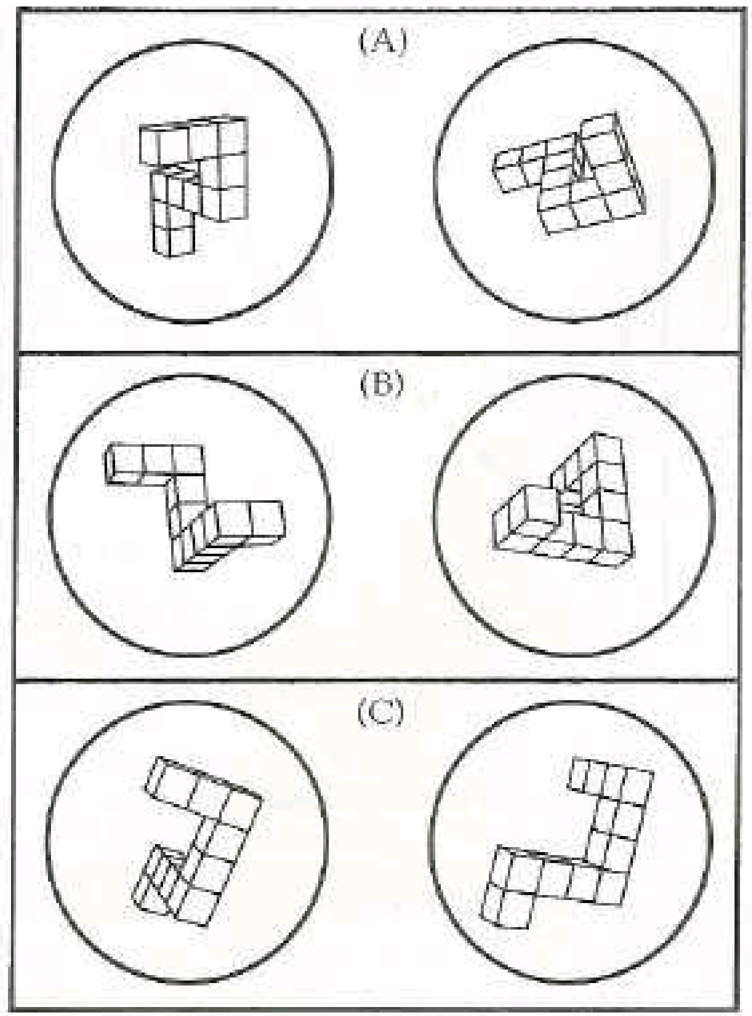
sex differences in spatial ability

$$\text{effect size } (d) = \frac{\bar{x}_M - \bar{x}_F}{s}$$

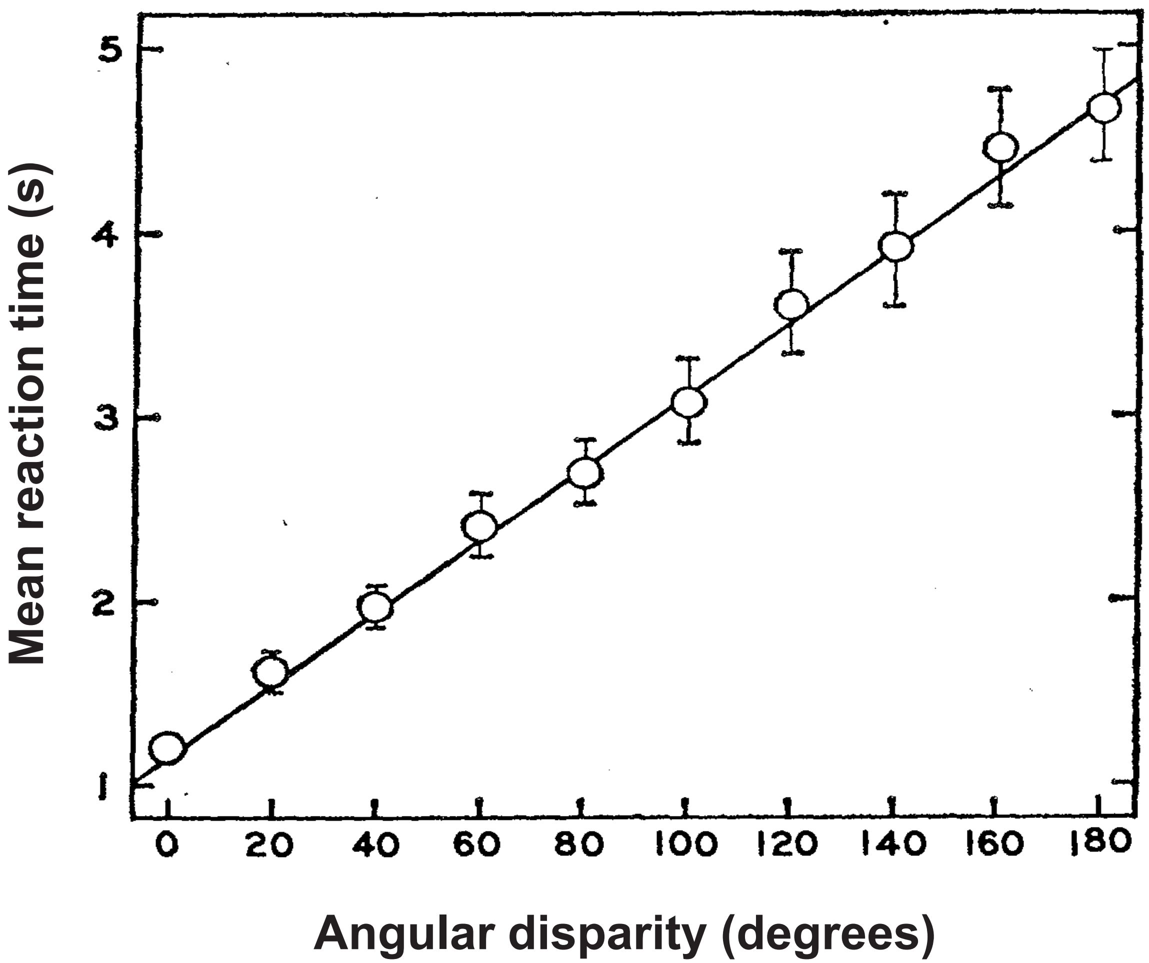
spatial visualization	$d = 0.1–0.2$
spatial perception	$d = 0.4$
mental rotation	$d = 0.6–0.7$

