Knowledge diversity effect on cognitive load, disorientation and comprehension in a non-linear learning

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The problem

- Situation models are not linear
- Texts are linear
- But non-linear texts
  - don't improve situation models
  - decrease the quality of situation models
- Why? Because of high cognitive load implicated in reading non-linear texts, managing navigation
- Then: How can a non-linear text improve situation model ?
- Hypothesis:
  - When prior knowledge is high, based on large number of schemas, AND
  - When non-linear structure is compatible with prior knowledge structure

Issues

- Prior knowledge effects in non-linear learning (i.e. learning with hypertexts)
  - Low prior knowledge learners benefit from linear texts
  - High prior knowledge learners should benefit from hypertexts… (Spiro, Feltovich, Jacobson & Coulson, 1991 ; Spiro & Jehng, 1990 ; Jacobson, 1994 ; Jacobson & Levin, 1995) … but they don't !
  - Investigations on the role of prior knowledge
    - On cognitive load
    - On reading strategies
    - On comprehension

What is an hypertext?

- Different types of hypertext systems
  - Macro literacy systems
  - Problem exploration tools
  - Browsing systems
- Shared features
  - Information semantically interrelated (nodes and links)
  - Non-linear organization: the reader can choose his/her own path
  - Information is structured (e.g. network, hierarchical)

Hypertexts – cognitive cost

- No consensus about a positive effect on learning (Amadieu & Tricot, 2006 ; Chen & Rada, 1996 ; Dillon & Gabard, 1998 ; Shapiro & Niederhauser, 2004)
- Hypertext processing = high cognitive cost ?
  - Hypertexts would entail disorientation = cognitive overload which reduces performance (Conklin, 1987; Wright, 1991; Ahuja & Webster, 2001)
  - However, no consistent empirical evidences about disorientation manifestation and relationship with learning performance

Our conception about hypertext requirements

Processes involved in a comprehension task with non-linear structure

Extraneous Cognitive Load	Intrinsic Cognitive Load	Germane Cognitive Load
-Sequence decision: decision making and planning of the reading order - Establishing semantic relationships between concepts	- Processing to hold inter-related elements in WM	-Organising information in a coherent and interconnected representation - Integrating information in knowledge base

Learner's prior knowledge in learning with hypertext

- Prior domain knowledge: a main factor on learning with hypertext (Dillon & Gabbard, 1998 ; Shapiro & Niederhauser, 2004 ; Shlechter, 1993).

- It is usually argued that high prior knowledge learners:
  - Do not encounter disorientation and cognitive overload
  - Use flexible, elaborated and deep navigation strategies
  - Should benefit from "real" hypertexts (network structures)

Expertise reversal effect in learning with hypertext

- Expertise reversal effect (Kalyuga *et al*., 2003) in hypertext research field:
  - Guidance for novices = Linear or hierarchical structure of hypertext (low requirement for the navigation control and the construction of macrostructure)
  - No guidance for experts = Non-linear structure would support deep processing for experts. Experts benefit from low coherence of texts (McNamara et al. 1996) or reading path (Salmeron et al., 2005).

No positive effect of non-linear structure for experts

- No effect of hypertext structure for experts
  Antonietti, et al. (2001), Calisir & Gurel (2003), Lee et Lee (1991), Potelle & Rouet (2003), Recker & Pirolli (1995), Shin et al. (1994).

- Our previous investigations failed to show benefits for high prior knowledge learners with a network conceptual map while low prior knowledge learners benefited from a hierarchical map

Effect of Knowledge Structure : Knowledge diversity

- Experts' cognitive structure
  - Experts' knowledge are organized around deep principles of a domain (Chi, Feltovich, & Glaser, 1981; Dee-Lucas & Larkin, 1988) : abstract relational schemas
  - Abstract schemas supports inferences, the elaboration of new information and retrieval from memory (Glaser, 1990)
- Effect of the knowledge diversity
  - Having only one type of experience may generate beliefs ill-adapted for a new situation (Briggs, 1988), contrary to a diversity of experiences which favours the construction of abstract schemas (Briggs, 1990)
  - Comparing different cases enhance transfer performance, rather than studying cases separately (Gentner *et al*, 2003) or studying only one case (Gick & Holyoak, 1983; Paas & van Merriënboer, 1994)

