Analysing the Relationship between Learning Styles and Cognitive Traits

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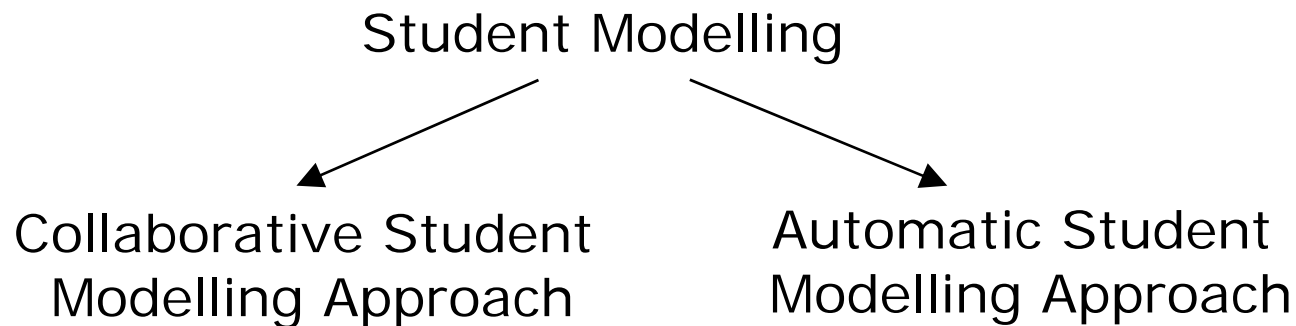New Zealand
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Motivation

- **Learners have different needs**
  - Background knowledge
  - Learning goals
  - Learning styles
  - Cognitive traits
  - ...

- **Incorporating these needs increase the learning progress, leads to better performance, and makes learning easier**

→ Adaptive systems

Student Modelling

- For providing adaptivity, the needs and characteristics of learners have to be known first

- Student Modelling refers to the process of building and updating a student model, which includes relevant data about the student

- How to get this information?

Student Modelling

Collaborative Student
Modelling Approach

Automatic Student
Modelling Approach

Collaborative & Automatic Student Modelling

- **Collaborative Student Modelling**
  - Learners are asked to provide explicitly information about their needs and characteristics (e.g., filling out a questionnaire, performing a task, and so on)
- **Automatic Student Modelling**
  - The system infers the needs and characteristics automatically from the behaviour and actions of students in an online course
  - Advantage:
    - Students do not have additional effort
    - Approach is direct and free from the problem of inaccurate self-conceptions
  - Drawback/Challenges:
    - Getting enough reliable information to build a robust student model
    - Suggestions: use of additional sources

Aim

- Find mechanisms that use whatever information about the learner is available to get as much reliable information to build a more robust student model

- Investigate relationship between learning styles and cognitive traits

→ Additional data

→ Improve the identification process of learning styles and cognitive traits in adaptive learning environments

Relationship between Cognitive Traits and Learning Styles

Why shall we relate cognitive traits and learning styles?

- Case 1: Only one kind of information (CT or LS) can be detected in the system
  - → Get some hints about the other one

$$\boxed{CT} \rightarrow \boxed{\sim LS} \qquad \text{or} \qquad \boxed{LS} \rightarrow \boxed{\sim CT}$$
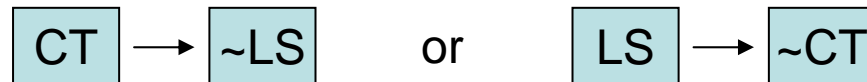
- Case 2: Both kinds of information are incorporated
  → The information about the one can be included in the identification process of the other and vice versa
  → The student model becomes more reliable