Voyer, Voyer, & Bryden, 1995

mental rotation



Shepard & Metzler, 1971

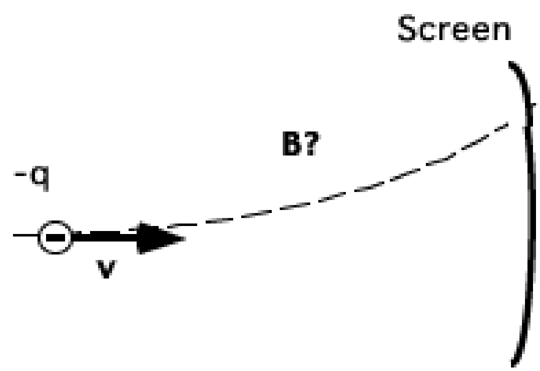


Shepard & Metzler, 1971

“[The magnetic field and force are] difficult to assimilate, because they involve vector cross-products and require difficult mental rotations.”

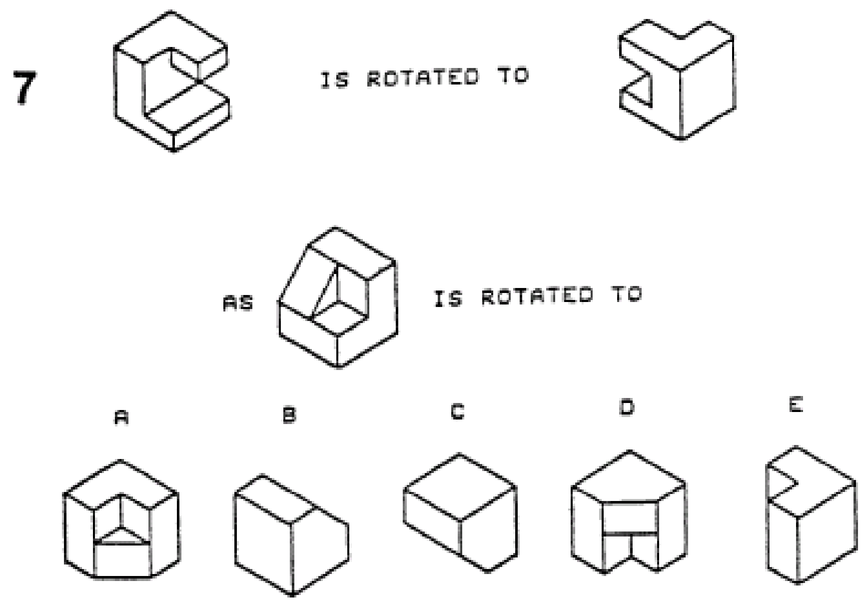
Chabay & Sherwood, 2006

HS students' understanding of E&M



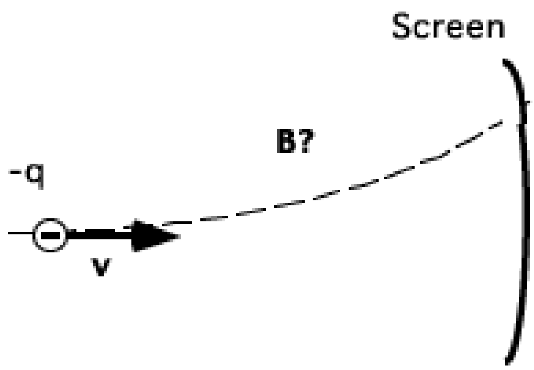
Sağlam and Millar, 2006

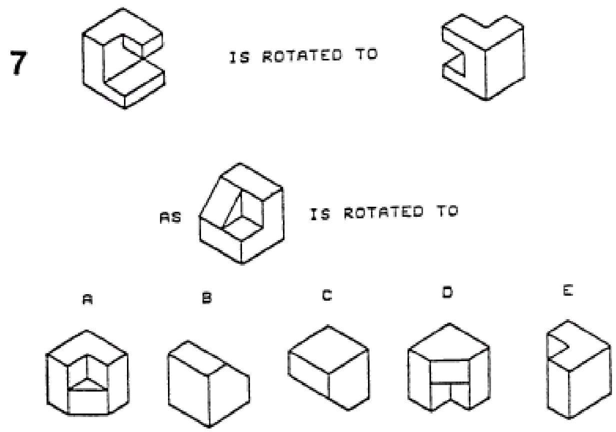
HS students' understanding of E&M



Bodner & Guay, 1997

HS students' understanding of E&M

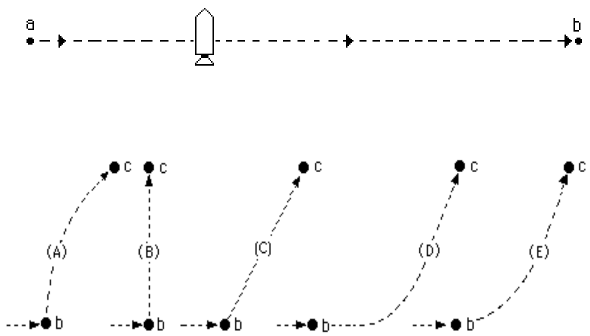




"The most positive conclusion that can be drawn about this... study is that the results were inconclusive."

