Stability and Change in Adults’ Literacy and Numeracy Skills: Recent Insights from Longitudinal Studies

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This presentation is mainly based on four papers


In a nutshell, what is this presentation about?
We present first insights from two longitudinal studies into adults’ literacy and numeracy skills

What we present

- Stability and change in adults’ literacy and numeracy skills
- Patterns and predictors
- Unique large-scale, multi-wave data (3 to 6 years of adulthood)

Why it matters

- New insights into the malleability of skills in adulthood
- Identifying factors that can foster skill growth
- Identifying groups at a heightened need for interventions and policy measures
What are literacy and numeracy skills – and why do they matter?
Technological and demographic change call for lifelong learning

- Globalization enhances international competition and accelerates technological change (Blossfeld et al., 2011)

- The workforce needs to continuously adapt their skills and knowledge (Autor, Levy, & Murnane, 2003; Jarvis, 2007)

- **Lifelong learning** gains in importance
  - For individuals: employability and productivity
  - For nation states: economic growth, innovation, competitiveness
Technological and demographic change call for lifelong learning

- Developed countries face a major **demographic transition**, with declining fertility rates and a growing share of older people

- An **ageing workforce** reinforces the need for lifelong learning
  - Workforce needs to be more productive (skilled) (Bloom & Sousa-Poza, 2013)
  - Individuals need to work longer before retiring (Murray, 2009)
In the context of lifelong learning, foundational literacy and numeracy skills gain currency

Definitions

- **Literacy**: ability to understand, use, and interpret written texts
- **Numeracy**: ability to access, use and interpret mathematical information

- Prerequisites to **handling any type of written or digital material** (Jäckle & Himmler, 2012)

- Prerequisites to **acquiring job-specific skills**

- Contribute to **important life outcomes** (e.g., income, health, well-being, social participation; Rammstedt, Danner, & Lechner, 2017; Hanushek & Woessmann, 2015)
Literacy and numeracy are foundational skills

- In the **Cattell–Horn–Carrol (CHC)** model of intelligence:
  - Stratum II of Broad Abilities
  - Literacy ~ Reading & Writing Ability ($Grw$)
  - Numeracy ~ Quantitative knowledge ($Gq$)
Our increasingly digital world demands high levels of literacy and numeracy skills

- Digitalization increasingly pervades all life areas
- Dealing with symbolic verbal and numerical material becomes the norm
- This requires foundational literacy and numeracy skills
The growing importance of these skills poses a number of policy-relevant questions:

- Age profiles of skills
- Skill gains in late adulthood
- Returns on skill investments
- Drivers of skill development
| ? | What do we know about these questions? |
Skills develop across the entire lifespan

- **Childhood as a ****sensitive period** (Cunha & Heckman, 2007)
- **Lifelong plasticity** (gains and losses)
- Literacy and numeracy show **inverted u-shaped age profiles** (Paccagnella, 2016)
Occupational factors are among the key influences on skill development in adulthood

Sources: Bynner & Parsons, 1998; Desjardins & Warnke, 2012; Grotlüschen et al., 2016; Paccagnella, 2016)
There are two comprehensive reviews of the literature on ageing and skills:

Desjardins & Warnke (2012)

Paccagnella (2016)
What are the limitations of the current body of evidence?
Existing evidence on adults’ skills has several limitations

Previous studies

- Almost exclusively based on **cross-sectional data**
- Few longitudinal studies mostly based on **small-scale, selective samples**
- Studies used **different skill measures**

- Age and cohort effects confounded
- Cause and effect unclear
- Generalizability limited
- Relevant subgroups not adequately covered
- Psychometric quality varies
- Not all studies are pertinent to literacy and numeracy
The few existing longitudinal studies conform to Cattell’s predicted age trajectories

Schaie (1994;2005) (USA)

McArdle et al. (2000) (USA)

Zelinski & Burnright (1997) (USA)

Giambra et al. (1995) (USA)

Alder et al. (1990) (USA)

Verbal Memory
Verbal Ability

Digit Span Forward

Vocabulary

Vocabulary

Vocabulary

Vocabulary

Age 30 40 50 60 70 80

$g_c$ – related measures (literacy domain)

