IS METACOGNITION DOMAIN-SPECIFIC OR DOMAIN-GENERAL?

INSIGHT FROM STUDIES IN MEMORY AND ARITHMETIC

MARIE GEURTEN – 12/06/2018
Cognitive skills

- Knowledge
- Expectation
- Theory
- Representation of the on-going activity

Metacognitive skills

Control

Monitoring

Cognitive skills

- Reading
- Reasoning
- Encoding
- Computing
- Categorizing
• To date, very few studies have explored whether metacognitive processes are involved in how participants select and execute strategies.

• Being able to accurately decide whether a selected strategy is the best to solve a problem allows:
  • To switch from a poorer to a better strategy, possibly improving cognitive performance
  • To learn what strategy is useful in specific contexts
  ➔ Investing limited resources in areas that yield optimal return
BACKGROUND

• Examining whether people can make accurate metacognitive judgments on strategy selection
• Determining whether there is age-related differences in the accuracy of these judgments
  • Inconsistent results in previous studies
BACKGROUND

The accuracy at the metacognitive level depends on the accuracy at the cognitive level.

Examining age-related differences in metacognitive abilities in a cognitive domain where older adults are not put at a disadvantage as compared to young adults.
AIMS

• Arithmetic is a domain where older and young adults have similar performances
  • Determining whether people can accurately judge whether they had selected the best strategy to solve an arithmetic problem
  • Examining whether there is age-related differences in the accuracy of metacognitive judgments for strategy selection
  • Exploring whether (a) the accuracy of metacognitive judgments and (b) age-related differences in the accuracy of metacognitive judgments depend on task characteristics (i.e., amount of cognitive resources required to solve the task)

METHODS

Participants

• 37 young adults (29 females; mean age = 21.14 years; age range = 18-29)
• 29 older adults (18 females; mean age = 72.99 years; age range = 64-88)

Stimuli

• 32 multiplication problems (a x b) – 16 homogeneous (21 x 32) VS. 16 heterogeneous (49 x 24) problems
• Half of the problems were better solved by rounding both operands up (39 x 48) – rounding-up problems
• Half of the problems were better solved by rounding both operands down (21 x 32) – rounding-down problems
• Participants had to select the best strategy to solve each problem between the two available strategies

METHODS

**SELECTION-ONLY TASK**

- 23 x 56
- 1 - Rounding-Down
- 2 - Rounding-Up
- Confidence? 1 - 2 - 3 - 4
- 58 x 19
- 3 sec.
- Unlimited

**SELECTION-EXECUTION TASK**

- 23 x 56
- 1 - Rounding Down
- 2 - Rounding Up
- 20 x 50 = 1000
- Confidence 1 - 2 - 3 - 4
- 58 x 19
- 3 sec.
- Unlimited

MEASURES

• Measures of metacognitive accuracy
  • A’ROC = A non-parametric measure from signal detection theory which plots the concordances (i.e., a higher judgment on correct better strategy selection or a lower judgment on incorrect better strategy selection) against the discordances (i.e., a higher judgment on incorrect better strategy selection or a lower judgment on correct better strategy selection)
  • An A’ROC of 0.5 (or lower) indicated no metacognitive discrimination between better or poorer strategy selections

# RESULTS

## ABOVE CHANCE METACOGNITIVE ACCURACY

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>t</th>
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</thead>
<tbody>
<tr>
<td><strong>Selection-Execution Task</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young adults (N=37)</td>
<td>.60 (.02)</td>
<td>6.23**</td>
</tr>
<tr>
<td>Older adults (N=29)</td>
<td>.60 (.02)</td>
<td>3.66*</td>
</tr>
<tr>
<td>All (N=66)</td>
<td>.60 (.02)</td>
<td>6.71**</td>
</tr>
<tr>
<td><strong>Selection-Only Task</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young adults (N=37)</td>
<td>.63 (.02)</td>
<td>6.46**</td>
</tr>
<tr>
<td>Older adults (N=29)</td>
<td>.72 (.02)</td>
<td>8.52**</td>
</tr>
<tr>
<td>All (N=66)</td>
<td>.67 (.02)</td>
<td>10.03**</td>
</tr>
</tbody>
</table>

*p < .05; **p < .001

RESULTS
AGE-RELATED AND TASK-RELATED DIFFERENCES IN METACOGNITIVE ACCURACY

SELECTION-ONLY TASK

SELECTION-EXECUTION TASK

CONCLUSION

• Participants made accurate (above chance) metacognitive judgments for strategy selection

• Participants’ age and tasks’ characteristics affect the accuracy of these judgments

  • Only the accuracy of older adults judgments is reduced when judgments are made on the more resource-consuming tasks (selection-execution task)
  ➔ Limited resources in older adults

  • Older adults made more accurate judgments than young adults on the less resource-consuming task (selection only task)
  ➔ Better metacognitive knowledge

Cognitive skills

- Reading
- Reasoning
- Encoding
- Computing
- Categorizing

Metacognitive skills

- Knowledge
- Expectation
- Theory

Representation of the on-going activity

Control

Monitoring

Requires resources processing
Results of our study focusing on age-related differences in metacognition for arithmetic problem solving are quite at odds with the results of studies conducted in the memory domain.

