

# Identifying Strategies of Information Processing in PIAAC Web Search Environments

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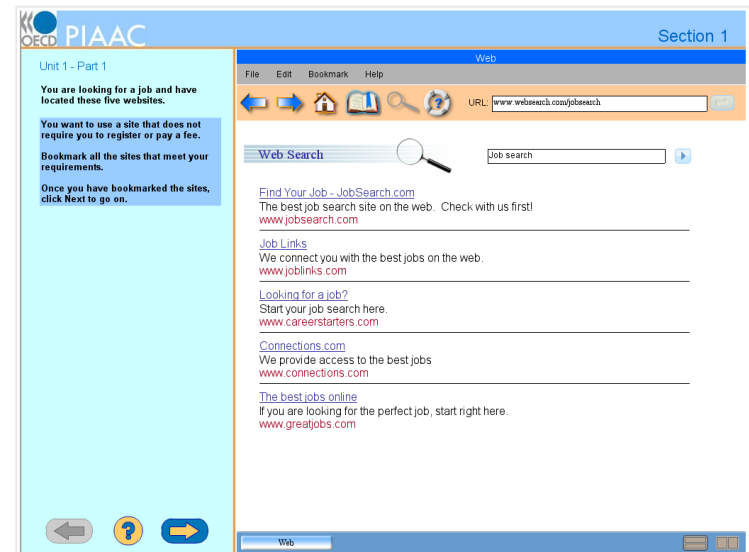
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# Processing information on the web

situation: huge amounts of mixed information but limited processing resources Flanagin & Metzger (2007)

- web searchers scan and evaluate information on search pages and websites (*IPS-I model*) Brand-Gruwel et al. (2009)
- systematic vs. heuristic processing (*dual processing*) Evans (2008); Wirth et al. (2007)
- often application of satisficing vs. sampling strategies Gao et al. (2022); Reader & Payne (2007)



# Selecting online information

- heuristic decision-making is characterized by a set of rule of thumbs

Gigerenzer & Gaissmaier (2011)

Search rule	Stopping rule	
	Early decision (= make a fast decision)	Late decision (= take time to evaluate options)
<u>S</u> ERP is the primary information source	SE	SL
<u>W</u> bsites are the primary information source	WE	WL

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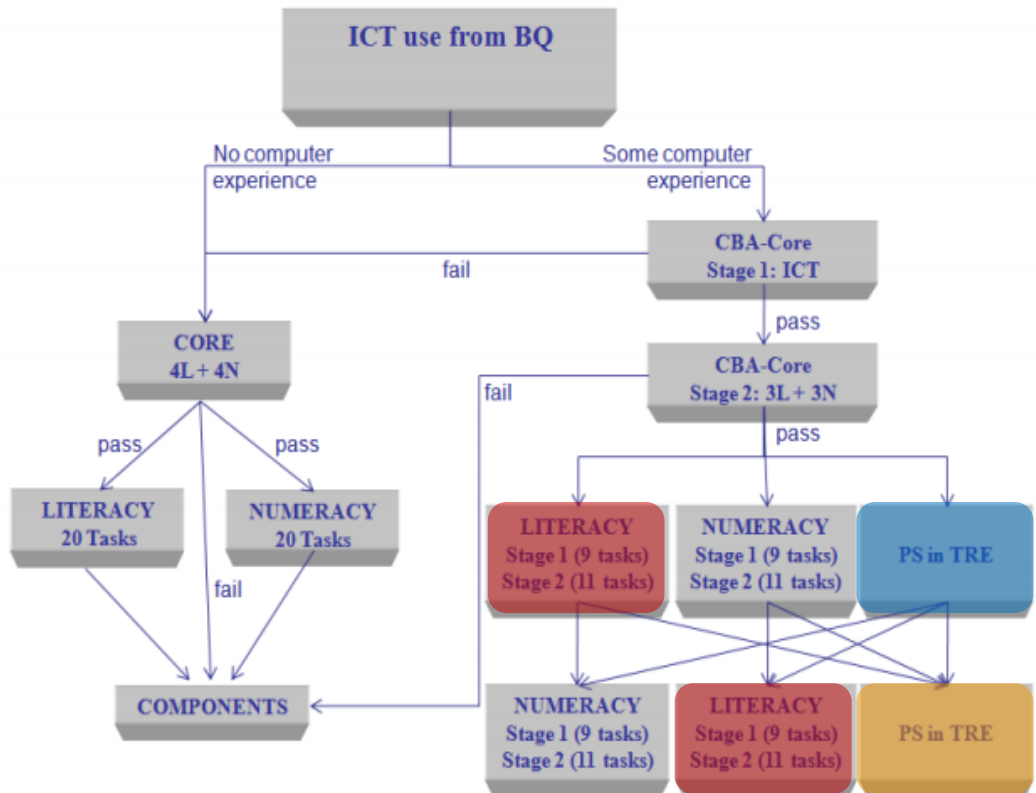
# Research Questions

1. Can we identify patterns of SE, SL, WE, and WL behaviors in PIAAC web search tasks (PSTRE)?
2. How consistently do adults stick to certain behaviors across tasks?
3. Are these behaviors explained by
  - information processing skills (reading and evaluation skills) and
  - background variables (age and educational attainment)?
4. Do these behaviors explain item success beyond information processing skills and background variables?