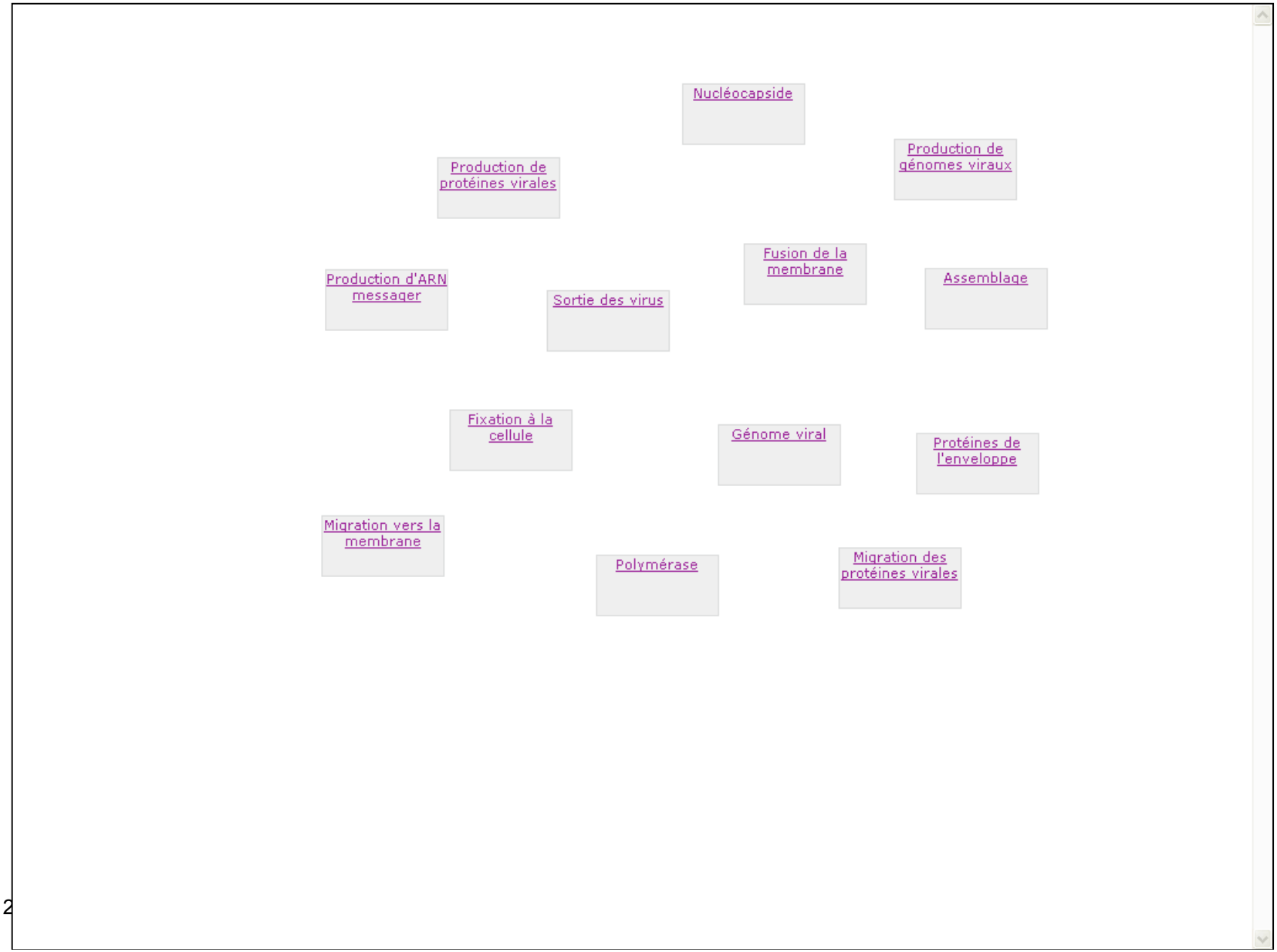
Assumptions

- A network could be not fitted to knowledge: Providing a conceptual map modifiable by the learners should favor higher cognitive engagement allowed (use of the schema structure to organize concepts).
- Domain knowledge diversity provided deeper and more abstract schemas (= cognitive resources)
- Knowledge diversity would support a deep comprehension of information organized in a non-linear electronic document
  - decrease mental effort and disorientation (intrinsic and extraneous cognitive load)
  - favor the organization of the reading sequence of nodes according knowledge structures
  - improve comprehension (conceptual knowledge: relationships between nodes)

