Intuitive interference: Insights from behavioral, brain imaging, and intervention studies

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IMBES 2014, November 6th 2014, FW, TX

Introduction

It is well known that many students encounter difficulties in science and mathematics (e.g., TIMSS or PISA).

Numerous studies have been carried out to understand students' conceptions and ways of thinking.

The underlying assumption is that understanding students' reasoning in science and mathematics will improve teaching in these domains.

Introduction

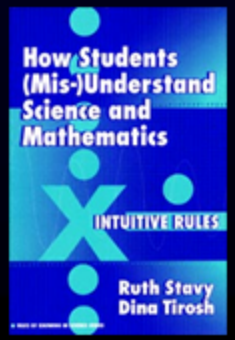
In our view, students' difficulties may stem from interference of a salient irrelevant variable with formal/logical reasoning (Stavy & Tirosh, 2000).

It appears that certain variables of the problem are so salient that they are automatically processed and thus may interfere with correct reasoning.

This interference is reflected in students' erroneous responses, even when they have the knowledge and skills to solve these tasks correctly.

Stavy & Tirosh (2000).

How students (mis-)understand science and mathematics.



Examples of interfering salient variables

Geometry:

Students were presented with these two shapes and were asked to compare their perimeters.

rectangle

polygon

About 70% of students in Grades 7-9 incorrectly answered that the *perimeter* of the rectangle was larger because “it is larger” or “it has larger area” (Stavy & Tirosh, 2000)

The interfering variable is the *area* of the shapes.

Interference of a salient irrelevant variable

In general, when students are presented with two objects that differ in a salient quantity A (automatically, intuitively processed) and are asked to compare the objects with respect to another quantity B, they tend to respond according to the salient quantity A:

larger A -- larger B

In daily life such intuitive responses are often correct.

However, in many cases these responses contradict normative reasoning in science and mathematics, leading to incorrect judgments.

Our research

Our research goal is to unveil the reasoning processes associated with intuitive interference.

To do that we recently started employing cognitive psychology and neuroscience methodologies.

We believe that employing these methodologies can contribute to a better understanding of students' difficulties and reasoning processes, and hence to improvements in science and mathematics education.

Our research

As a model system, we focus on a task in geometry:

comparison of perimeters task

This task allows manipulations of the variables and design of task conditions with or without interference.

Comparison of perimeters: Reaction time

Students were asked to compare the perimeters of pairs of shapes. In some of the pairs there was no interference of the salient variable (congruent condition) and in others there was interference of the salient variable (incongruent conditions):

Congruent -- no intuitive interference as one shape has a larger area and a longer perimeter than the other shape.

Incongruent -- there is intuitive interference as one shape has a larger area, but not a longer perimeter.

Incongruent inverse: One shape has a larger area but a shorter perimeter.

Incongruent equal: One shape has a larger area but the perimeters are equal.

Reaction time study

Forty-seven 8th graders compared perimeters and areas of congruent and incongruent problems.

Accuracy of responses and reaction time were recorded.

Zilber, 2004, MA thesis

Reaction time study: Results

Comparison of perimeters

Condition	% Correct	RT in sec of correct responses
Congruent	93	1.6
Incongruent inverse	56	2.5
Incongruent equal	23	2.9

Accuracy was significantly higher and reaction time was significantly shorter in congruent than in incongruent comparison of perimeter conditions.

In comparison of areas, accuracy was high and similar in all conditions (92%) and reaction time was very short and similar in all conditions (1.1 sec).

Reaction time study: Conclusions

In many comparison of perimeters studies we consistently find that among schoolchildren, adolescents, and adults the congruent condition yields significantly higher accuracy and significantly shorter reaction time than do the incongruent conditions.

Comparison of areas yields a very high success rate and a very short reaction time in all conditions, supporting our conjecture that area is indeed the salient variable in our task.

It seems that students cannot avoid comparing the salient variable *area* when comparing perimeters.

Babai, Levyadun, Stavy, & Tirosh (2006). *International Journal of Mathematical Education in Science and Technology*, *37*, 913-924.
Stavy & Babai (2008). *Mind, Brain, and Education*, *2*, 170-176.

Reaction time study: Conclusions

We suggested that in the comparison of perimeter task:

When the processing of *area* and *perimeter* result in the same conclusion (congruent trials, in line with intuitive reasoning) this is the end of the processing.