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# METHOD




# Design







- PSTRE item u06a  
("Sprained Ankle I:  
Site Evaluation Table")
- **PSTRE item u06b**  
("Sprained Ankle II:  
Reliable/ Trustworthy Site")
- **PSTRE item u07**  
("Digital Photography  
Book Purchase")
- assessment of reading  
literacy

# Sample

public use files and log data of 11 countries

-  sample 1:  $n = 8691$ 
  - 52.2% female,  $M_{\text{age}} = 37.1$ ,  $SD_{\text{age}} = 14.0$
-  sample 2:  $n = 4373$ 
  - 52.3% female,  $M_{\text{age}} = 37.5$ ,  $SD_{\text{age}} = 14.0$
-  sample 3:  $n = 4349$ 
  - 52.8% female,  $M_{\text{age}} = 37.6$ ,  $SD_{\text{age}} = 13.9$

-  PSTRE item u06a  
("Sprained Ankle I:  
Site Evaluation Table")
-  **PSTRE item u06b**  
("Sprained Ankle II:  
Reliable/ Trustworthy Site")
-  **PSTRE item u07**  
("Digital Photography  
Book Purchase")
-  assessment of reading  
literacy

1) **PSTRE item u06b** (“Sprained Ankle – Reliable/ Trustworthy Site”)

Content: information search about medical treatment

Structure: 5 clickable links with at least one website per link

Task: select the website with the most **reliable and trustworthy** information

Rates of correct responses: 49.1% (sample 1) and 47.2% (sample 2)

We connect you with the best jobs on the web.  
[www.joblinks.com](http://www.joblinks.com)

[Looking for a job?](#)  
 Start your job search here.  
[www.careerstarters.com](http://www.careerstarters.com)

[Connections.com](#)  
 We provide access to the best jobs  
[www.connections.com](http://www.connections.com)

[The best jobs online](#)  
 If you are looking for the perfect job, start right here.  
[www.greatjobs.com](http://www.greatjobs.com)





1) **PSTRE item u06b** (“Sprained Ankle – Reliable/ Trustworthy Site”)

Content: information search about medical treatment

Structure: 5 clickable links with at least one website per link

Task: select the website with the most **reliable and trustworthy** information

Rates of correct responses: 49.1% (sample 1) and 47.2% (sample 2)

...ve connect you with the best jobs on the web.  
[www.joblinks.com](http://www.joblinks.com)

2) **PSTRE item u07** (“Digital Photography Book Purchase”)

Content: buying a book about digital photography

Structure: 6 clickable links with at least one website per link

Task: find and order a **product that matches** a list of specific criteria

Rates of correct responses: 49.2% (sample 1) and 43.6% (sample 3)



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# Variables at a glance

- **process indicators from PIAAC logfile data for clustering**
  - **time on task** (log-transformed and standardized per country)
  - **log SERP–website time ratio** (positive value = more time on SERP, negative values = more time on websites)
  - **number of websites visited** (u06b: range = 0–5 websites, u07: range = 0–6 websites)
  - **dichotomous satisficing indicator** (last visited website was chosen as response, no multiple visits)
- **u06b and u07 item scores** (correct/incorrect)
- **demographic variables** (i.e., country, age in years, educational attainment in low / medium / high categories)
- **reading skill** (indicated by factor scores, CFA with logit link based on 49 items, MLR estimation)
- **evaluation skill** [recoding of the responses in item u06a into scores of 1) usefulness evaluation and 2) deficiency identification]

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# Steps of data analysis

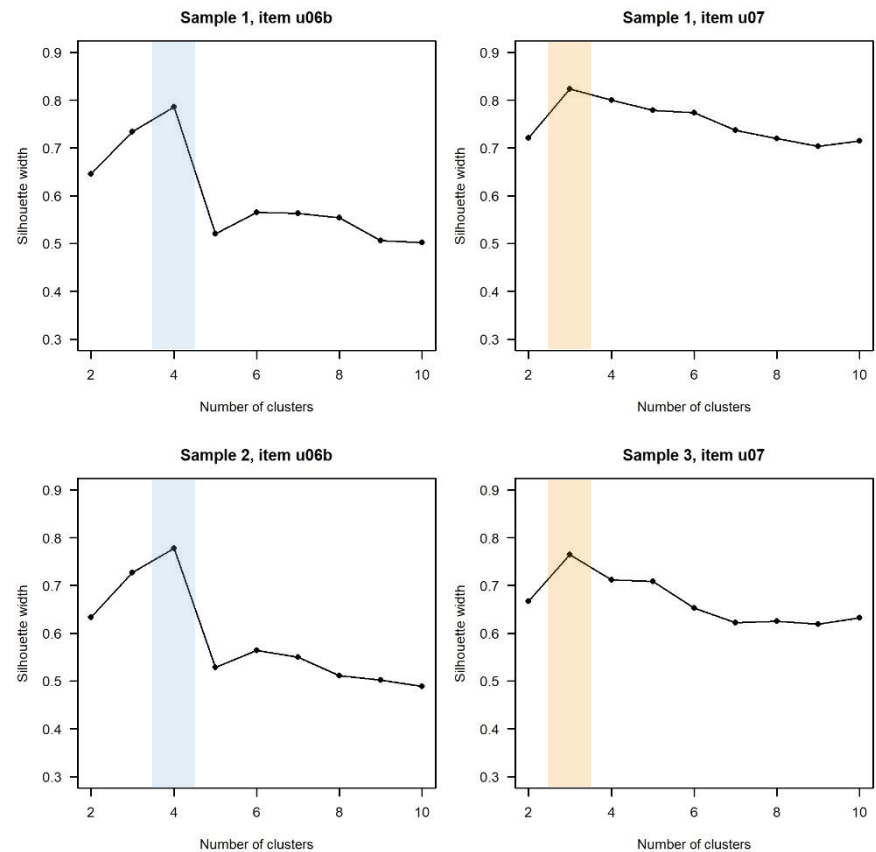
1. feature engineering from logfile data with LogFSM Kroehne, 2019
2. partitioning around medoids (PAM) clustering Everitt et al., 2001
3. multinomial regression analysis to predict cluster membership Venables & Ripley, 2002
4. **generalized linear mixed models to predict item success** De Boeck et al., 2011
  - linear and quadratic fixed effect of age and fixed effects of educational attainment
  - fixed effects of cluster membership
  - random intercepts: country
  - sample specificities:
    - [sample 1: random intercepts for persons and fixed effects of items → was planned, but did not work out]
    - samples 2 and 3: fixed effects of reading skills
    - samples 1 and 2: fixed effects of evaluation skills

