On costs of good intentions:

The detrimental effect of problem contextualisation on learning

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Complex Problem Solving

To study information processing, decision making, intelligence, knowledge acquisition, learning …

Complex, dynamic problems change as a result of the decisions made by the problem solver, as well as autonomously.

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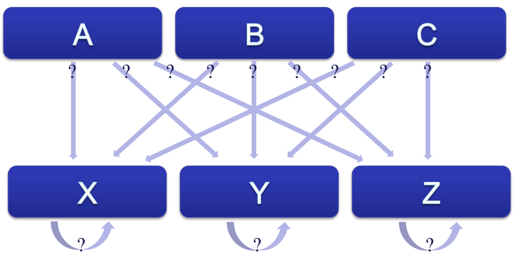

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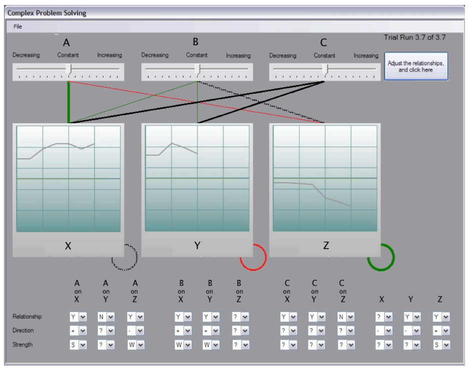

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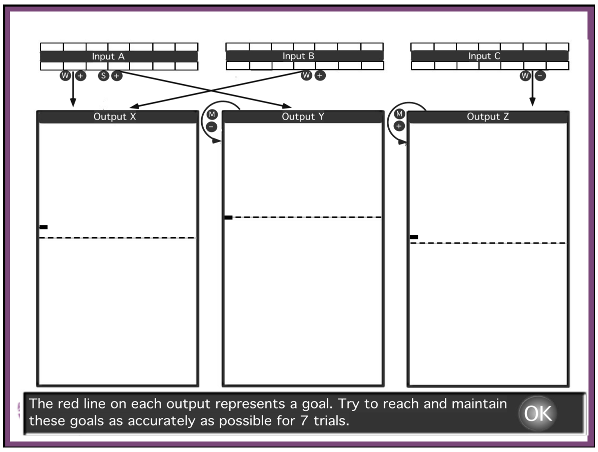
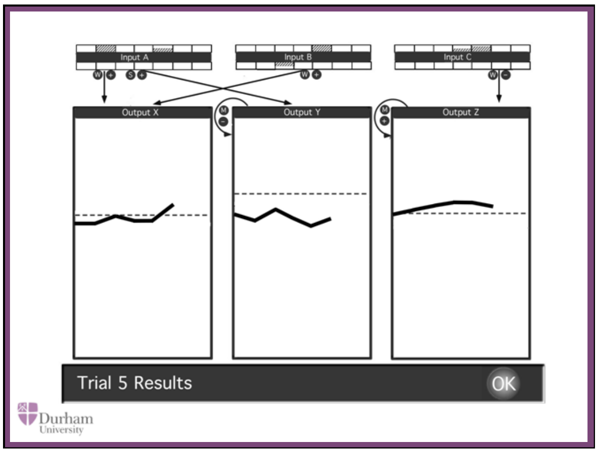
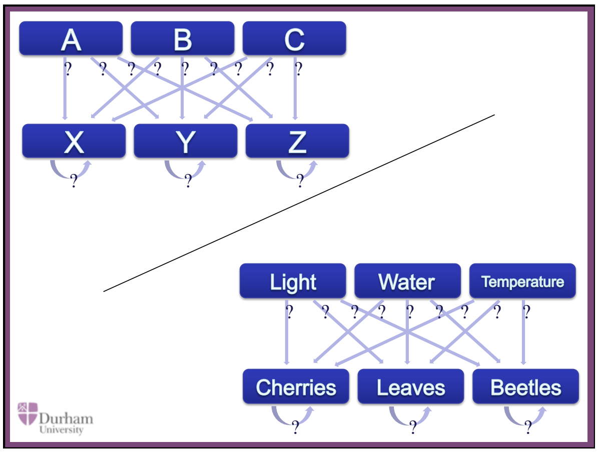
Learning Task

1. Acquire knowledge about the causal structure
   - Direct learning task
   - Rule induction
   - Systematic interaction / experimentation
2. Apply knowledge to control the system
   - Indirect learning task
   - Utilisation of rule knowledge acquired to reach and maintain set target values in output variables
   - Knowledge based and goal orientated interaction

Generic problem solving skill central to scientific enquiry: drawing causal inferences based on systematic experimentation







… in favour of the cherry tree?