If, however, the outcome is two different conclusions (one based on intuitive processing of *area* and the other on appropriate processing of *perimeter*), the created conflict must be resolved, either by overcoming the intuitive interference, a more complex, demanding and time-consuming process, or by giving an incorrect response.

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Brain imaging study (fMRI)

14 adult participants - an event-related fMRI study

We used congruent and incongruent equal conditions.

Congruent -- no interference **Incongruent -- interference of *area***

Participants were asked to compare perimeters.
Accuracy of responses, reaction time, and brain activity were recorded.

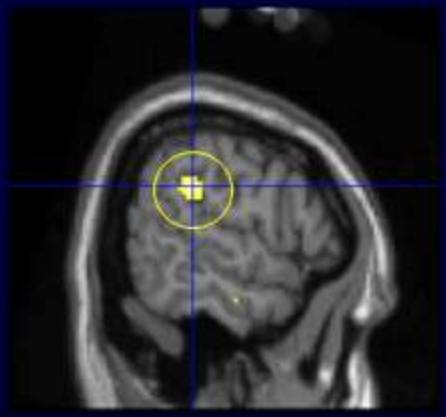
Stavy et al. (2006). *Brain Research, 1073-1074*, 383-388.
Stavy & Babai (2010). *ZDM-The International Journal on Mathematics Education, 42*, 621-633.

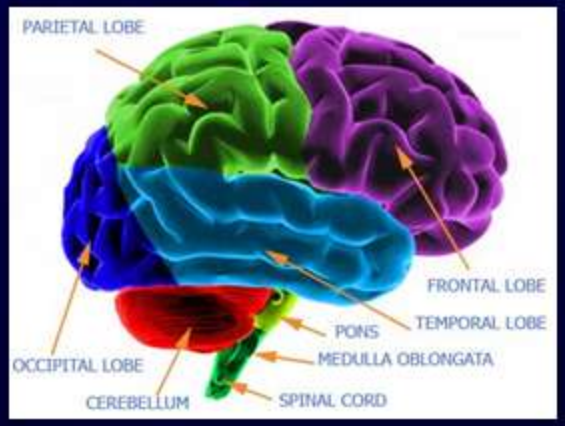
Brain imaging study: Behavioral results

	% Correct	RT in sec of correct responses
Congruent	92	1.2
Incongruent equal	65	1.4

As expected, significant effect of congruity was found for accuracy as well as for reaction time of correct responses.

Brain activity of congruent vs. incongruent (correct responses)

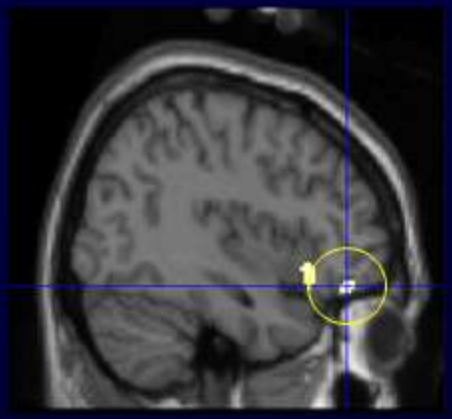


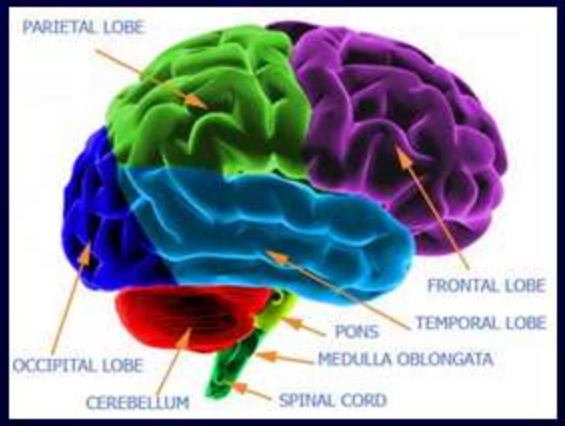


Enhanced activity was observed in bilateral parietal areas known to be involved in perceptual and spatial processing, including processing related to comparison of quantities.

This activation is likely to reflect the automatic processing of the intuitive variable *area*.

Brain activity of incongruent vs. congruent (correct responses)





Enhanced activity was observed in bilateral prefrontal areas in association with overcoming the intuitive interference in incongruent trials.