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# RESULTS

# Determining the number of clusters

- PSTRE item **u06b** (Sprained Ankle): 4 clusters in both samples
- PSTRE item **u07** (Digital Photography): 3 clusters in both samples
- all average silhouette widths above .75 → high within-group homogeneity and low overlap with other groups



# Clusters of item u06b (Sprained Ankle)

## Sample 1: Means and SDs

Nr.	<i>n</i>	Time on task (in sec)	SERP-website time ratio (log)	Number of websites visited	Satisficing behavior	Label
1	1585	48.00 (35.8)	17.44 (0.78)	0.00 (0.00)	0.00 (0.00)	SE
2	5124	161.77 (65.12)	-0.56 (0.65)	4.87 (0.40)	0.00 (0.00)	WL
3	1176	79.13 (48.40)	0.37 (0.98)	1.41 (0.66)	0.00 (0.00)	SL*
4	794	88.31 (48.98)	0.26 (0.94)	1.99 (1.30)	1.00 (0.00)	SL

## Sample 2: Means and SDs

Nr.	<i>n</i>	Time on task (in sec)	SERP-website time ratio (log)	Number of websites visited	Satisficing behavior	Label
1	2526	164.58 (66.77)	-0.54 (0.61)	4.87 (0.39)	0.00 (0.00)	WL
2	390	88.30 (48.16)	0.26 (0.94)	1.90 (1.23)	1.00 (0.00)	SL
3	814	45.74 (32.90)	17.37 (0.79)	0.00 (0.00)	0.00 (0.00)	SE
4	643	81.25 (47.79)	0.28 (0.95)	1.39 (0.66)	0.00 (0.00)	SL*

# Predicting success: u06b (Sprained Ankle)

	Sample 1			Sample 2		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
<b>Fixed effects</b>						
intercept	-0.16	-0.13	-0.36 ***	-0.22 *	-0.15	-0.30 **
age (linear effect)	-0.22 ***	-0.09 ***	-0.07 *	-0.23 ***	-0.04	-0.02
age (quad. effect)	0.04	0.04	0.04	0.04	0.02	0.03
educational level – low	-0.35 ***	-0.20 **	-0.16 *	-0.39 ***	-0.09	-0.09
educational level – high	0.31 ***	0.09	0.04	0.33 ***	-0.06	-0.06
evaluating usefulness	-	0.42 ***	0.33 ***	-	0.40 ***	0.36 ***
identifying deficiencies	-	0.13 ***	0.09 *	-	0.08	0.07
reading skill	-	-	-	-	0.40 ***	0.33 ***
behavior: SL	-	-	0.24 **	-	-	0.32 *
behavior: SL*	-	-	-0.61 ***	-	-	-0.49 ***
behavior: WL	-	-	0.50 ***	-	-	0.30 **
<b>Random intercepts</b>						
SD country	0.28	0.23	0.22	0.21	0.19	0.19

# Clusters of item u07 (Book purchase)

## Sample 1: Means and SDs

Nr.	<i>n</i>	Time on task (in sec)	SERP-website time ratio (log)	Number of websites visited	Satisficing behavior	Label
1	780	24.53 (26.48)	14.05 (5.76)	0.15 (0.36)	0.00 (0.00)	SE
2	4553	170.78 (59.26)	-0.76 (0.48)	5.70 (0.84)	0.00 (0.00)	WL
3	3348	81.62 (43.74)	0.04 (0.79)	2.46 (1.72)	1.00 (0.00)	SL

## Sample 3: Means and SDs

Nr.	<i>n</i>	Time on task (in sec)	SERP-website time ratio (log)	Number of websites visited	Satisficing behavior	Label
1	2256	91.16 (46.06)	0.23 (0.75)	2.29 (1.56)	1.00 (0.00)	SL
2	1621	169.67 (56.33)	-0.43 (0.55)	5.23 (1.36)	0.00 (0.00)	WL
3	472	27.69 (26.32)	14.03 (5.86)	0.17 (0.37)	0.00 (0.00)	SE