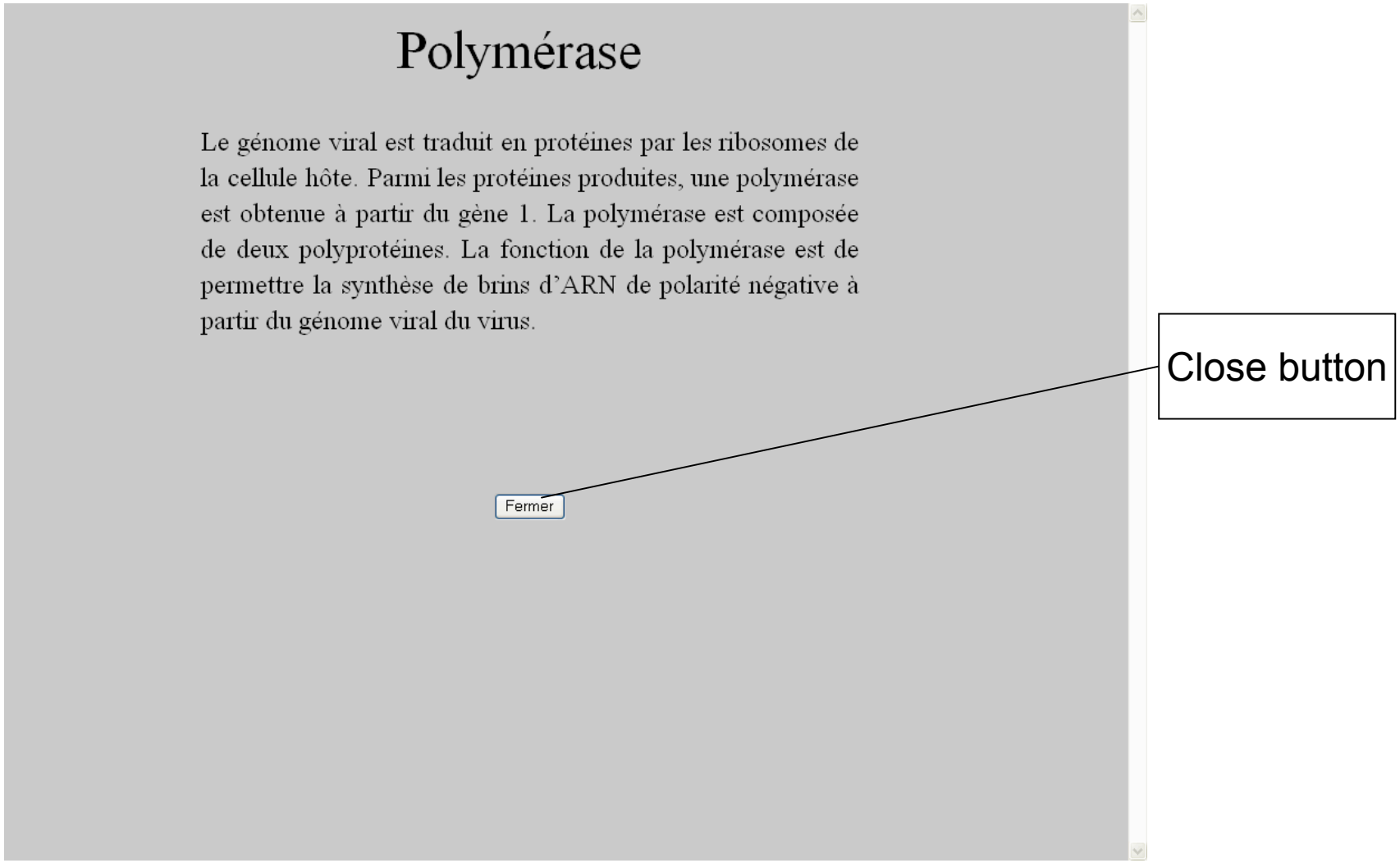
Method

- Domain: virology (multiplication cycles of viruses)
- Participants
  - 14 advanced learners: master students in immunology
  - Knowledge diversity: global score at 40 MCQ (4 by virus type) + number of known viruses self-reported by the participants
- Learning material
  - Content: the multiplication cycle of a specific virus (Coronavirus)
  - Interactive conceptual map: display of 13 concepts randomly organized on screen.
  - Learning task: comprehension/learning task (15 min) - manipulating concepts spatially and opening the concept to access information.