$g_t$-related measures
Large-scale longitudinal data on adults’ literacy and numeracy skills are in very short supply

Sample

<table>
<thead>
<tr>
<th>Design</th>
<th>Sample Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-sectional</td>
<td>National Child Development Study (NCDS) (Bynner &amp; Parson, 1998)</td>
</tr>
<tr>
<td>Multi-wave</td>
<td>Longitudinal Study of Adult Learning (LSAL) (Reder, 2009)</td>
</tr>
</tbody>
</table>

OECD-initiated studies:
- ALL (2003 & 2008)
- PIAAC (2012)
What are the research opportunities offered by longitudinal data?
There are questions that only longitudinal studies can conclusively answer

Longitudinal data can...

- Unravel **age-related changes** in skills
- Disentangle **age vs. birth cohort** effects
- Improve **causal inference** (LDV, FE/FD models)
Two German panel studies offer repeated measures of adults’ skills

**PIAAC-L**
- Follow-up to the German PIAAC 2012 study
- Random sample of adults (age 16–65) and their household members
- Three annual waves (2014-2016)
- Sample size: ~ 3,000 adults

**NEPS SC6**
- National Educational Panel Study in Germany
- Multi-cohort longitudinal design (Starting Cohort 6: age 22–65)
- Nine waves (2008–2016), ongoing
- Sample size: ~ 12,000 adults
PIAAC and NEPS assessed literacy and numeracy skills twice, spaced 3 to 6 years apart.
The PIAAC and NEPS measures of literacy and numeracy are highly similar to each other.

<table>
<thead>
<tr>
<th></th>
<th>correlation r</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIAAC literacy w/ PIAAC numeracy</td>
<td>.87</td>
</tr>
<tr>
<td>NEPS reading w/ NEPS math</td>
<td>.81</td>
</tr>
<tr>
<td>PIAAC literacy w/ NEPS reading</td>
<td>.87</td>
</tr>
<tr>
<td>PIAAC numeracy w/ NEPS math</td>
<td>.90</td>
</tr>
</tbody>
</table>

Source: PIAAC-L/NEPS linking study, based on PIAAC-L wave 2016 (Carstensen et al., in preparation)
Our project leverages the unique analytical potential of PIAAC-L and NEPS

**Patterns of Change**

- Quantifying **stability and change** in skills
- **Sub-group differences** in skill change

**Predictors of Change**

- **Identifying factors** that foster skill development, e.g.
  - Skill use on the job
  - Participation in training

New insights on:

- Longitudinal findings on the **stability and malleability** of skills
- Identifying **factors that drive skill growth** or prevent decline
- Identifying **groups at a heightened need** for interventions
Patterns of stability and change in adults’ literacy and numeracy
We analyzed these indicators of stability and change in parallel in both samples.

<table>
<thead>
<tr>
<th></th>
<th>PIAAC (3-year period)</th>
<th>NEPS (6-year period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>51.0</td>
<td>49.6</td>
</tr>
<tr>
<td>Female</td>
<td>49.0</td>
<td>50.4</td>
</tr>
<tr>
<td>Age in years ($M$)</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td>Education (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (ISED 1&amp;2)</td>
<td>6.9</td>
<td>4.6</td>
</tr>
<tr>
<td>Medium (ISCED 3&amp;4)</td>
<td>56.0</td>
<td>45.3</td>
</tr>
<tr>
<td>High (ISCED 5&amp;6)</td>
<td>37.1</td>
<td>50.2</td>
</tr>
<tr>
<td>Number of respondents</td>
<td>2,490</td>
<td>3,071 (literacy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,010 (numeracy)</td>
</tr>
</tbody>
</table>
We approached the question of stability and change from two complementary perspectives

**Rank-order stability**

- How consistent is individuals’ relative standing in the skill distribution over time?
  - Correlation of skills at two time points
  - $r_{t1, t2}$

**Intraindividual stability**

- By how much do individuals’ skills change over time on average?
  - Difference scores between skills at two time points
  - $\Delta_{t2, t1}$
We approached the question of stability and change from two complementary perspectives.