# Predicting success: u07 (Book purchase)

	Sample 1			Sample 3		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
<b>Fixed effects</b>						
intercept	-0.17	-0.14	-5.19 ***	-0.45 ***	-0.41 ***	-16.8
age (linear effect)	-0.33 ***	-0.15 ***	-0.10 **	-0.32 ***	-0.10 *	-0.03
age (quad. effect)	-0.05 *	-0.06 *	-0.06 *	-0.02	0.01	-0.02
educational level – low	-0.49 ***	-0.29 ***	-0.25 **	-0.54 ***	-0.04	-0.01
educational level – high	0.67 ***	0.38 ***	0.26 ***	0.72 ***	0.05	0.03
evaluating usefulness	-	0.45 ***	0.22 ***	-	-	-
identifying deficiencies	-	0.39 ***	0.28 ***	-	-	-
reading skill	-	-	-	-	1.23 ***	0.95 ***
behavior: SL	-	-	4.53 **	-	-	16.2
behavior: WL	-	-	5.84 ***	-	-	17.3
<b>Random intercepts</b>						
SD country	0.28	0.23	0.25	0.26	0.32	0.19

# Predicting success: u07 (Book purchase)

	Sample 1			Sample 3		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
<b>Fixed effects</b>						
intercept	-0.17	-0.14	-5.19 ***	-0.45 ***	-0.41 ***	-16.8
age (linear effect)						
age (quad. effect)						
educational level – low						
educational level – high						
evaluating usefulness						
identifying deficiencies						
reading skill	-	-	-	-	1.23 ***	0.95 ***
behavior: SL	-	-	4.53 **	-	-	16.2
behavior: WL	-	-	5.84 ***	-	-	17.3
<b>Random intercepts</b>						
SD country	0.28	0.23	0.25	0.26	0.32	0.19

	SE	SL	WL
Score 0	777	2281	1356
Score 1	3	1067	3197

	SE	SL	WL
Score 0	472	1486	493
Score 1	0	770	1128

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# DISCUSSION

# Summary and implications

- identification of substantial group structures with logfile data
  - cluster combine time and navigational information
  - similar groups across subsamples/items, except SL\* in reliability task
- open questions
  - SE group and response format of u07
  - no WE group – too small information space or irrelevant behavior?
  - web search behaviors or test-taking strategies?



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# Summary and implications

- further limitations, e.g.,
  - secondary data analysis (→ suboptimal test design)
  - two items and different task types (limited generalizability)
- but also many strengths, e.g.,
  - multi-country sample of the broad adult population → web search research seldomly investigates relations to educational attainment and a continuous age range

Thank you!

Comments, suggestions, ideas are always welcome 😊

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## Further Details and Findings

# The PIAAC LogDataAnalyzer (LDA)



Online Documentation & Software Development

Log Data Analyzer (Plugin: Round 1 - Main Study)