Sağlam and Millar, 2006

studies in kinematics

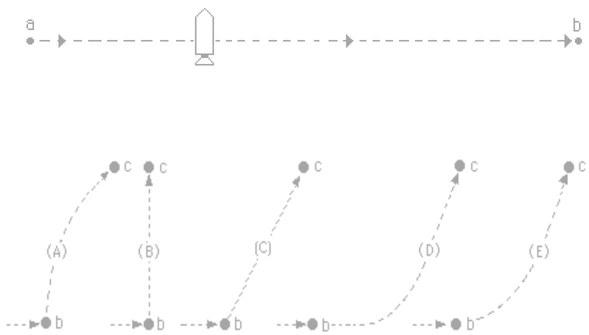


spatial visualization $r = 0.35$

mental rotation $r = 0.02–0.20$

Kozhevnikov, Hegarty, & Mayer, 2002

studies in kinematics



spatial visualization $r = 0.35$

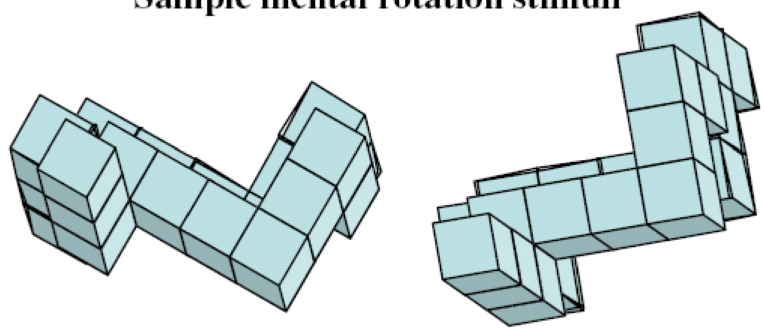
mental rotation $r = 0.02–0.20$

"It seems that the ability to solve mental rotation problems quickly is not as crucial in problem-solving in kinematics as spatial visualization..."