- Common view held by educationalists, teachers, instructional designers …
- Goldstone & Sakamoto (2003): the use of variable labels referring to familiar contexts facilitates the understanding of abstract scientific concepts (see also Lazonder, Wilhelm & Hagemans, 2008; Lazonder, Wilhelm & Van Lieburg, 2009)
- Reference to prior knowledge helps generating hypotheses that can be tested
- Sense of familiarity is considered helpful

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… well, maybe not!

- Beckmann, 1994; Beckmann & Guthke, 1995; Burns & Vollmeyer, 2002;
- *Lazonder, Wilhelm & Hagemans, 2008*; Lazonder, Wilhelm & Van Lieburg, 2009**
- Poorer performance under "semantically meaningful" conditions

→ Semantic Effect

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Aim

Why is the acquisition of *new* knowledge inhibited by a "semantically meaningful" context?

Two explanatory mechanisms:

- Goal Adoption
  - despite instruction to explore problem solvers tend to adopt goals (i.e. self-defined optimisation of values in output variables)
- Presumptions
  - Semantic contexts induces sense of familiarity
  - Familiarity triggers assumptions
  - Testing of assumptions is cognitively more demanding than seeking for confirmation

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Design

N	Condition	Input	Output
21	abstract	A B C	X Y Z
20	concrete	Light Water Temperature	Cherries Leaves Beetles

Age: 18 – 48 (20, 5)
Sex: 72 % female

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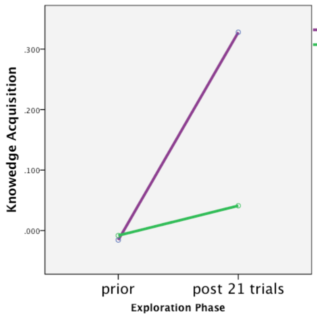
Results (Replication Semantic Effect)



Main effect *Knowledge Acquisition*: $F_{1,39} = 22.47$, $p < .01$, $\eta^2 = 0.37$

Main effect *Condition*: $F_{1,39} = 8.35$, $p < .01$, $\eta^2 = 0.17$

Interaction *Knowledge Acquisition X Condition*: $F_{1,39} = 12.62$, $p < .01$, $\eta^2 = 0.25$

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Design

N	Condition	Input	Output
21	abstract	A B C	X Y Z
19	abstract output	Light Water Temperature	X Y Z
20	concrete output	A B C	Cherries Leaves Beetles
20	concrete	Light Water Temperature	Cherries Leaves Beetles

Goal Adoption unlikely (abstract, abstract output)

Goal Adoption likely (concrete output, concrete)

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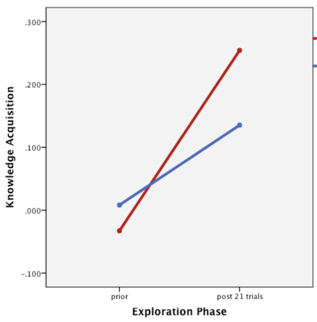
Results (Goal Adoption)



Main effect *Knowledge Acquisition*: $F_{1,78} = 39.72$, $p < .01$, $\eta^2 = 0.34$

Main effect *Condition*: $F_{1,78} = 1.15$, $p = .26$, $\eta^2 = 0.01$

Interaction *Knowledge Acquisition X Condition*: $F_{1,78} = 5.92$, $p = .02$, $\eta^2 = 0.07$

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Design

N	Condition	Input	Output
21	Abstract in & out	A B C	X Y Z
19	Abstract output	Light Water Temperature	X Y Z
20	Concrete output	A B C	Cherries Leaves Beetles
20	Concrete in & out	Light Water Temperature	Cherries Leaves Beetles