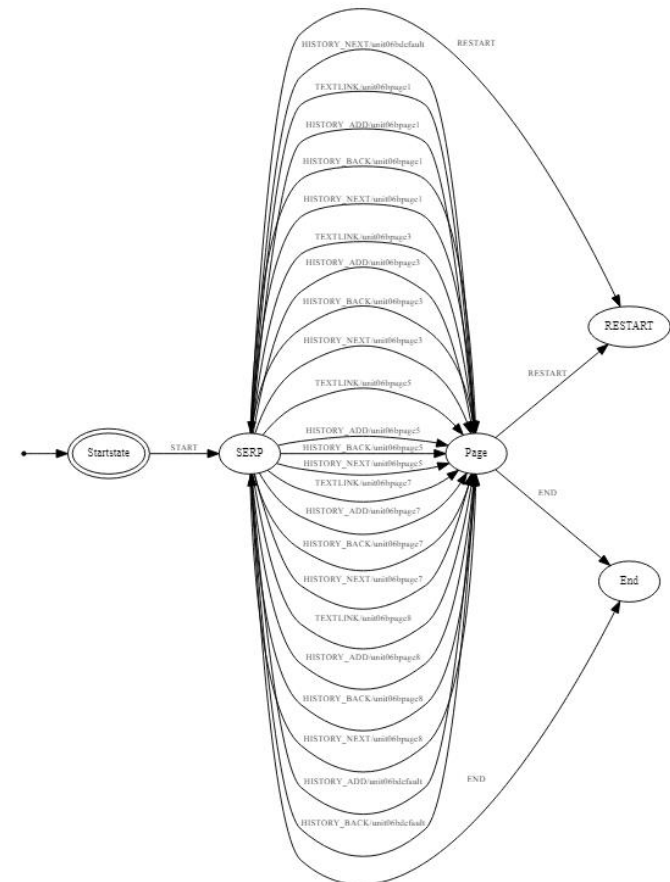
FILE DATA SELECTION HELP

LITERACY	NUMERACY	PROBLEM SOLVING
<input checked="" type="checkbox"/> L1: Dutch Women - C3118701	<input checked="" type="checkbox"/> N11: Candles - C615A602	<input checked="" type="checkbox"/> PS1: Party Invitations - Accommodations - u01a
<input checked="" type="checkbox"/> L1: Internet Poll - C321P001	<input checked="" type="checkbox"/> N11: Candles - C615A603	<input checked="" type="checkbox"/> PS1: Party Invitations - Can/Cannot Come - u01b
<input checked="" type="checkbox"/> L1: Internet Poll - C321P002	<input checked="" type="checkbox"/> N11: BMI - C623A619	<input checked="" type="checkbox"/> PS1: CD Tally - u03a
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A117	<input checked="" type="checkbox"/> N11: BMI - C623A620	<input checked="" type="checkbox"/> PS1: Sprained Ankle, Site Evaluation Table - u06a
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A119	<input checked="" type="checkbox"/> N11: GasGauge - C604A505	<input checked="" type="checkbox"/> PS1: Sprained Ankle, Reliable/Trustworthy Site - u06b
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A120	<input checked="" type="checkbox"/> N11: Photo - C605A506	<input checked="" type="checkbox"/> PS1: Tickets - u21
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A121	<input checked="" type="checkbox"/> N11: Photo - C605A507	<input checked="" type="checkbox"/> PS1: Class Attendance - u04a
<input checked="" type="checkbox"/> L1: TMN AntiTheft - C305A215	<input checked="" type="checkbox"/> N11: Photo - C605A508	<input checked="" type="checkbox"/> PS2: Club Membership - Eligibility for Club President - u19a
<input checked="" type="checkbox"/> L1: TMN AntiTheft - C305A218	<input checked="" type="checkbox"/> N11: UrbanPopulation - C650P001	<input checked="" type="checkbox"/> PS2: Club Membership - Member ID - u19b
<input checked="" type="checkbox"/> L1: Mexican Cities Distances - C315B512	<input checked="" type="checkbox"/> N11: GasGauge - C604A505	<input checked="" type="checkbox"/> PS2: Digital Photography Book Purchase - u07
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A117	<input checked="" type="checkbox"/> N12: Photo - C605A506	<input checked="" type="checkbox"/> PS2: Meeting Rooms - u02
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A118	<input checked="" type="checkbox"/> N12: Photo - C605A507	<input checked="" type="checkbox"/> PS2: Reply All - u16
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A119	<input checked="" type="checkbox"/> N12: Photo - C605A508	<input checked="" type="checkbox"/> PS2: Locate Email - File 3 emails - u11b
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A121	<input checked="" type="checkbox"/> N12: UrbanPopulation - C650P001	<input checked="" type="checkbox"/> PS2: Lamp Return - u23
<input checked="" type="checkbox"/> L1: TMN AntiTheft - C305A215	<input checked="" type="checkbox"/> N12: Wine - C623A616	
<input checked="" type="checkbox"/> L1: TMN AntiTheft - C305A218	<input checked="" type="checkbox"/> N12: Wine - C623A617	
<input checked="" type="checkbox"/> L1: Contact Employer - C304B710	<input checked="" type="checkbox"/> N12: Package - C657P001	
<input checked="" type="checkbox"/> L1: Contact Employer - C304B711	<input checked="" type="checkbox"/> N12: Tiles - C619A609	
<input checked="" type="checkbox"/> L1: Mexican Cities Distances - C315B512	<input checked="" type="checkbox"/> N13: Wine - C623A616	
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<input checked="" type="checkbox"/> L1: Contact Employer - C304B711	<input checked="" type="checkbox"/> N13: Package - C657P001	
<input checked="" type="checkbox"/> L1: Baltic Stock Market - C308A116	<input checked="" type="checkbox"/> N13: Tiles - C619A609	
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<input checked="" type="checkbox"/> L1: Summer Streets - C327P003	<input checked="" type="checkbox"/> N13: Inflation - C620A610	
<input checked="" type="checkbox"/> L1: Summer Streets - C327P004	<input checked="" type="checkbox"/> N13: Inflation - C620A612	
<input checked="" type="checkbox"/> L2: MEDCO Aspirin - C307B401	<input checked="" type="checkbox"/> N21: Logbook - C613A520	
<input checked="" type="checkbox"/> L2: MEDCO Aspirin - C307B402	<input checked="" type="checkbox"/> N21: Watch - C614A601	
<input checked="" type="checkbox"/> L2: Generic Medicines - C309A319	<input checked="" type="checkbox"/> N21: SixPack1 - C618A607	
<input checked="" type="checkbox"/> L2: Generic Medicines - C309A320	<input checked="" type="checkbox"/> N21: SixPack1 - C618A608	
<input checked="" type="checkbox"/> L2: Generic Medicines - C309A321	<input checked="" type="checkbox"/> N21: ParkinsonMan - N635P001	