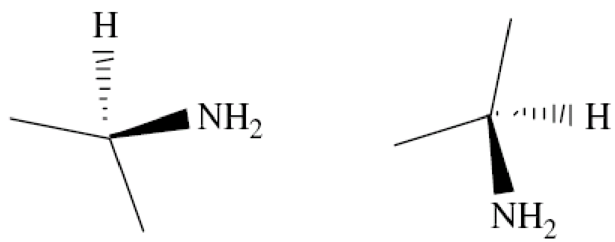
Kozhevnikov, Hegarty, & Mayer, 2002

studies in chemistry

Sample mental rotation stimuli



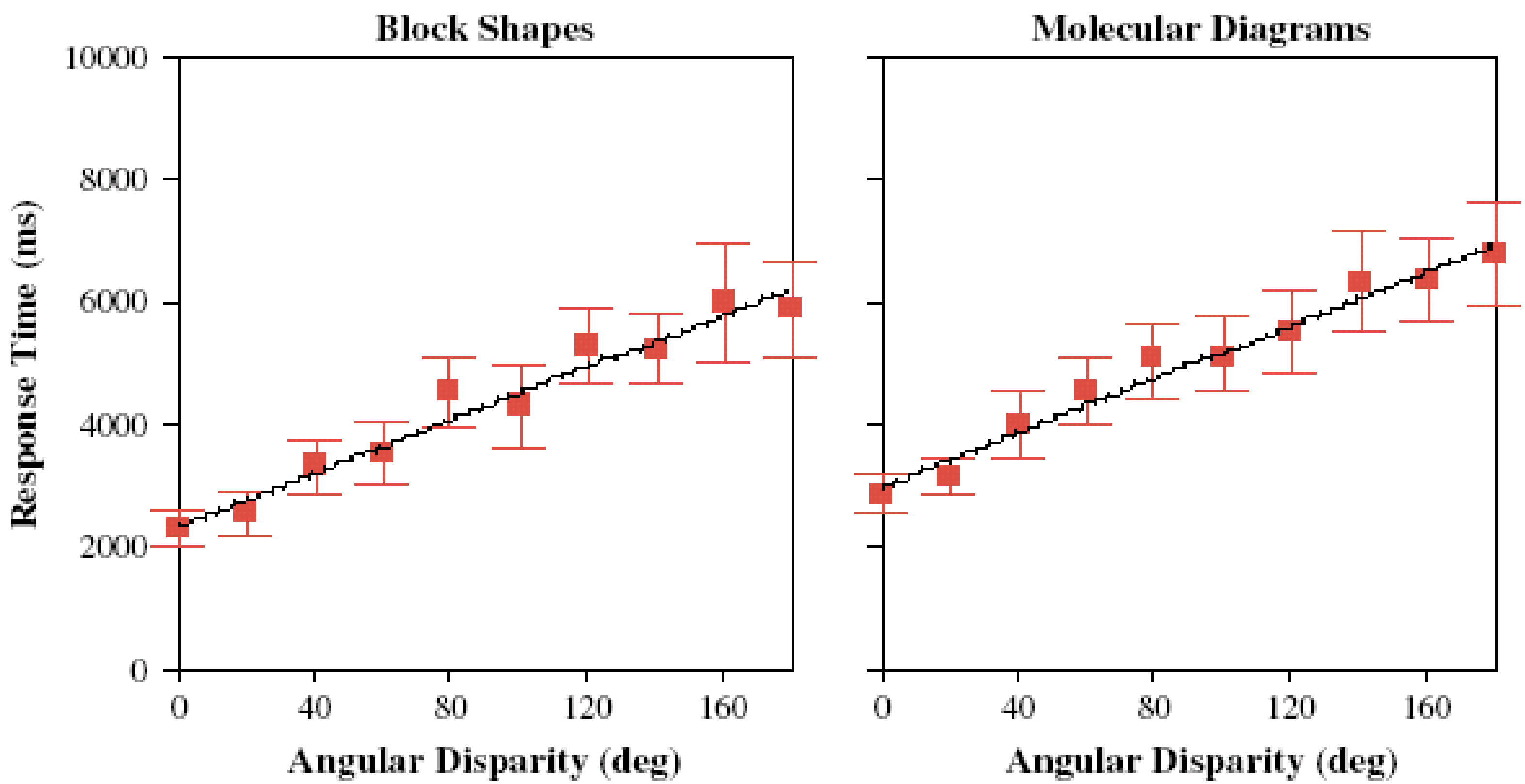
Sample textbook stereochemistry task



Are these molecules enantiomers?