**Rank-order stability**
- How consistent is individuals’ relative standing in the skill distribution over time?
  - Correlation of skills at two time points
    - \( r_{t1, t2} \)

**Intraindividual stability**
- By how much do individuals’ skills change over time on average?
  - Difference scores between skills at two time points
    - \( \Delta_{t2, t1} \)
# Rank-order change ($r_{t1, t2}$)

<table>
<thead>
<tr>
<th></th>
<th>Literacy</th>
<th>Numeracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 years (PIAAC)</td>
<td>3 years (PIAAC)</td>
</tr>
<tr>
<td></td>
<td>6 years (NEPS)</td>
<td>6 years (NEPS)</td>
</tr>
<tr>
<td>Full</td>
<td>0.85 [0.72]</td>
<td>0.82 [0.67]</td>
</tr>
<tr>
<td>Sample</td>
<td>0.62 [0.38]</td>
<td>0.71 [0.50]</td>
</tr>
</tbody>
</table>

Brackets: Amount of variance (%) shared by the two time points
Rank-order change \((r_{t1, t2})\) in literacy

3 years

6 years

- \(r = 0.85\)
- \(r = 0.62\)
Rank-order change ($r_{t1, t2}$) in numeracy

3 years

6 years

$r = 0.82$

$r = 0.70$
## Rank-order change (correlations) by age group

<table>
<thead>
<tr>
<th>Age group</th>
<th>Literacy</th>
<th>Numeracy</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 years (PIAAC)</td>
<td>6 years (NEPS)</td>
<td>3 years (PIAAC)</td>
<td>6 years (NEPS)</td>
</tr>
<tr>
<td>24–34</td>
<td>0.86</td>
<td>0.64</td>
<td>0.84</td>
<td>0.71</td>
</tr>
<tr>
<td>35–54</td>
<td>0.85</td>
<td>0.61</td>
<td>0.82</td>
<td>0.70</td>
</tr>
<tr>
<td>&gt; 55</td>
<td>0.81</td>
<td>0.56</td>
<td>0.80</td>
<td>0.66</td>
</tr>
</tbody>
</table>
Rank-order change (correlations) by age group

**Literacy**

- 24–34
- 35–54
- > 55

**Numeracy**

- 24–34
- 35–54
- > 55

- PIAAC (3 years)
- NEPS (6 years)
# Rank-order change (correlations) by Educational Attainment

<table>
<thead>
<tr>
<th>Education</th>
<th>Literacy</th>
<th></th>
<th>Numeracy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 years (PIAAC)</td>
<td>6 years (NEPS)</td>
<td>3 years (PIAAC)</td>
<td>6 years (NEPS)</td>
</tr>
<tr>
<td>Low</td>
<td>0.83</td>
<td>0.59</td>
<td>0.82</td>
<td>0.40</td>
</tr>
<tr>
<td>Medium</td>
<td>0.83</td>
<td>0.60</td>
<td>0.79</td>
<td>0.65</td>
</tr>
<tr>
<td>High</td>
<td>0.81</td>
<td>0.59</td>
<td>0.77</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Rank-order change (correlations) by Educational Attainment

**Literacy**

- Low
- Medium
- High

**Numeracy**

- Low
- Medium
- High

- PIAAC (3 years)
- NEPS (6 years)
We approached the question of stability and change from two complementary perspectives

**Rank-order stability**
- How consistent is individuals’ relative standing in the skill distribution over time?
  - Correlation of skills at two time points
  - \( r_{t1, t2} \)

**Intraindividual stability**
- By how much do individuals’ skills change over time on average?
  - Difference scores between skills at two time points
  - \( \Delta_{t2, t1} \)
The majority of adults’ skills change by less than one standard deviation

<table>
<thead>
<tr>
<th></th>
<th>3 years</th>
<th>6 years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Literacy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 0.5 SD</td>
<td>40%</td>
<td>32%</td>
</tr>
<tr>
<td>&lt; 1 SD</td>
<td>70%</td>
<td>53%</td>
</tr>
<tr>
<td><strong>Numeracy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 0.5 SD</td>
<td>41%</td>
<td>27%</td>
</tr>
<tr>
<td>&lt; 1 SD</td>
<td>70%</td>
<td>51%</td>
</tr>
</tbody>
</table>

- % of respondents who change +/- 0.5 SD or less
- % of respondents who change +/- 1 SD or less
Intra-individual Change in literacy ($\Delta t_2, t_1$) is roughly normally distributed.
Even among adults aged 40+, gains and losses are almost equally likely!