- Differences at the cognitive level?
- Metacognition is domain-specific?
**BACKGROUND**

- In adults, the assumption that metacognition is domain-general is supported by two types of evidence:
  - Behavioral studies: measures of metacognitive sensitivity correlated across unrelated cognitive tasks
  - Imaging data: metacognitive abilities for different types of tasks partially depend on common neural structures

- In children, available data sets suggest that metacognition could be domain-specific in early development
  - Vo et al. (2014): 5- to 8-year-olds’ metacognition for a numerical discrimination task was unrelated to their metacognition for an emotion discrimination task

- Generalization of metacognitive abilities across domains as children mature?
The primary goal of this study was to:

- Document the developmental course of domain-generality/specificity of metacognition for strategy selection in both the arithmetic and the memory domains

  ➔ monitoring the accuracy of strategy selection could involve more global metacognitive skills than monitoring cognitive performance, increasing our chances of showing a generalization of metacognitive processes
METHODS

Participants

• 24 typically developing children aged 8-9 years (13 girls; mean age = 9.25 years; SD = 0.48)
• 24 typically developing children aged 10-11 years (13 girls; mean age = 11.19 years; SD = 0.43)
• 24 typically developing children aged 12-13 years (16 girls; mean age = 12.79 years; SD = 0.60)

Stimuli

• 32 addition problems – 16 rounding-down (21 + 32) VS. 16 rounding-up (49 + 26) problems
• 32 triads of words – 16 phonologic (Bat – Cat – Hat) VS. 16 semantic (Dog – Frog – Bee) triads
• Participants had to select the best strategy to solve each problem between the two available strategies

METHODS

ARITHMETIC TASK

21 + 56
1 - Rounding Down
2 - Rounding Up
RCJ

MEMORY TASK

Dog – Frog – Bee
1 - Semantic
2 - Phonologic
RCJ

Strategy selection

Rounding Down 21 + 56 ?

Strategy execution

Countdown task (10 sec.)

MEASURES

• We computed three measures of metacognition for each strategy selection tasks: \( \phi \), \( \gamma \), and \( A'_{ROC} \)
  • They all represent the relation between selection accuracy and metacognitive judgments
  • The \( \phi \) and \( \gamma \) coefficients are popular measures of metacognitive sensitivity and provide a common scale to compare our results to those of previous studies examining the domain-generality of metacognition
  • The \( A'_{ROC} \) index provides a bias-free measure of metacognition

## RESULTS

**ABOVE CHANCE METACOGNITIVE ACCURACY**

<table>
<thead>
<tr>
<th></th>
<th>$\Phi$</th>
<th>$\gamma$</th>
<th>$A'_{ROC}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$t$</td>
<td>$M$</td>
</tr>
<tr>
<td><strong>Arithmetic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-9 year olds</td>
<td>.25</td>
<td>4.33**</td>
<td>.35</td>
</tr>
<tr>
<td>10-11 year olds</td>
<td>.23</td>
<td>6.48**</td>
<td>.28</td>
</tr>
<tr>
<td>12-13 year olds</td>
<td>.39</td>
<td>7.23**</td>
<td>.45</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-9 year olds</td>
<td>.24</td>
<td>5.24**</td>
<td>.39</td>
</tr>
<tr>
<td>10-11 year olds</td>
<td>.31</td>
<td>5.33**</td>
<td>.46</td>
</tr>
<tr>
<td>12-13 year olds</td>
<td>.37</td>
<td>8.48**</td>
<td>.42</td>
</tr>
</tbody>
</table>

*Note. Comparisons against chance: i.e., 0 for $\phi$ and $\gamma$; 0.5 for Area under the Receiver-Operating-Characteristic (ROC) curve ($A'_{ROC}$).*