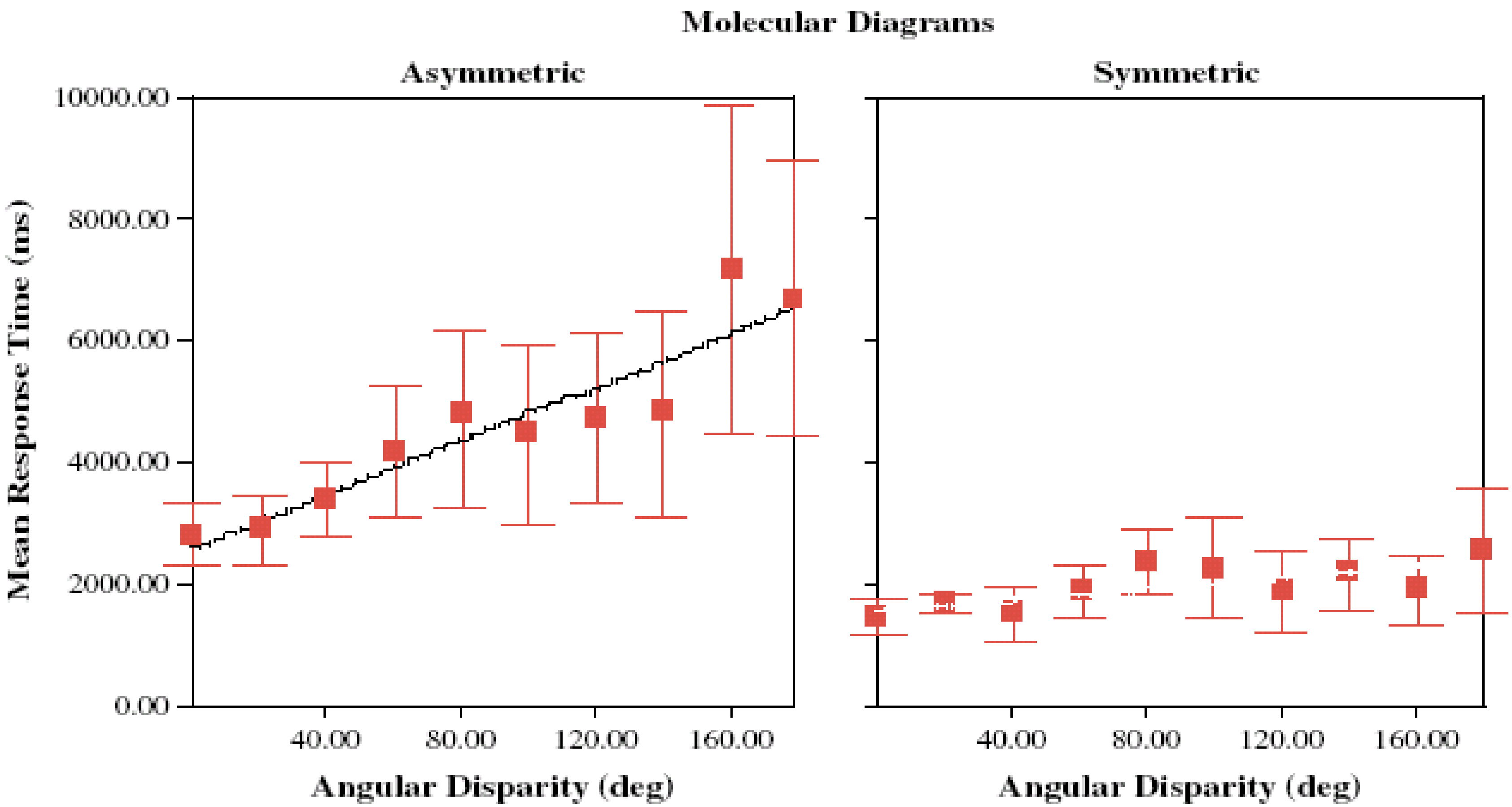
Stieff, 2007

studies in chemistry



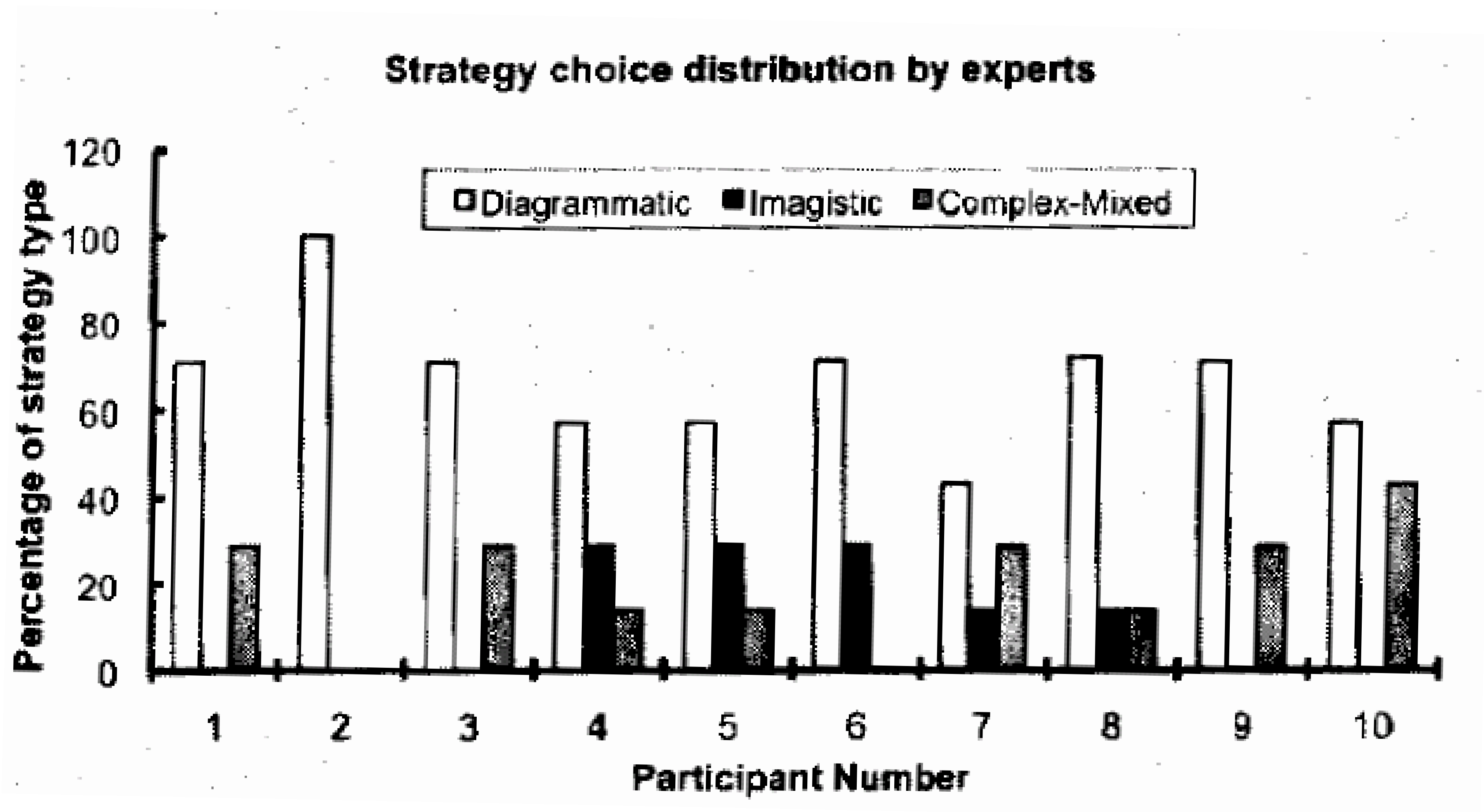
Stieff, 2007

studies in chemistry



Stieff, 2007

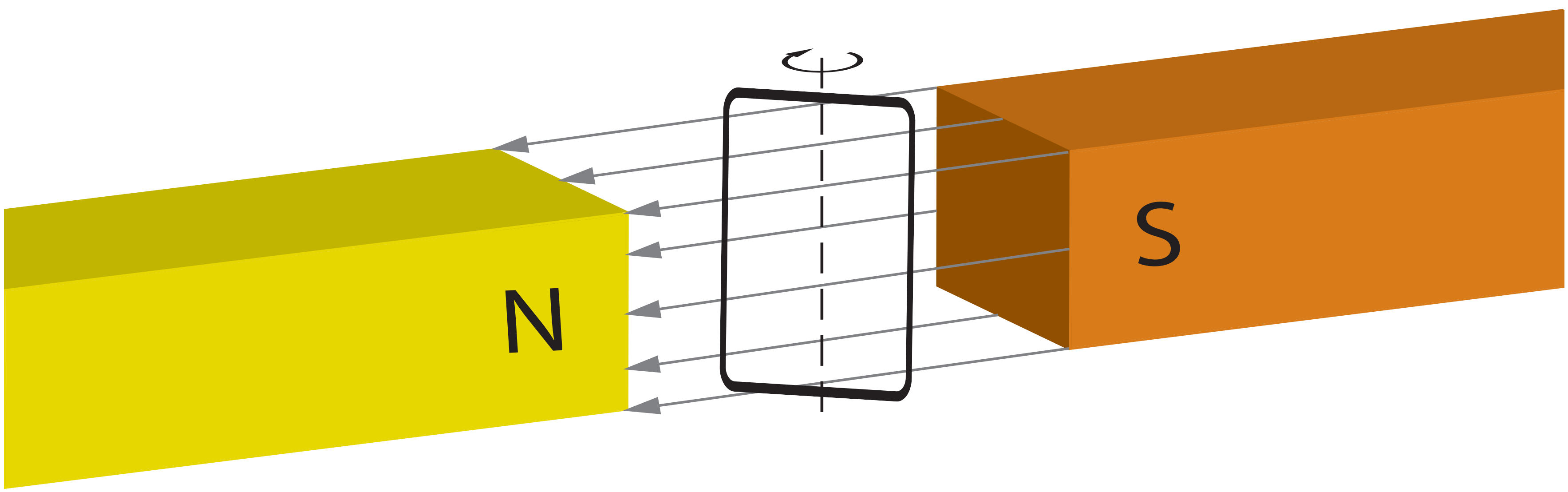
studies in chemistry



Stieff and Raje, 2010

background quantitative qualitative

introductory physics courses



Chabay & Sherwood, 2006

introductory physics courses

PS: Physical Science course

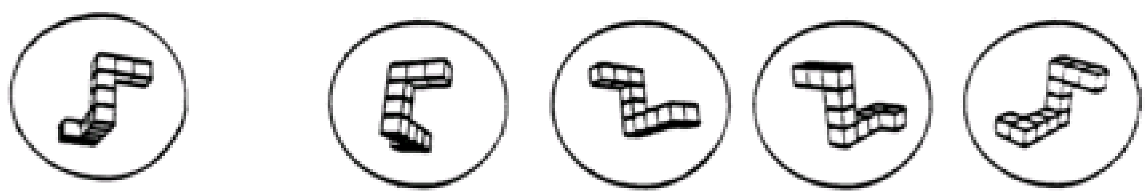
HP: Honors Physics course

student population

	N	% female	majors	year in school
PS	190	70%	bioscience	3rd
HP	58	43%	physics/ engineering	1st/2nd

measures

MRT Vandenburg-Kuse Mental Rotations Test



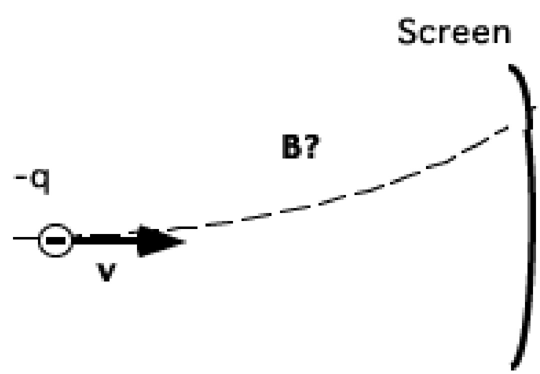
Vandenberg & Kuse, 1978
Peters, et al., 1995

measures

MRT
CSEMpre

CSEMpost

Conceptual Survey on Electricity and Magnetism