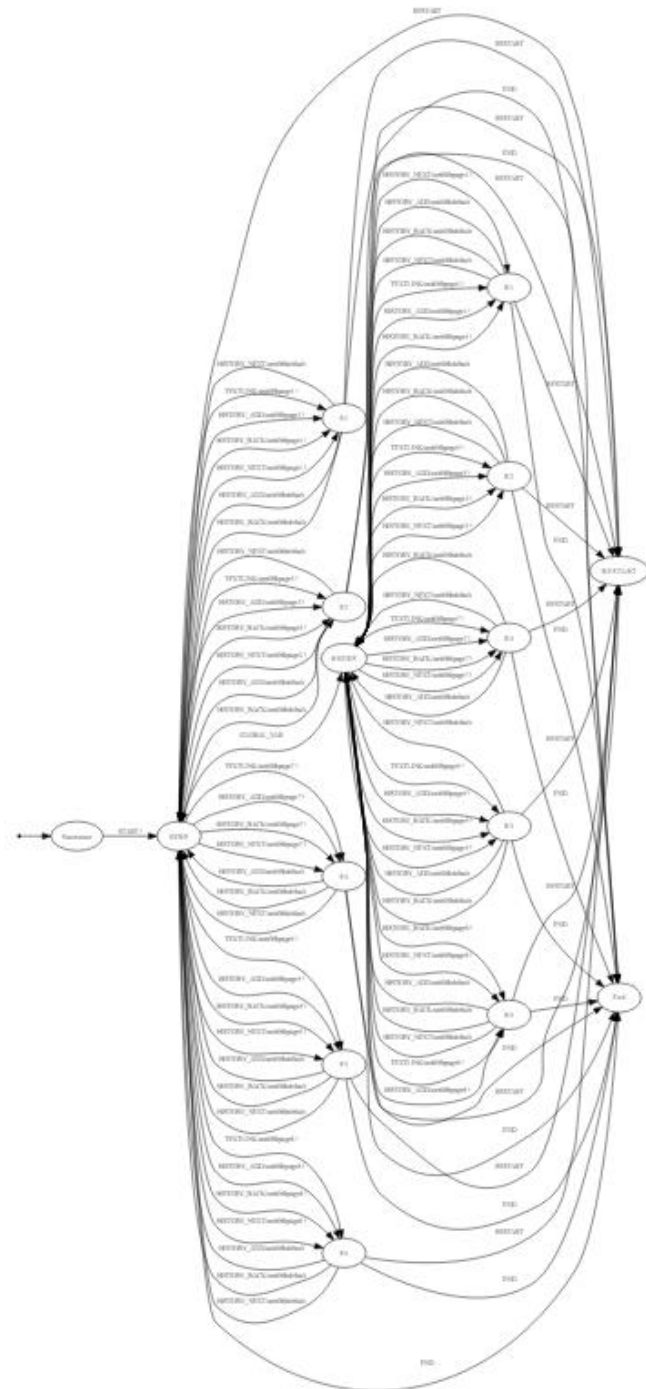
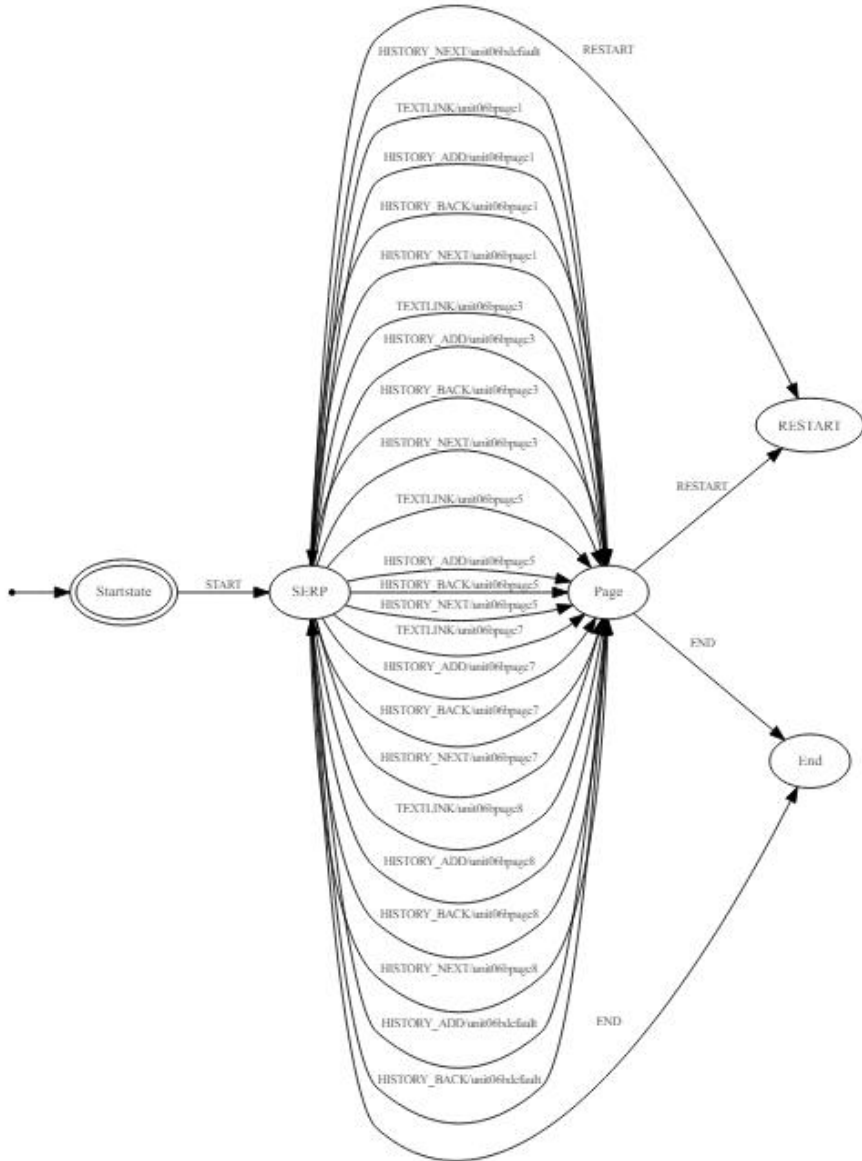
Select All   
  Deselect All   
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  Deselect All   
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  Deselect All