Detection of CT	and	Detection of LS

... ... LS   ... ... CT
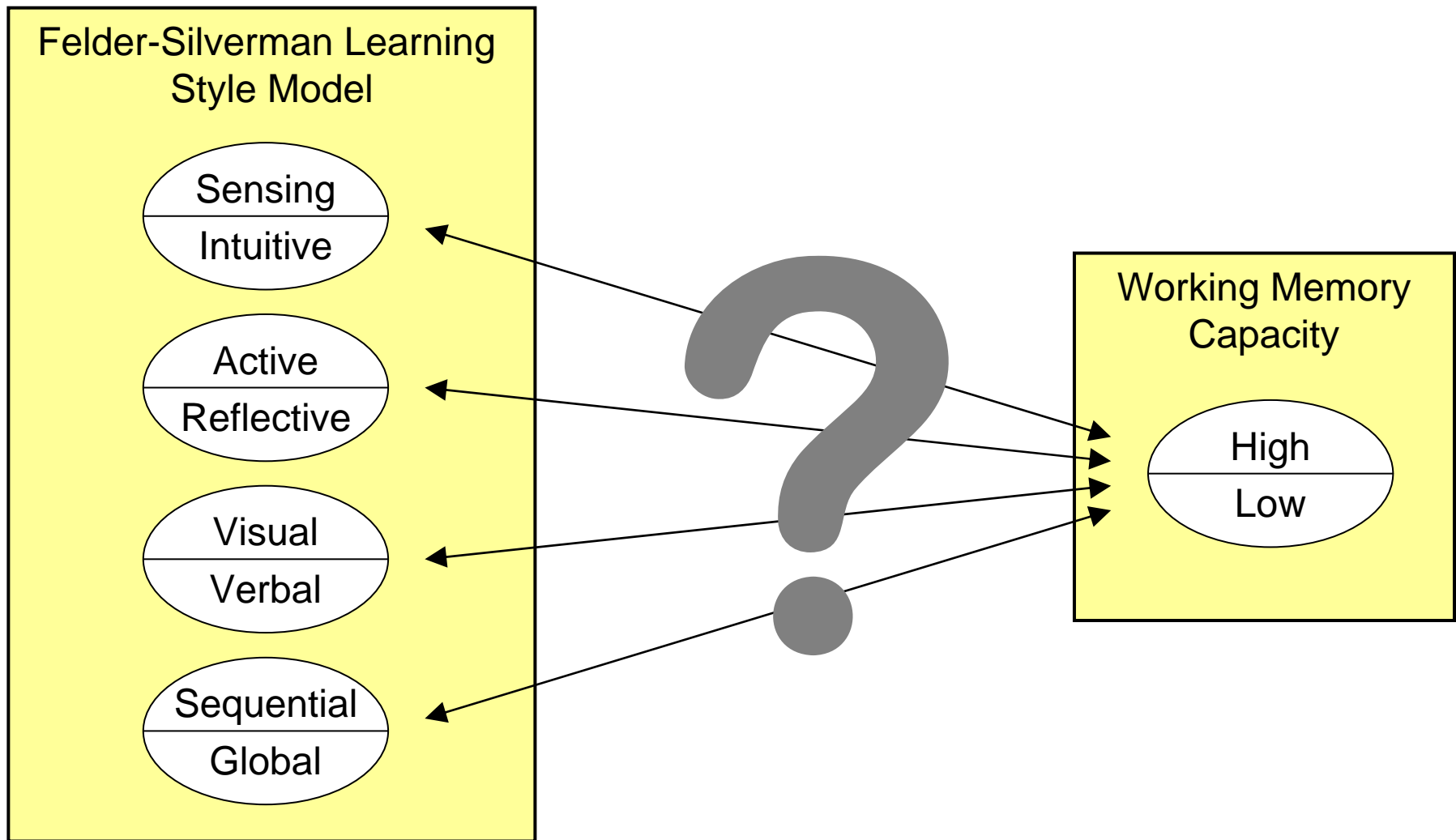
Felder-Silverman Learning Style Model
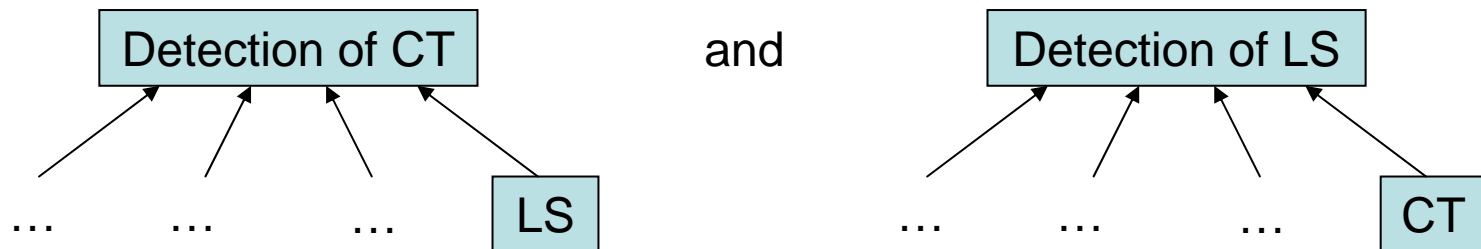
- Richard M. Felder and Linda K. Silverman, 1988
- Each learner has a preference on each of the four dimensions
- Dimensions:
  - Active – Reflective
    learning by doing – learning by thinking things through
    learning by discussing & group work – work alone
  - Sensing – Intuitive
    concrete material – abstract material
    more practical – more innovative and creative
    patient and careful/not patient and careful with details
    standard procedures – challenges
  - Visual – Verbal