Age 25–39

Age 40+
Intra-individual Change in numeracy ($\Delta_{t2, t1}$) is roughly normally distributed

3 years

6 years
Literacy over age (cross-sectional, t1 only)
Chance in literacy ($\Delta_{t_2, t_1}$) over age

3 years

6 years
Numeracy over age (cross-sectional, t1 only)
Chance in numeracy ($\Delta_{t2, t1}$) over age

3 years

6 years
Change in Literacy ($\Delta_{t2, t1}$) over Education

3 years

6 years
Change in Numeracy ($\Delta_{t2, t1}$) over Education

3 years

6 years
Our findings portray skills as highly but not perfectly stable

**Key findings**

- Skills are highly rank-order stable over 3 – but less so over 6 years
- Average skill gains during young adulthood, losses after age 35 to 40 years
- **Skills are not set like plaster but show considerable plasticity**

**Further findings**

- Literacy and numeracy are roughly equally stable
- Stability similar across educational groups
- Exception: 6-year stability of numeracy lower among the lower-educated
2  Predictors of change: Participation in job-related training
Studies suggest that participation in job-related training might foster adults’ skills

- **Job-related training** usually designed to foster **job-specific skills** (rather than literacy or numeracy)
- Still, cross-sectional findings suggest a substantial correlation between (job-related) training and literacy or numeracy (OECD, 2013, Cegolon, 2015, Desjardins 2017)

![Cross-sectional findings: PIAAC-L](chart)

Are there positive **spill-over effects** of job-related training on more general skills?
Purported training effects may arise from self-selection or unobserved confounders.

- **Literacy** $t_1$
- **Job-related training**
- **Literacy** $t_2$

**Possible confounders**
- Time-invariant or time-variant
- Observed or unobserved
What longitudinal data contributes to these problems

- Correct **temporal ordering**: Possible cause (training) precedes purported effect (changes in literacy skills)

- Control for previous level of literacy skills (t1) and estimate effect of training on **residual change in skills**

- Control for **time-invariant third variable confounders** by using fixed-effects-methods
The relationship between job-related training and literacy using longitudinal data

<table>
<thead>
<tr>
<th>Data &amp; Sample</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIAAC 2012 &amp; PIAAC-L 2015 → two-wave panel data</td>
<td>Lagged-dependent-variable (LDV) model to control for t1 literacy</td>
</tr>
<tr>
<td>Native-speaking employed individuals</td>
<td>Fixed-effects (FE) model to control for time-invariant confounders</td>
</tr>
<tr>
<td>( N = 1,773 )</td>
<td>Instrumental-variables (IV) approach to control for other confounders</td>
</tr>
<tr>
<td>Relationship between literacy and job-related training (within the last 12 months)</td>
<td>Selection models to check reverse causality</td>
</tr>
</tbody>
</table>
Our analyses suggest **no** causal effect of job-related training on literacy or numeracy skills.

Positive cross-sectional association confirmed (+ 0.14 $SD$)

No training effects on residual *changes* in literacy (i.e. controlling for T1 literacy)

No training effects on changes in literacy after accounting for unobserved confounders and reverse causality

Reverse causality confirmed: higher literacy skills increase likelihood to participate in training (7 pp)
What about training type, training intensity, and subgroups?

- **Types of training:** self-financed vs. employer–financed training
  - employer–financed training has stronger associations in OLS but not in panel models

- **Training intensity:** number of trainings taken
  - No differential effects

- **Subgroups:** „skills beget skills“ vs. „catch-up effect“? (Cunha & Heckman, 2007; Blossfeld & von Maurice, 2011)
  - Higher training effect for low-skilled individuals in OLS but not in panel models

- Again, no evidence for causal training effects
Our findings suggest that the link between job-related training and skills reflects self-selection.