# Feature engineering with LogFSM Kroehne (2019)

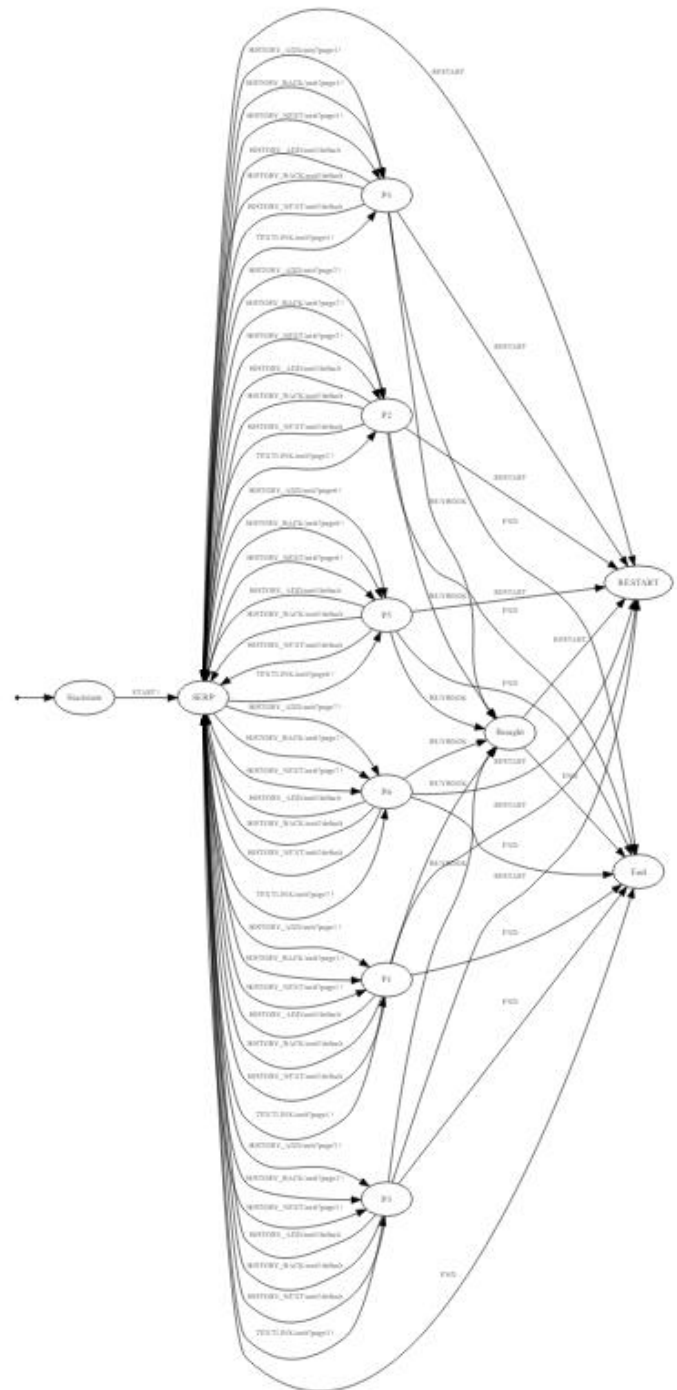
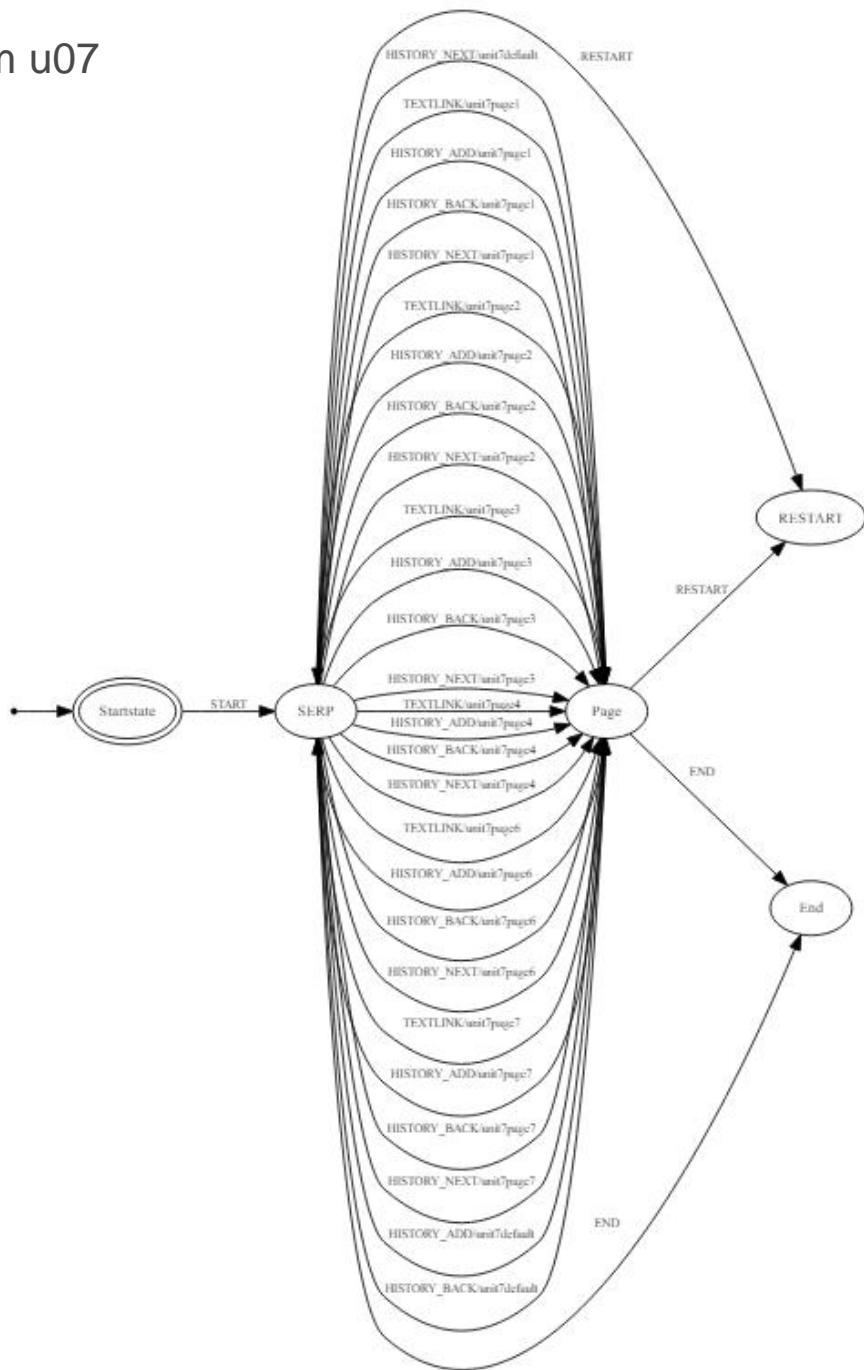
- after pre-processing the PIAAC logfiles with the PIAAC LogDataAnalyzer
- deriving process indicators by describing the test-taking process in form of finite state machines (FSMs)
  - states during test-taking represented as states in in the machine
  - process indicators as properties of the FSM states