*$p<.05$; **$p<.001$*

## RESULTS

**DOMAIN-SPECIFICITY/-GENERALITY OF METACOGNITION**

### 8-9 years

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arithmetic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phi</td>
<td>-.76</td>
<td>.62</td>
</tr>
<tr>
<td>Gamma</td>
<td>-.70</td>
<td>.55</td>
</tr>
<tr>
<td>$A'_{ROC}$</td>
<td>-.78</td>
<td>.49</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phi</td>
<td>-.58</td>
<td>-.68</td>
</tr>
<tr>
<td>Gamma</td>
<td>-.57</td>
<td>-.77</td>
</tr>
<tr>
<td>$A'_{ROC}$</td>
<td>-.53</td>
<td>-.68</td>
</tr>
<tr>
<td>% explained variance</td>
<td>53%</td>
<td>37%</td>
</tr>
</tbody>
</table>

$R_{Canon} = .53$

$\chi^2(9) = 9.11$  $p = .43$
## RESULTS

### DOMAIN-SPECIFICITY / -GENERALITY OF METACOGNITION

<table>
<thead>
<tr>
<th>10-11 years</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phi</td>
<td>-.90</td>
<td>.17</td>
</tr>
<tr>
<td>Gamma</td>
<td>-.92</td>
<td>.14</td>
</tr>
<tr>
<td>(A'_{ROC})</td>
<td>-.71</td>
<td>.47</td>
</tr>
<tr>
<td>Memory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phi</td>
<td>-.70</td>
<td>-.61</td>
</tr>
<tr>
<td>Gamma</td>
<td>-.64</td>
<td>-.62</td>
</tr>
<tr>
<td>(A'_{ROC})</td>
<td>-.87</td>
<td>.24</td>
</tr>
<tr>
<td>% explained variance</td>
<td>61%</td>
<td>20%</td>
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</table>

\[
R_{Canon} = .85 \\
\chi^2(9) = 31.92 \ p < .001
\]
# RESULTS

## DOMAIN-SPECIFICITY/-GENERALITY OF METACOGNITION

<table>
<thead>
<tr>
<th>12-13 years</th>
<th>Factor 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arithmetic</strong></td>
<td></td>
</tr>
<tr>
<td>Phi</td>
<td>-.91</td>
</tr>
<tr>
<td>Gamma</td>
<td>-.87</td>
</tr>
<tr>
<td>$A'_{ROC}$</td>
<td>-.95</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td></td>
</tr>
<tr>
<td>Phi</td>
<td>-.94</td>
</tr>
<tr>
<td>Gamma</td>
<td>-.83</td>
</tr>
<tr>
<td>$A'_{ROC}$</td>
<td>-.84</td>
</tr>
<tr>
<td>% explained variance</td>
<td>80%</td>
</tr>
</tbody>
</table>

$R_{Canon} = .86$

$\chi^2(9) = 31.96 \ p < .001$
CONCLUSION

• Our results indicated a gradual shift toward domain-general metacognition in children aged between 8 and 13

   ➔ Metacognition is first domain-specific, and then seems to generalize across domains as children mature

• Clinical perspective
  • Major impact on metacognitive revalidation programs
  • If metacognition does not depend on domains, it implies that metacognitive interventions in one domain could have positive effects across all domains.
GENERALIZATION. BUT OF WHAT?
CONCLUSION

• According to the dual-process framework of metacognition (Koriat, 2007), two mechanisms come into play when people have to distinguish what they know from what they do not know:

  • Experience-based judgments = fast and automatic inferences made from a variety of cues (e.g., processing fluency) that are heuristically used to guide decisions.
    ➔ Based on cues that reside from the immediate feedback from the task
    ➔ Task-dependent
    ➔ Difficult to generalize across domains.

  • Information-based judgments = conscious and deliberate inferences, in which various pieces of information retrieved from memory are consulted and weighted in order to reach an educated judgment.
    ➔ Conscious and effortful processes
    ➔ More likely to be generalized to other domains
Cognitive skills

- Reading
- Reasoning
- Encoding
- Computing
- Categorizing

Metacognitive skills

- Knowledge Expectation Theory
- Representation of the on-going activity

Control

Monitoring

- Implicit
- Specific
- Developmental stability
- Explicit
- General
- Developmental change

Developmental change

Explicit

General

Developmental stability

Specific

Implicit

Knowledge Expectation Theory

Representations of the on-going activity

Control
Cognitive skills

Representation of the on-going activity

Knowledge Expectation Theory

Metacognitive skills

Control

Monitoring

Specific

↑ in childhood = in aging

↗ in childhood

↘ in aging

General

Reading

Reasoning

Encoding

Computing

Categorizing

= in aging
THANKS FOR YOUR ATTENTION
Any questions ?