Semanticity

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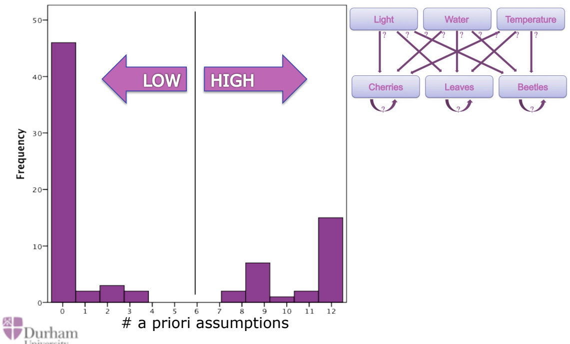
A priori Assumptions

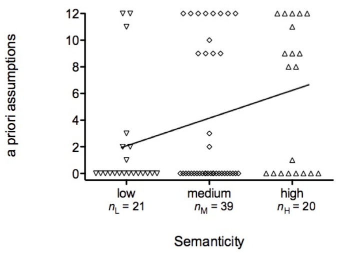


A priori Assumptions

	Conditions				
# assumptions	Abstract in & out	Concrete out	Abstract out	Concrete in & out	total
High (7 – 12)	3	5	8	11	27
Low (0 – 6)	18	15	11	9	53
	21	20	19	20	80

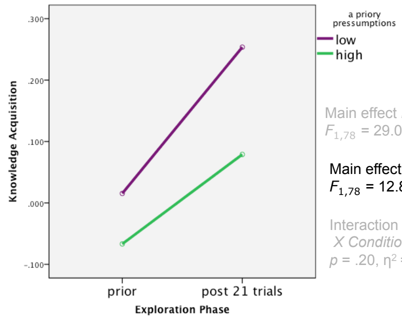
	Semanticity			
# assumptions	low	medium	high	total
High (7 – 12)	3	13	11	53
Low (0 – 6)	18	16	9	27
	21	39	20	80

	Semanticity			
# assumptions	low	medium	high	total
High (7 – 12)	3	13	11	53
Low (0 – 6)	18	16	9	27
	21	39	20	80



Concrete variable labels encourage formation of a priori assumptions about the structure of the system (Somer's D = .25, p = .003).

Results (Presumptions)



Main effect *Knowledge Acquisition*: $F_{1,78}$ = 29.00, p < .01, η^2 = 0.27

Main effect *Condition*: $F_{1,78}$ = 12.89, p < .001, η^2 = 0.14

Interaction *Knowledge Acquisition X Condition*: $F_{1,78}$ = 1.68, p = .20, η^2 = 0.02

Results Summary

Goal Adoption?
- contrast b/w conditions with concrete and abstract labels for outputs
- Knowledge acquisition: $F_{1,78} = 3.48$, $p = .07$, $\eta^2 = 0.04$
- System control: $F_{1,78} = 1.38$, $p = .24$, $\eta^2 = 0.02$

Presumptions?
- higher levels of semanticity increases significantly the likelihood to adopt high numbers of presumptions (Somer's $D = .25$, $p = .003$)
- contrast b/w high and low levels of a priori assumptions
- Knowledge acquisition: $F_{1,78} = 12.89$, $p < .01$, $\eta^2 = 0.14$
- System control: $F_{1,78} = 24.60$, $p < .01$, $\eta^2 = 0.24$

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Systematicity

- **only 4 interventions** are **necessary** to completely identify the underlying causal structure
  - Leave all inputs at zero → identifies autonomic changes
  - Vary one input at a time → identifies effects of inputs on each output
  - Combined: Vary One or None at A Time (***VONAT***) as indicator of **systematicity**
- **High levels of assumptions are associated with low levels of systematicity in exploration behaviour ($r_{pb} = -.53$, $p < .001$)**
- Low levels of systematicity is associated with low levels of accuracy of acquired knowledge ($r = .32$, $p = .002$).

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Summary

Semantic effect replicated

No support for goal adoption as explanatory mechanism

Support for presumption hypothesis:
- Concrete labels induce sense of familiarity
- Familiarity generates presumptions
- **Presumptions are less likely to be tested systematically**
- Unsystematic exploration behaviour impedes knowledge acquisition
- Poor knowledge acquisition leads to poor system control

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Implications

It is presumptuous to assume that hypotheses testing does occur "naturally" in learners.
- "instructional disobedience" or "instructional idealism"?
- challenge for constructivist, discovery, problem-based, experiential, and inquiry-based teaching
- guidance needed on how to (a) explicate assumptions and (b) test them systematically.

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