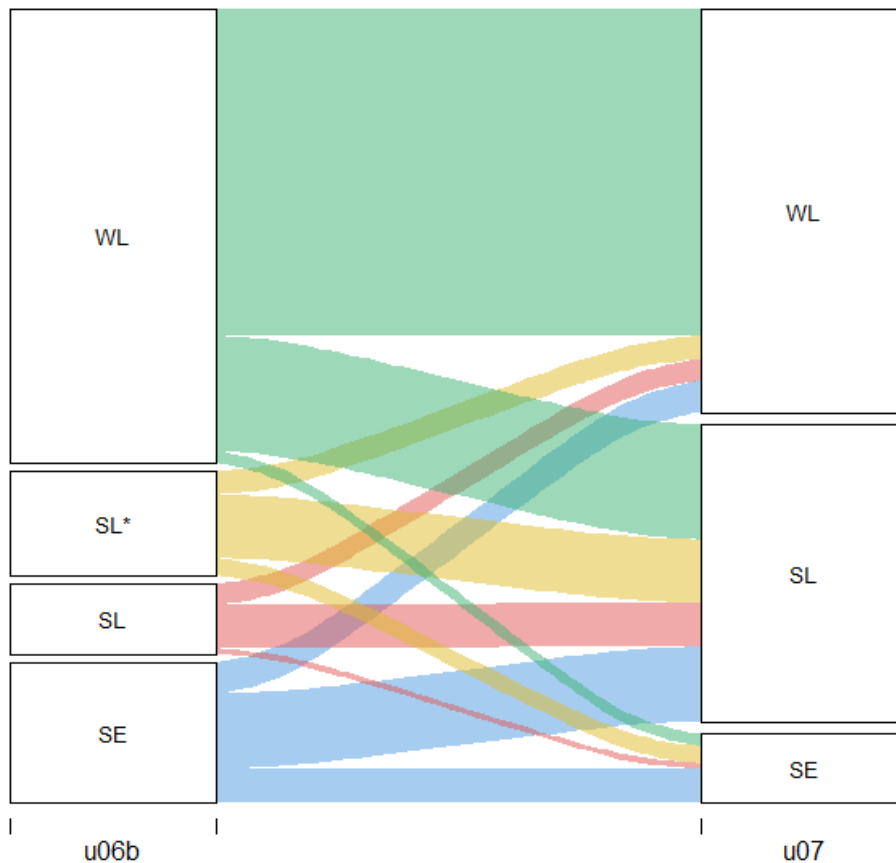
# Item u06b



Item u07



# Consistency in cluster membership (sample 1)



- tendency of WL group to stick to this pattern
- SE/SL/SL\* groups in u06b are likely to show SL behavior in u07

# Predicting cluster membership (u06b)

## Multinomial regressions (reference category is SE)

	Sample 1						Sample 2					
	SL		SL*		WL		SL		SL*		WL	
<b>Fixed effects</b>												
intercept	-0.60	***	-0.45		1.05	***	-0.53	***	-0.33	***	1.17	***
age (linear effect)	-0.04		0.21	***	0.00		0.04		0.29	***	0.12	*
educational level – low	0.07		0.17		-0.13		-0.01		0.11		0.15	
educational level – high	-0.08		0.04		0.40	***	-0.11		-0.05		-0.02	
evaluating usefulness	0.33	***	-0.03		0.65	***	0.33	***	0.17	*	0.61	***
identifying deficiencies	0.00		-0.10		0.35	***	-0.20	*	-0.27	**	0.00	
reading skill	-		-		-		0.33	***	-0.01		0.90	***

# Predicting cluster membership (u07)

## Multinomial regressions (reference category is SE)

	Sample 1				Sample 3			
	SL		WL		SL		WL	
<b>Fixed effects</b>								
intercept	1.99	***	2.03	***	2.28	***	1.66	***
age (linear effect)	-0.05		-0.15	**	-0.16	**	-0.19	**
educational level – low	-0.07		-0.22	*	-0.07		0.08	
educational level – high	-0.08		0.44	***	-0.15		0.00	
evaluating usefulness	0.82	***	1.21	***	-		-	
identifying deficiencies	-0.06		0.49	***	-		-	
reading skill	-		-		1.04	***	2.03	***