These brain areas are known for their executive inhibitory control over other posterior brain regions during processing of different cognitive functions.

This activity is likely to reflect the inhibition of the processing of the irrelevant variable *area*.

Brain imaging study: Conclusions

The study showed that different brain areas are activated when there is no interference and when overcoming the interference.

Although participants are not aware of the problem type (congruent or incongruent):

During responses to congruent problems, parietal regions related to automatic comparison of quantities are activated.

During correct responses to incongruent problems, prefrontal brain areas related to executive inhibitory control are activated.

Stavy et al. (2006). *Brain Research*, *1073-1074*, 383-388.
Stavy & Babai (2010). *ZDM-The International Journal on Mathematics Education*, *42*, 621-633.

Brain imaging study: Conclusions

The findings suggest that control mechanisms play an important role in overcoming intuitive interference.

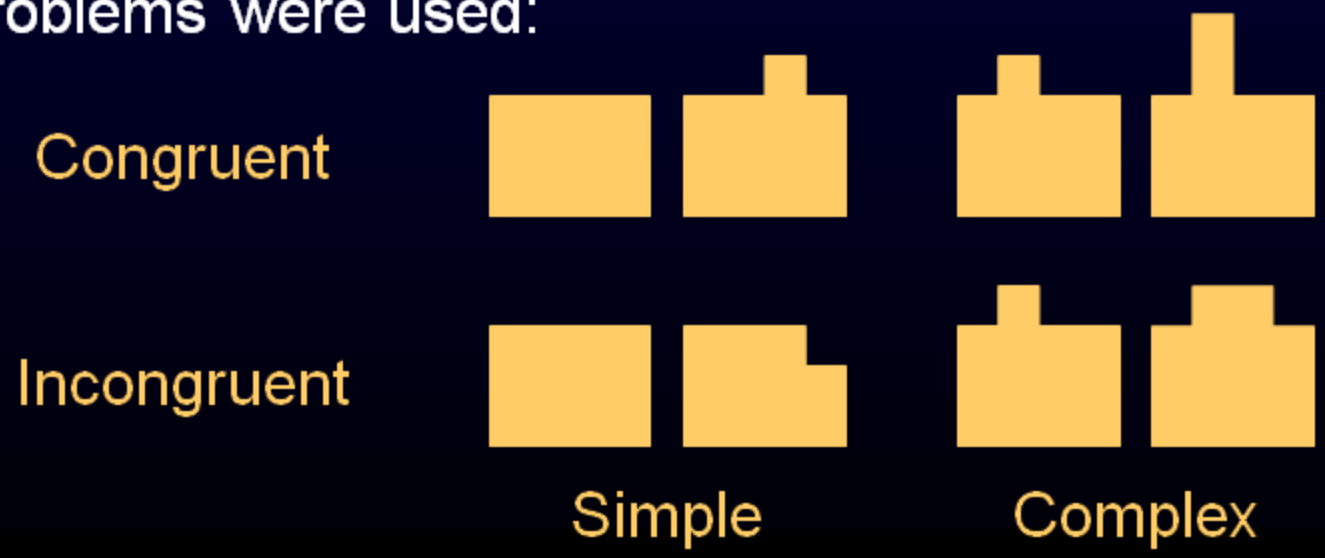
In order to better understand the involvement of such mechanisms, we conducted a tDCS study.

The study was carried out in collaboration with Stefan Elmer & Lutz Jäncke, Department of Neuropsychology, University of Zurich

tDCS study

Twenty-seven adult participants performed the comparison of perimeters task.
Later they performed the task again after anodic stimulation (1 mA for 9 min) in the right prefrontal region [experimental (*n*=17)], or after sham treatment [control (*n*=10)].
The groups were similar in their short-term memory and visuospatial abilities.

Four types of problems were used:



tDCS study: Conclusions

These preliminary findings suggest that stimulating the right prefrontal cortex improves participants' ability to overcome intuitive interference, possibly due to activation of inhibitory control mechanisms and/or other relevant cognitive functions.

Warning intervention

The brain imaging study (fMRI) showed that when participants are correctly responding to incongruent problems, prefrontal brain regions related to inhibitory control mechanisms are activated.

Moreover, stimulating these areas (by tDCS) improved participants' ability to overcome intuitive interference.