    learning from pictures – learning from words
  - Sequential – Global
    learn in linear steps – learn in large leaps
    good in using partial knowledge – need „big picture"
    interested in details – interested in the overview

Cognitive Trait Model (CTM)

- Developed by Lin et al., 2003
- CTM is a student model that profiles learners according to their cognitive traits
- Includes cognitive traits such as
  - Working Memory Capacity
  - Inductive Reasoning Ability
  - ...
- Cognitive traits are more or less persistent
  → CTM can still be valid after a long period of time
  → CTM is domain independent and can be used in different learning environments, thus supporting life long learning

Working Memory Capacity (WMC)

- Also known as short-term memory

- Researchers do not agree on the structure of working memory, they agree that it consists of storage and operational sub-systems

- Allows us to keep active a limited amount of information (7+/-2 items) for a brief period of time

	High WMC	Low WMC
Felder-Silverman Learning Style Dimensions	**Reflective** Beacham, Szumko, and Alty (2003) Hadwin, Kirby, and Woodhouse (1999) Kolb (1984) Summervill (1999) Witkin et al. (1977)	**Active**
	Intuitive Bahar and Hansell (2000) Davis (1991) Ford and Chen (2000) Hudson (1966) Kinshuk and Lin (2005) Scandura (1973) Witkin et al. (1977)	**Sensing**
	Verbal or Visual Beacham, Szumko, and Alty (2003) Simmons and Singleton (2000) Wey and Waugh (1993)	**Visual**
	Sequential Beacham, Szumko, and Alty (2003) Ford and Chen (2000) Huai (2000) Liu and Reed (1994) Mortimore (2003) Witkin et al. (1977)	**Global**