Instruction material: conceptual map



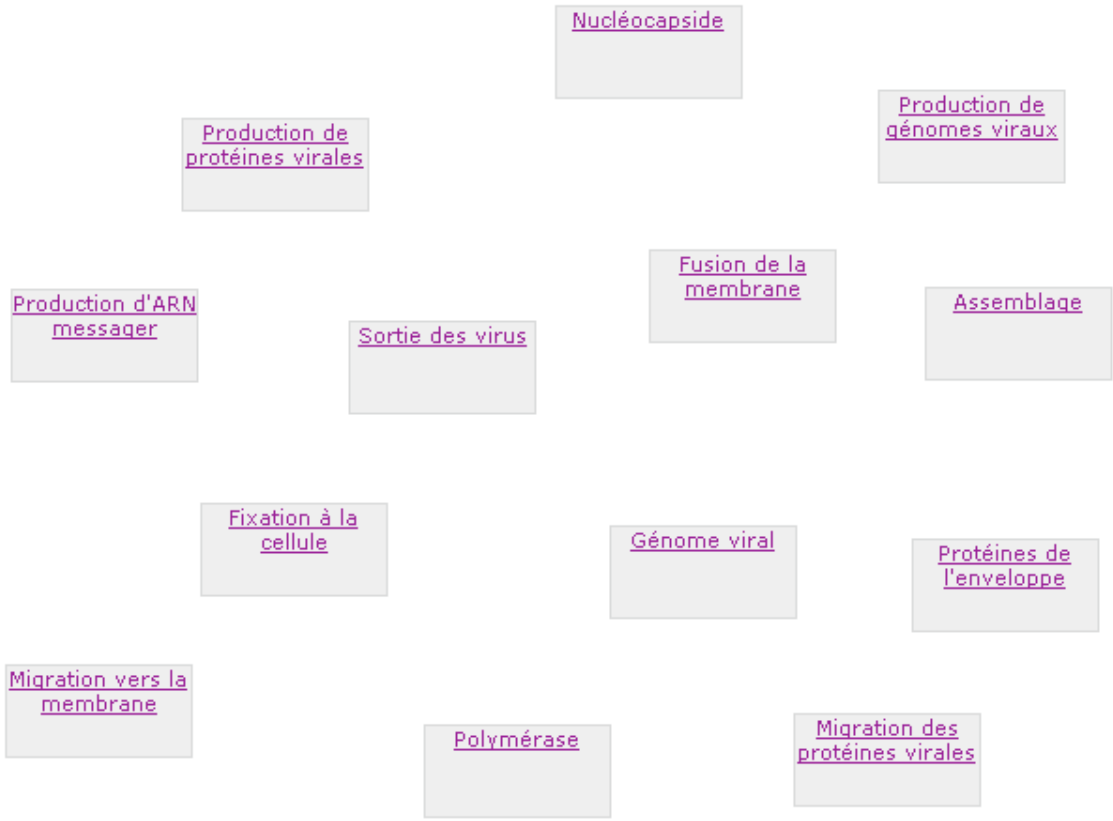
Instruction material: example of a node

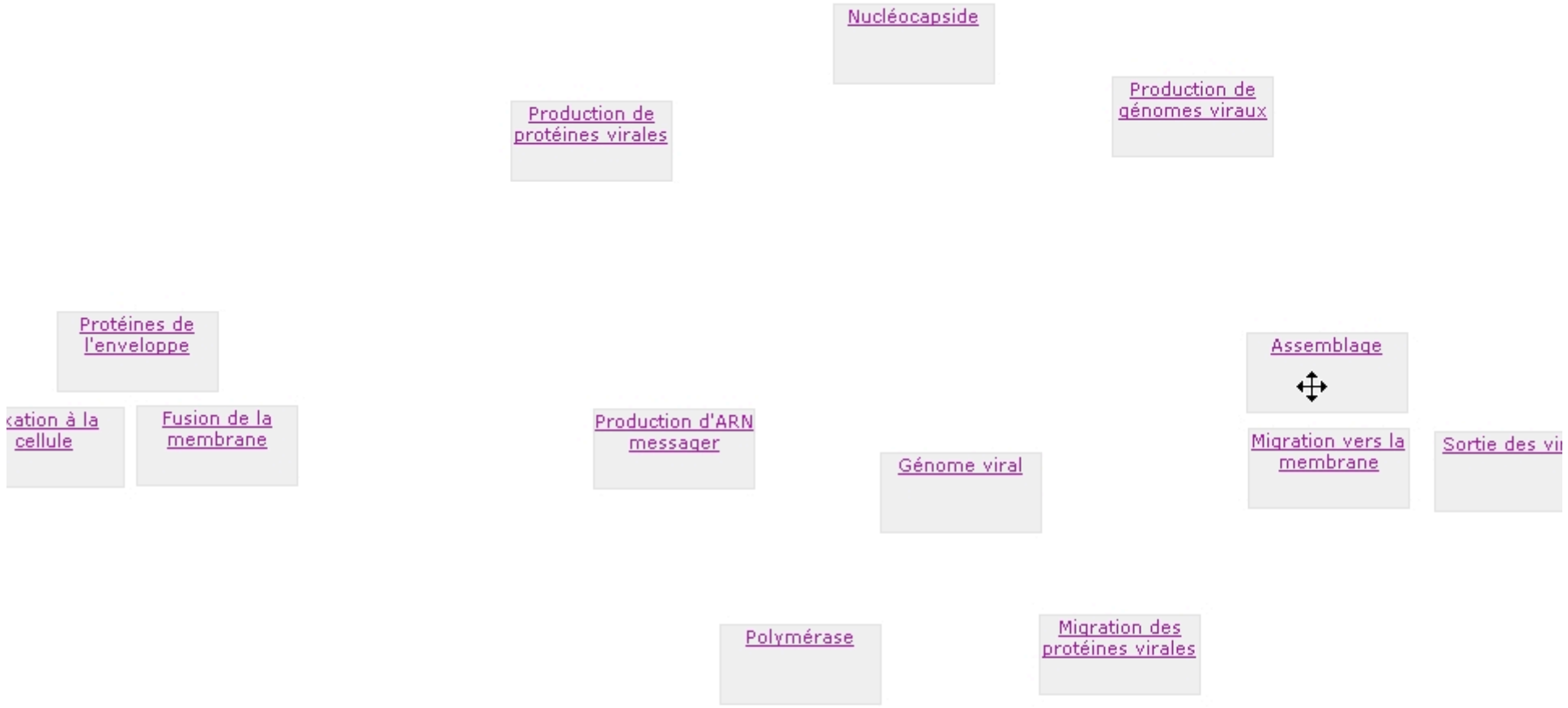


Outcomes measures

- Cognitive load measurement (9 points scales):
  - Mental effort scale (Paas & van Merriënboer, 1993)
  - Perceived complexity
  - Disorientation: 6 scales
- Comprehension scores: statements judgment
  - Text-based representation (explicit information intra-node): 11 statements
  - Situation model representation (implicit information between several nodes): 13 statements
  - Free recall