Babai, Shalev, Stavy, Submitted revised

Warning intervention

In the intervention study we examined whether activation of inhibitory control mechanisms would improve students' performance.

We activated students' control mechanisms by providing an explicit task-specific warning on the possible interference of the variable *area* when comparing perimeters.

Babai, Shalev, Stavy, Submitted revised

Warning intervention

Before the beginning of the comparison of perimeters test, students in the warning group were presented with the following warning slide:

Pay attention: you are requested to compare the perimeters and not the areas of the two shapes.

There is a tendency to compare the areas of the shapes instead of their perimeters.

This tendency may lead to errors.

Try to overcome this tendency.

Warning intervention

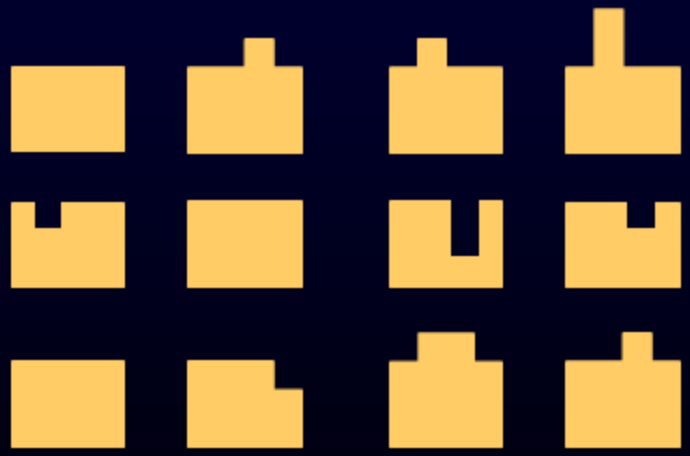
Eighty-four sixth graders were randomly divided into warning (n=44) and control (n=40) groups.
They were asked to compare perimeters with/without warning.

We used congruent, incongruent inverse, and incongruent equal conditions.

Congruent

Incongruent inverse

Incongruent equal



Accuracy of responses and reaction time were recorded.

Results: Warning intervention

Congruity	Warning group		Control group	
	% Correct	RT in sec	% Correct	RT in sec
Congruent	**86**	1.9	**90**	1.7
Incongruent inverse	**59**	2.3	**35**	1.9
Incongruent equal	**33**	2.4	**19**	1.9

Accuracy in the warning group was significantly higher than in the control group in both incongruent conditions.
Reaction time in the warning group was significantly longer than that in the control group in all conditions.

Warning intervention: Conclusions

The findings show that this short, focused, and minimal warning intervention significantly improved students' accuracy of responses for both incongruent conditions.

The explicit warning regarding the trap in the task appears to activate inhibitory control mechanisms and thus helps students overcome the interference.

The effect of this inhibition is general to all comparison of perimeter conditions, as it increases reaction time in all conditions, even when it is not needed (congruent condition).

General discussion and conclusions

We showed that irrelevant salient variables strongly interfere with formal/logical reasoning, leading to difficulties in science and mathematics.

The interference is robust, leading to a very high percentage of errors.

It is evident in different content domains and across different age groups, including adults.

General discussion and conclusions

Cognitive psychology and neuroscience methodologies reveal that executive control mechanisms have a key role in overcoming this intuitive interference.

These executive control mechanisms probably inhibit the processing of the salient irrelevant variable and thus prevents its effect.

Intervention that strengthen executive control mechanisms significantly improved students' performance.

Educational significance

Our findings indicate the importance of control mechanisms in reasoning associated with overcoming intuitive interference in science and mathematics.

They point to the possibility of improving students' performance by simple interventions aimed at raising their awareness of the possible interference of irrelevant salient variables, rather than, or in addition to, supporting relevant content knowledge, the traditional practice in schools.

Educational significance

Such research-based simple interventions appear to require only teachers' knowledge and awareness.

Knowledge and awareness about the intuitive interference could also aid educators in making rational decisions about the nature of tasks and examples that they use.

Educational significance

We also demonstrate that applying cognitive psychology and neuroscience methodologies in science and mathematics education research can contribute to science and mathematics education and to cognitive neuroscience both theoretically and practically.

We believe that construction of direct links between brain data and educational practice is important for both fields.

This requires collaboration among educators, educational researchers and cognitive neuroscientists.

Thank you for your attention

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