Maloney, et al., 2001

measures

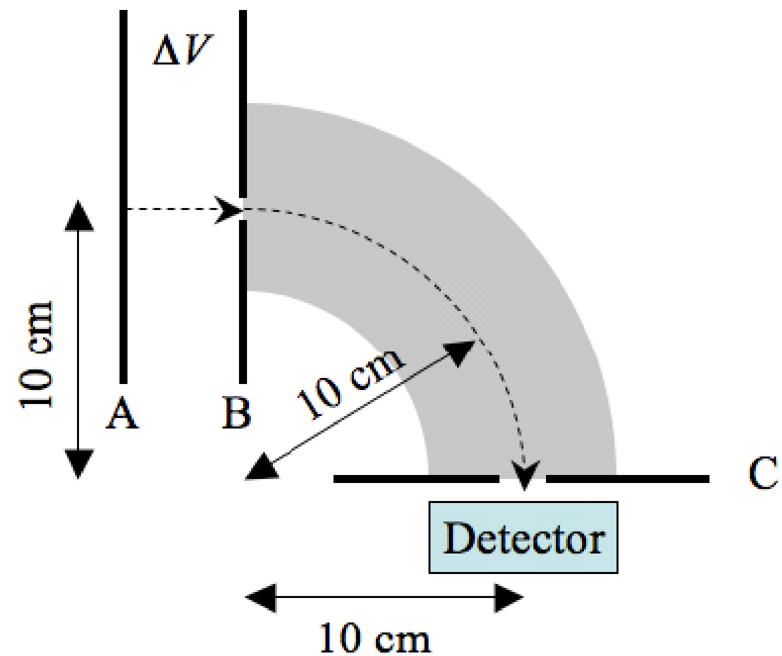
MRT

CSEMpre

CSEM

final exam

final grades



gender differences

$$\text{effect size } (d) = \frac{\bar{x}_M - \bar{x}_F}{s}$$

gender differences

$$\text{effect size } (d) = \frac{\bar{x}_M - \bar{x}_F}{s}$$

	PS
MRT	0.63***

gender differences

$$\text{effect size } (d) = \frac{\bar{x}_M - \bar{x}_F}{s}$$

	PS
MRT	0.63^{***}
CSEMpre	0.36^{*}
CSEMpost	0.22
final exam	0.33^{*}
final grade	$0.27^{\sim}$

gender differences

$$\text{effect size } (d) = \frac{\overline{x}_M - \overline{x}_F}{s}$$

	PS	HP
MRT	0.63***	0.66*
CSEMpre	0.36*	-0.25
CSEMpost	0.22	-0.03
final exam	0.33*	-0.39
final grade	0.27~	-0.44

correlations

$$r_{xy} = \frac{\sum_i (x_i - \overline{x})(y_i - \overline{y})}{(n-1)\, s_x\, s_y}$$