An example of participant's activity


Nucléocapside
Production de protéines virales
Production de génomes viraux
Fusion de la membrane
Production d'ARN messager
Assemblage
Sortie des virus
Fixation à la cellule
Génome viral
Protéines de l'enveloppe
Migration vers la membrane
Polymérase
Migration des protéines virales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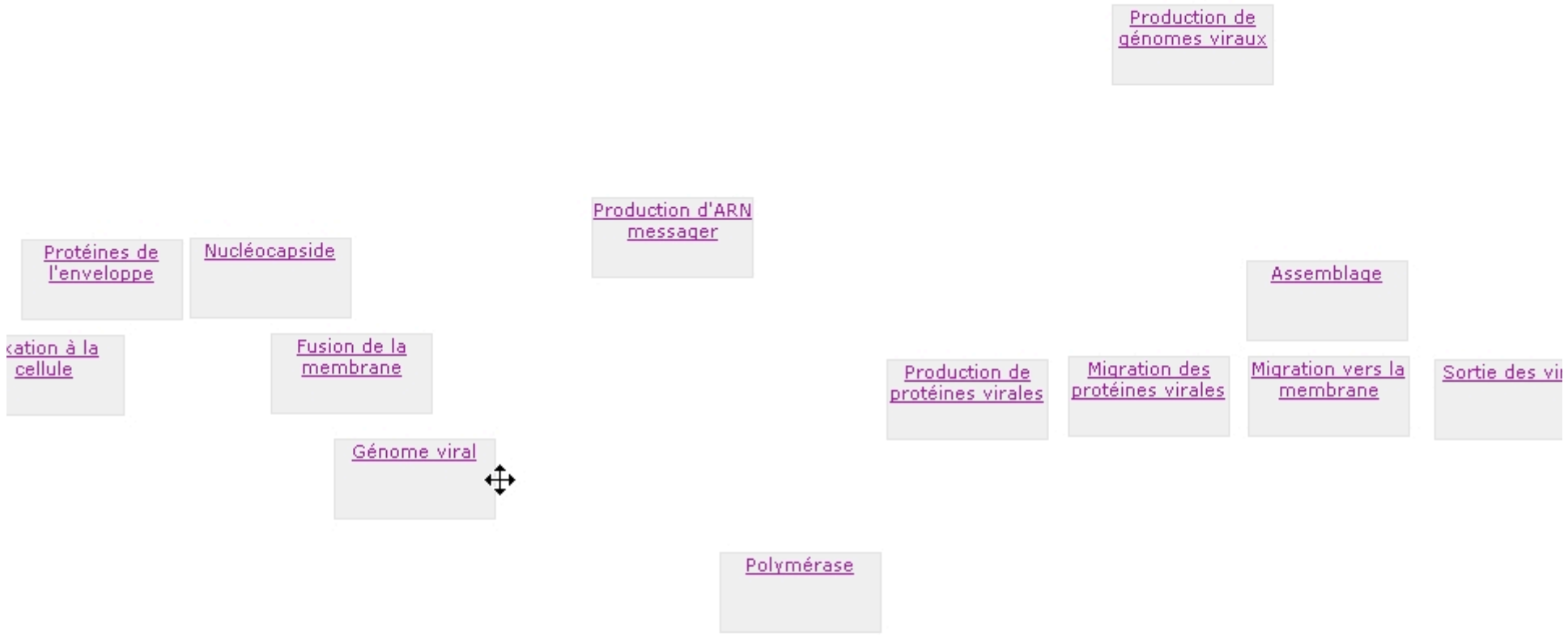
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Comprehension performance

Positive correlations between the level of prior knowledge diversity and the comprehension measures.