---

No training effects…

- No spill-over effects of training on literacy or numeracy
- No effects of training type or intensity
- No differential effects for subgroups (save skill level)

…but selection effects

- Skill predict subsequent participation in training
- Higher skills also predict higher training intensity

➢ Training specifically designed to foster literacy / numeracy skills likely a more viable option
3

Predictors of change: Skill use
If training does not foster skills – does skill use?

Skill use

- Extent to which different literacy-related and numeracy-related skills are used
  - At work / on the job
  - Outside of work (e.g. at home)
- Examples:
  - Reading documents
  - Writing documents
  - Carrying out calculations

Analyses

- Lagged-dependent-variable (LDV) model predicting T2 literacy
  - Gender, age, level of education (ISCED-97)
  - Skill use at home and at work
  - T1 literacy
More frequent use of skills prevents skill loss

<table>
<thead>
<tr>
<th></th>
<th>PIAAC</th>
<th>NEPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Literacy ( t_1 )</strong></td>
<td>0.761*** (0.017)</td>
<td>0.567*** (0.021)</td>
</tr>
<tr>
<td><strong>Female</strong></td>
<td>−0.013 (0.027)</td>
<td>−0.031 (0.037)</td>
</tr>
<tr>
<td><strong>Age (Ref:)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35-55 years</td>
<td>−0.086∗ (0.036)</td>
<td>−0.231*** (0.056)</td>
</tr>
<tr>
<td>&gt; 55 years</td>
<td>−0.153** (0.050)</td>
<td>−0.478*** (0.070)</td>
</tr>
<tr>
<td><strong>Education (Ref: high)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>−0.193 (0.100)</td>
<td>−0.195*** (0.040)</td>
</tr>
<tr>
<td>Medium</td>
<td>−0.189*** (0.033)</td>
<td>−0.299** (0.106)</td>
</tr>
<tr>
<td><strong>Skill Use @home (Ref:low)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.073 (0.038)</td>
<td>0.098 (0.068)</td>
</tr>
<tr>
<td>High</td>
<td>0.139*** (0.039)</td>
<td>0.146* (0.072)</td>
</tr>
<tr>
<td><strong>Skill Use @work (Ref:low)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>0.084 (0.042)</td>
<td>0.033 (0.044)</td>
</tr>
<tr>
<td>High</td>
<td>0.104* (0.042)</td>
<td>0.130** (0.047)</td>
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More frequent use of skills prevents skill loss

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More frequent use of skills prevents skill loss
Our findings suggest that skill use matters for skill retention (or growth)

Positive effects of skill use...
- Both, skill use at and outside of work, are positively related to skill development
- Incremental effects
- Similar effect sizes for skills use outside of work and at work

...but
- Skill use may not fully offset negative age effects
- Results might also represent reverse relationship: high levels of skills drive skill use
4

Implications and outlook
Summary of key findings

**Patterns**

- Literacy and numeracy skills are not set like plaster in adulthood
- Beyond age 35–40, skills decline on average
- Few subgroup differences
- **Substantial inter-individual variability**
There are several open questions we yet need to answer

- Whence the **variability in skill development**?
  - General slowing hypothesis / biological ageing?
  - Practice engagement effects?

- What are the **consequences of skill loss**?
  - For life outcomes (income, social participation, well-being, etc.)?
  - For learning ability?
  - Linear functions vs. critical thresholds?

- What are the **returns on investments** in adults’ literacy and numeracy skills?
  - How and when to deliver interventions?
  - For what subgroups?
More longitudinal data would greatly benefit research on adults’ skills

- ... more measurement occasions
  - Three or more measurement occasions would be ideal
  - Some factors might only affect skills over a longer time span

- ... additional skill domains
  - Digital /technological skills
  - More job-specific skill and skill use measures

- ...multiple countries
  - Comparing changes over time across country (diff-in-diff)
  - Role of educational systems and labor market regimes
Only the German follow-up study contains a reassessment of literacy and numeracy skills.
Thank you for your attention!
References