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MRT	PS
CSEMpost	0.18*

correlations

$$r_{xy} = \frac{\sum_i (x_i - \overline{x})(y_i - \overline{y})}{(n-1)\, s_x s_y}$$

MRT	PS
CSEMpost	0.18*
final exam	0.21**
final grade	0.22**

correlations

$$r_{xy} = \frac{\sum_i (x_i - \overline{x})(y_i - \overline{y})}{(n-1)\, s_x\, s_y}$$

MRT	PS	HP
CSEMpost	0.18*	0.08
final exam	0.21**	-0.11
final grade	0.22**	-0.13

low, but significant correlations in Physical Science

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CSEMpost	0.18*	0.08
final exam	0.21**	-0.11
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low, but significant correlations in Physical Science

***no* significant correlations in Honors Physics**

MRT	PS	HP
CSEMpost	0.18*	0.08
final exam	0.21**	-0.11
final grade	0.22**	-0.13

background quantitative **qualitative**

How does performance on an assessment of mental rotation abilities relate to performance in introductory physics courses?

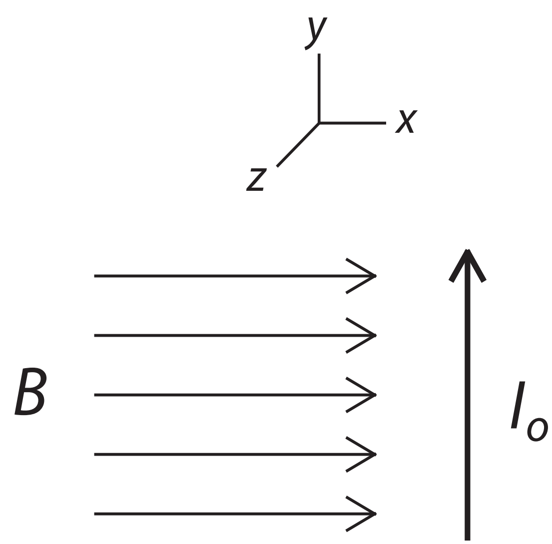
Are mental rotations necessary for introductory physics problem-solving?

student interviews

	PS	HP
low MRT	6	2
med/high MRT	2	2

6 males, 6 females

highly spatial physics problems



b) If the wire is rotated 30° clockwise about the x-axis, as seen from the right, what would the magnitude of the force on the wire be?

coding for mental imagery

1. explicit verbal references to use of mental imagery
2. representational (iconic) gestures
3. gap in student reasoning

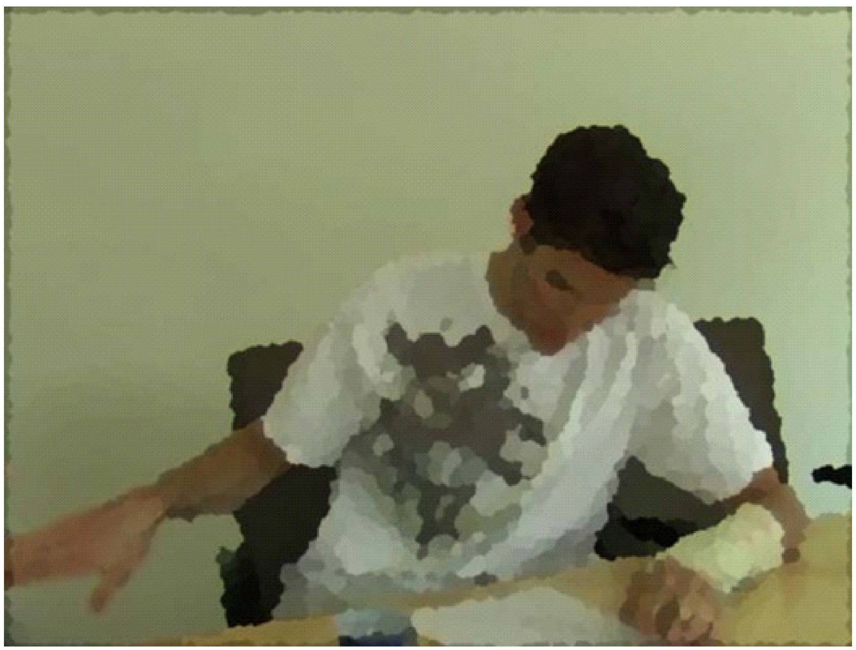
Stieff and Raje, 2008
Clement, 1994
Alibali, 2005
Wess, et al. 2001