	High WMC	Low WMC
Cognitive Styles	Field-independent Al-Naeme (1991) Bahar and Hansell (2000) El-Banna (1987) Pascual-Leone (1970)	Field-dependent
	Divergent Bahar and Hansell (2000)	Convergent
	Serial Huai (2000)	Holistic
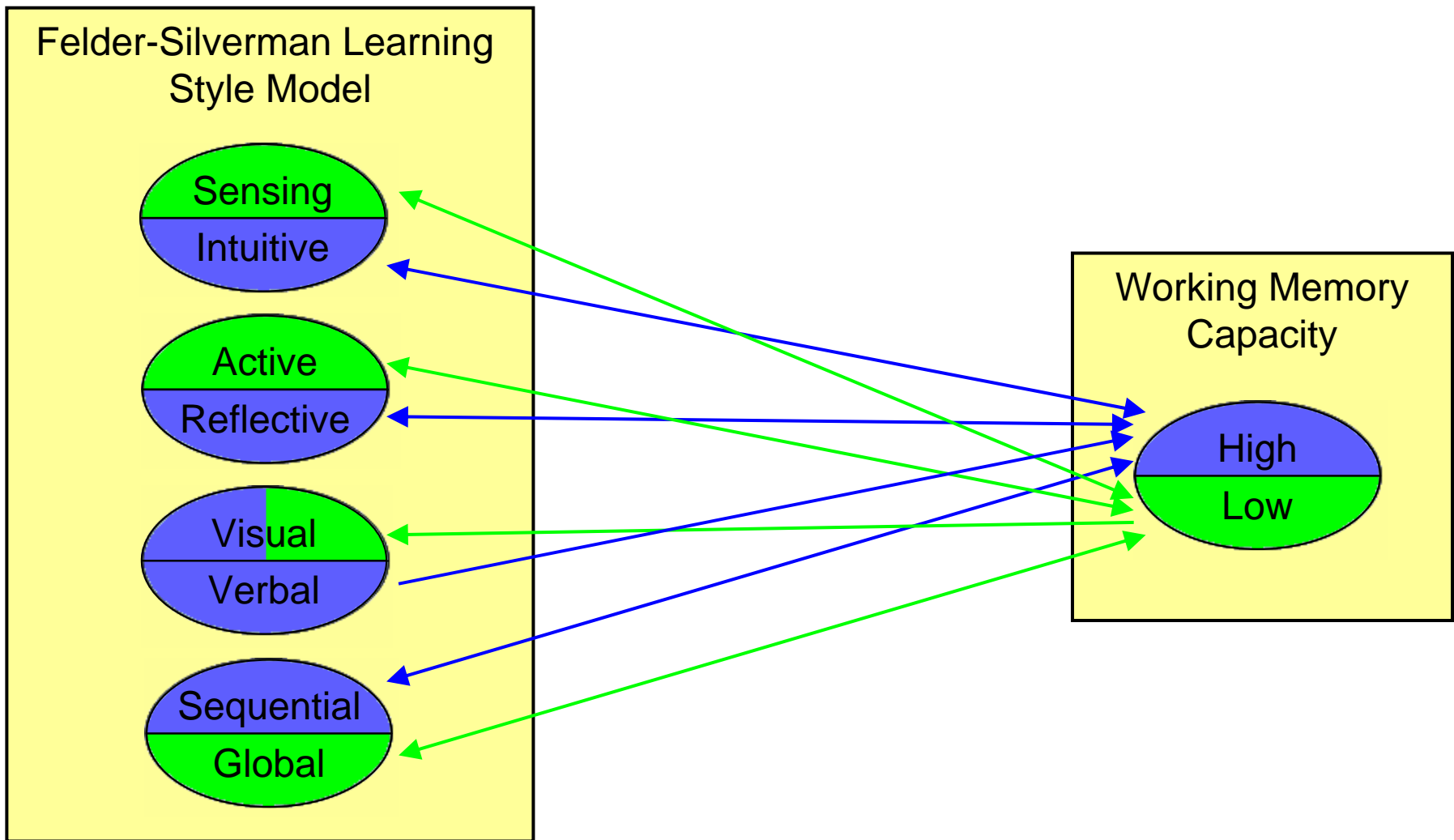
- Analyse the relationship between learning styles and working memory capacity by the use of real data

- Compare results of analyses with results from literature review

- 297 students from Vienna University of Technology participated

- Students were asked to fill out a questionnaire in order to detect their learning styles and perform a psychometric test in order to measure their WMC

Identify Learning Styles according to FSLSM

- **Index of Learning Style (Felder & Soloman, 1997)**
  - Commonly used instrument for identifying learning styles according to FSLSM
  - 44-item questionnaire (11 questions per dimension)
  - Each learner is characterised by four values between +11 and -11
  - Questionnaire is available in German