	Text-based representation				Situation model representation		
	Correct judgment M = 9.36	Judgement time M = 5339(ms)	Mental effort for judging M = 4,93		Correct judgment M = 8.14	Judgement time M = 7143(ms)	Mental effort for judging M =5,64
Pretest scores	.605*	.130	.023		.699**	.000	-.032
Self-reported knowldge	.217	.052	-.035		.415	-.258	-.102

Cognitive load and disorientaion

Mental effort and perceived complexity

	Mental effort M = 5.21	Perceived complexity M = 3.93
Pretest scores	-0,072	-0,388
Self-reported knowldge	.009	-.053

Disorientation

	Relationships between the texts M = 3.07	Choice of the next page to read M = 3.21	Find an information previously red M = 2.57	Difficulty to understand multiplication cycle M = 3.14	Knowing his position in the lesson M = 2.93	Following of a strategy to consult the concepts M = 7.36
Pretest scores	-0,077	-0,060	-0,559*	-0,166	-0,315	,667**
Self-reported knowldge	.002	.034	-.017	-.106	-.035	.591*

Readings behaviors

Sequence of the reading path : 2 measures of the coherence of the reading path

- Number of jumps from one node to another consistent with the chronological sequence
- Distance of the learner's reading sequence with the chronological sequence (gap between to events or actions within the multiplication process)

	Number of node openings	Number of jumps according to the process chronology	Distance between reading path and the chronological sequence
Pretest scores	,079	,305	-,535*
Self-reported knowldge	,129	,512*	-,495*

Organization strategies

- Self-reported strategies : all participants reported organization strategies of the concepts according to the chronological sequence of the cycle.
  - A learner with low knowledge diversity failed to predict the nodes content
  - The learner with the highest knowledge diversity used a general schema of the cycle and organize the concepts according the schema

Reading path: relationships with cognitive load and comprehension

	Mental effort	Perceived complexity	Find an information previously red	Following of a strategy to consult the concepts
Number of jumps consistent with the process chronology	,005	-,241	,024	,528(*)
Distance between reading path and the chronological sequance	,008	,326	,221	-,818(**)

	Text-based representation			Situation model representation		
	Mental effort for judging	Correct judgment	Judgment time	Mental effort for judging	Correct judgment	Judgment time
Number of jumps consistent with the process chronology	,260	,326	,058	,334	,485(*)	-,472(*)
Distance between reading path and the chronological sequance	-,154	-,547(*)	-,112	-,276	-,594(*)	,662(**)

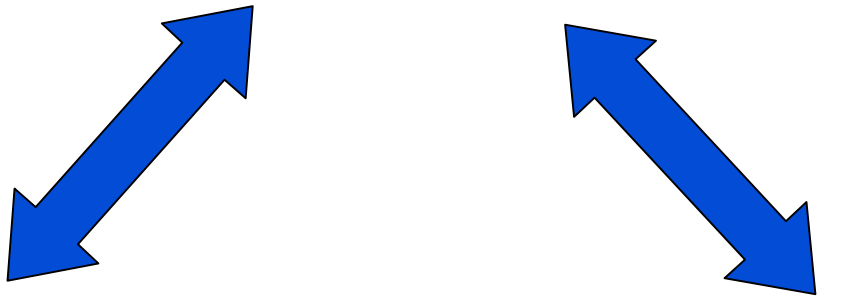
Conclusion – knowledge diversity

- The knowledge diversity favours:
  - higher comprehension performance for text-based and situation model
  - decrease of disorientation linked to information search and the use of strategies
  - use of strategies to organize the consultation order of information on the basis of the chronological sequence
- The objective measures are more sensitive than the self-reported knowledge scores
- Relationship between comprehension and knowledge diversity is linear

Conclusion

- Disorientation may be used as a measure of cognitive load in hypertext learning domain: disorientation is linked to the extraneous cognitive load.
- Multiplying and designing different cognitive load measures
- Need to identify processes linked to the different forms of CL (as the reading sequence)

3 interrelated dimensions



Cognitive load

- Forms of CL

Navigation

- Strategies
- Path coherence
- Using tasks (functions)
- …

Performance

- Searching task
- Comprehension
- Learning

Thank you for your attention !

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