context dependence

Maverick

PS student
low MRT score
high CSEM scores

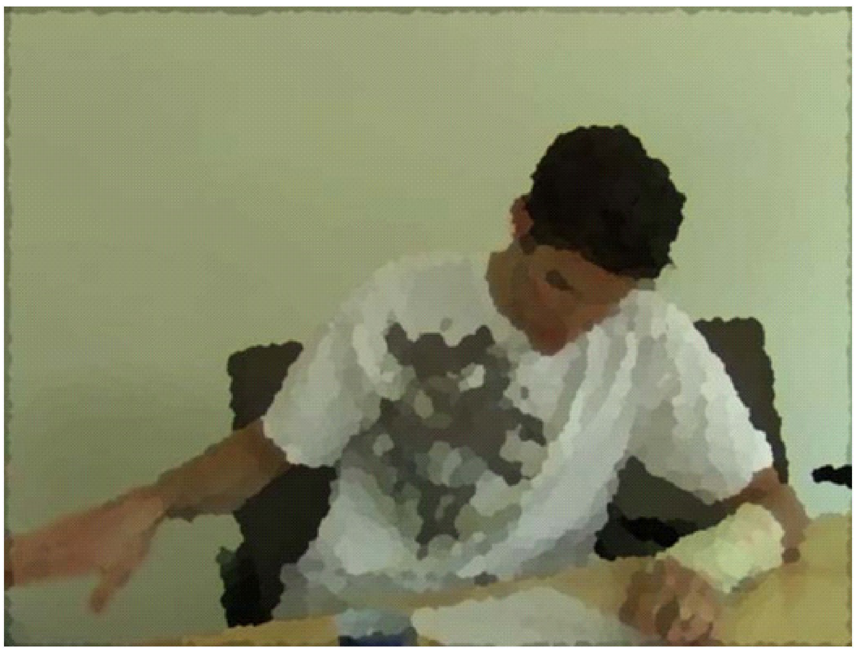
context dependence



"So I'm a little confused about which direction these axes point in or what it means to be rotated about...

I'm thinking now that means the plane perpendicular to, that means rotated in the zy plane."

context dependence



"I is always pointing like this, and B is always that way, in which case they're always perpendicular to each other. The magnitude does not change."

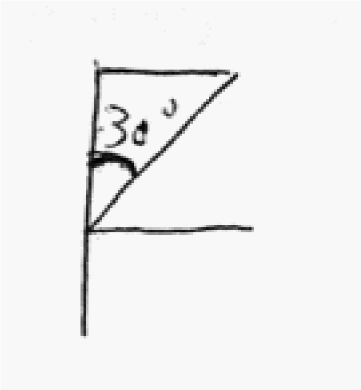
context dependence

Kyle

PS student
med/high MRT score
high CSEM scores

context dependence

"So since I cross B gives you the maximum magnitude of force, rotating it 30°... so I'm just drawing a diagram... I think it's the sine of 30°."



context dependence

"I'm just trying to visualize what that would look like, so that's – so this is an xy plane, z is coming out of the page, and rotate..."

context dependence

"So I think the result is the same because... the angle between the magnetic field, which is pointing in the x direction, and the wire, which is pointing up in the y direction, is still the same. So... I think that's the same answer as [before]."

context dependence

low MRT score

high MRT score

is mental imagery required?

Kelly

HP student
low MRT score
low CSEM scores

is mental imagery required?

“So the magnitude is going to change by the function of the angle between the wire and the magnetic field. It’s a cross-product… But now, they’re 30 degrees apart, right? Yeah. So I think the magnitude is going to be $I_o B$… sine 30 degrees.

is mental imagery required?

"So it's gonna be a maximum when the angle between them is 90…when's it gonna be 0?"

is mental imagery required?

"And here, that can't be right... there's not gonna be a force when they're parallel.

But if I'm thinking about B coming along the x-axis, I must be thinking about it the wrong way. Because they're always gonna be perpendicular."

is mental imagery required?

"Here's my B-field, here's my wire. So it's perpendicular. Perpendicular here, perpendicular here. So I'm rotating it – I'm wondering whether the force changes at all."

background	quantitative	qualitative

background **quantitative** **qualitative**

low, but significant correlations in Physical Science

no significant correlations in Honors Physics

tests of mental rotation ability may not capture what students can do on physics problems

there are other tools/strategies students can use to solve physics problems

"The male advantage in physics may be partly due to the spatial and visualization demands common to physics problems."

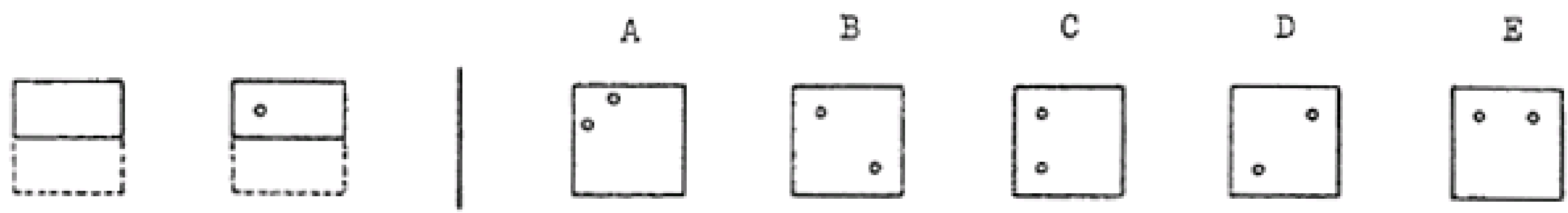
Taasoobshirazi & Carr, 2008

Thanks!

Jason Dowd
Eugenia Etkina
Joe Redish
Eric Mazur
Mazur Group

spatial visualization

Paper Folding Test



Ekstrom, et al., 1976

students used lots of different tools

physics tools

math calculation tools

representations

other tools

physics concepts
right-hand rule
extreme values

students used lots of different tools

physics tools

math calculation tools

representations

other tools

students used lots of different tools

physics tools

math calculation tools

representations

- equations
- graphs
- pictures
- physical objects
- mental imagery

other tools

students used lots of different tools

physics tools

math calculation tools

representations

other tools

other problems
expectations
metacognition