Identifying working memory capacity

- **From Simple Span Task to Web-OSpan Task**
  - Simple Span Task: participants have to remember a series of stimulus items (digits or words)
  - Complex Span Task: Researchers agree that WMC covers also operational aspects rather than only storage aspects
  - Several versions exist, the operation word span task becomes the most popular task to measure WMC
- **Web-OSpan Task (Lin, 2005)**
  - Simple operations such as $1+(2*3) = 6$ are presented
  - Participant has to answer with true or false
  - After each operation, a word is displayed
  - After 2-6 operations, all words have to be typed in (in the correct order)
  - Overall 60 operations and 60 words

Identifying working memory capacity

- **Web-OSpan Task**
  - Measures:
    - Total number of correct recalled words
    - Total number of correct calculations (process measure)
    - Maximum set size the subject had the words correctly recalled (set size memory span)
    - Mean response latency
    - Partial correct memory span
  - WMC is measured by the number of correct recalled words
- **Available in German**

Method for Statistical Data Analysis

- **Data Cleansing**
  - Discard data from students who made more then 15 mistakes in the calculations or spend less than 5 minutes at ILS
    - → 225 students
  - Improved reliability of ILS through removing weak reliable questions
    - 1 question from active/reflective dimension
    - 1 question from sensing/intuitive dimension
    - 3 question from visual/verbal dimension
    - 2 question from sequential/global dimension

Method for Statistical Data Analysis

- **General Analysis**
  - Correlation analysis (Pearson's & rank correlation)
- **In-depth Analysis**
  - Three groups were build for each dimension (e.g., active, balanced, reflective)
  - Chi-Square test was used to identify differences between the groups
  - If differences exist
    - Correlation analysis between WMC and the absolute values of ILS dimensions
    - Split data into two subsets (positive pole & balanced; negative pole and balanced)
    - For each subset, correlation analysis and group comparison methods were performed

- **In-depth Analysis**
  - For visual/verbal dimension:
  - Used correlation of frequencies in order to prove one-directional relationship
    - Separate visual and verbal learners
      - For each subset, the number of learners in WMC groups was calculated
      - Rank correlation analysis was preformed in order to find a correlation between frequencies of WMC groups for e.g. verbal learners
      - Results of verbal and visual learners were compared
    - Same was done for the two subsets with high and low WMC learners

Results – Measures of Web-OSPAN task

- **General Analysis**
  - Correlation with total number of recalled words

	Corr. Value	p
set size memory span	tau=0.649	0.0
	rho=0.757	0.0
partial correct memory span	tau=0.741	0.0
	rho=0.883	0.0
Mean response time	r = -0.361	0.0
process measure	tau=0.191	0.0
	rho=0.258	0.0

Results – Active/Reflective Dimension

- **General Analysis:** No significant correlation
- **In-depth Analysis**
  - Chi-Square Test: significant result → difference between active/balanced/reflective group
    - Correlation analysis between WMC and the absolute act/ref values: significant negative results for WMC, set size memory span, partial correct memory span
      - **balanced learning style <-> low WMC**
      - **strong active or reflective learning style <-> high WMC**
    - Subset (active & balanced)
      - Correlation analysis: significant negative result for WMC, set size memory span, partial correct memory span, process measure
        - **active learning styles <-> low WMC**
        - **balanced learning style <-> high WMC**
      - Mann-Whitney U test (comparing low and high WMC over active/balanced values):
        - **Low WMC -> active learning style**
        - **High WMC -> balanced learning style**
    - Subset (reflective & balanced)
      - Correlation analysis: significant positive result for WMC (according to Spearman's rho)
        - **Reflective learning style -> low WMC**
        - **Balanced learning style -> high WMC**
      - T test (comparing reflective and balanced group over WMC)
        - **Reflective learning style -> low WMC**
        - **Balanced learning style -> high WMC**

→ **balanced learning style <-> low WMC**
→ **active learning style <-> high WMC**
→ **reflective learning style <-> high WMC**

Results – Sensing/Intuitive Dimension

- **General Analysis:** significant negative correlation for size set memory span
- **In-depth Analysis**
  - Chi-Square Test: significant result → difference between active/balanced/reflective group
    - Correlation analysis between WMC and the absolute sen/int values: not significant → indication for linear correlation
    - Subset (active & balanced)
      - Correlation analysis: significant negative result for set size memory span
        - **Sensing learning styles <-> low WMC**
        - **balanced learning style <-> high WMC**
      - Mann-Whitney U test (comparing low and high WMC over sensing/balanced values):
        - **Low WMC -> sensing learning style**
        - **High WMC -> balanced learning style**
      - T test (comparing reflective and balanced group over WMC)
        - **Sensing learning style -> low WMC**
        - **Balanced learning style -> high WMC**
    - Subset (reflective & balanced)
      - Correlation analysis: significant negative result for mean response latency

→ **Sensing learning style <-> low WMC**
→ **The more balances, the higher is WMC**
→ **No evidence about intuitive part**

Results – Visual/Verbal Dimension

- **General & In-depth Analysis:** no significant results for bi-directional relationship
- **Analysis of correlations of frequencies in sub-datasets (→ one-directional relationship)**
  - Subset (low & high WMC)
    - Correlation of frequencies of vis/ver preferences:
      strong positive correlation for low and high WMC
      → argued by the fact that more learners have visual than verbal preference
  - Subset (visual and verbal learning style)
    - Correlation of frequencies of WMC groups
      - Significant positive correlation for learners with verbal preference
        → for verbal learners a high frequency is associated with high WMC, whereas few verbal learners have low WMC
      - No significant correlation for visual learners

→ **Verbal learning style → high WMC**

- General & In-depth Analysis: no significant results

- Disagreement with literature (indicating that a correlation between sequential learners and high WMC as well as global learners and low WMC)

- **Active/reflective:**
  - High WMC <-> balanced learning preference
  - Low WMC <-> strong active preference
  - Low WMC <-> strong reflective preference

- **Sensing/intuitive:**
  - Low WMC <-> sensing preference
  - High WMC <-> balanced learning preference

- **Visual/verbal:**
  - Verbal learning preference -> high WMC
  - Low WMC -> visual preference

- **Sequential/Global:**
  - No relationship found
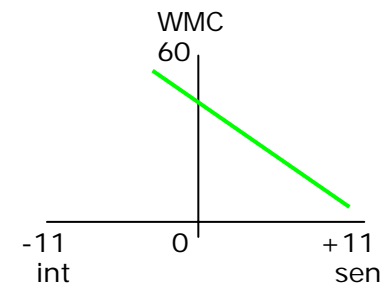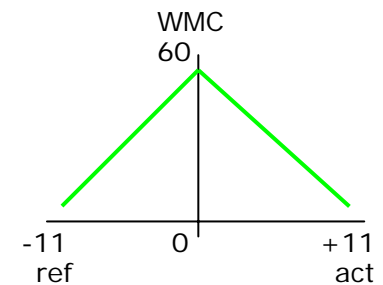
→ Identified relationships can be included in the detection process of learning styles and cognitive traits

→ Improve student modelling process and lead to a more robust student model

Conclusion & Future Work

- Investigated the relationship between FSLSM and WMC by conducting a study with 297 students
- Results show a relationship between WMC and active/reflective, sensing/intuitive and visual/verbal dimension, whereas no relationship was found for the sequential/global dimension
- Relationships provide additional information about the learners which can be used to improve the detection process of learning styles or/and cognitive traits
- Future Work
  - Include the findings of this study to improve the detection process of cognitive traits in CTM
  - Include the findings of this study to improve the detection process of learning styles
  - More granular analysis by considering specific characteristics within the FSLSM dimensions