The stability of objective numeracy: A seven-year longitudinal study

Marcus Mayorga
University of Oregon, Decision Research

Mary Kate Tompkins
Ohio State University

Abstract

Prior research has demonstrated the importance of numeracy in judgment and decision-processing in health and financial domains. However, little is known about how numeracy changes over the lifespan and if individual ability remains stable over time. We mined data from the Decision Research web panel—a diverse group of Americans—to track numerical ability over a seven-year period. Results indicated that numeracy (assessed using the 8-item scale from Weller et al., 2013) decreased slightly over time. Significant predictors of initial objective numeracy included gender and IQ, but not age, education, subjective numeracy, nor use of math in an occupation.

Methods

The Decision Research web panel, a diverse sample of US citizens, was surveyed 3 times (in unrelated studies) over the course of 7 years. The panel completed the first assessment in 2008 (N=1283), the second in 2013 (N=575), and the third in 2015 (N=639). 204 participants completed all three waves. Each assessment contained the 8-item scale from Weller et al. (2013). We also included measures of IQ (T2) and subjective numeracy (T3).

Items from the Objective Numeracy Scale:

1. **Imagine that we role a fair, six-sided die 1,000 times. Out of 1,000 roles, how many times do you think the die would come up even (2, 4, or 6)? In the BIG BUCKS LOTTERY, the chances of winning a $10.00 prize is 1%.**
2. **What is your best guess about how many people would win a $10.00 prize if 1,000 people each by a single ticket to BIG BUCKS?**
3. **In the ACME PUBLISHING SWEEPSTAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSTAKES win a car?**
4. **If the chance of getting a disease is 10%, how many people would be expected to get the disease out of 1000?**
5. **If the chance of getting a disease is 20 out of 100, this would be the same as having a ____% chance of getting the disease.**
6. **Suppose you have a close friend who has a lump in her breast and must have a mammogram. Of 100 women like her, 10 of them actually have a malignant tumor and 90 of them do not. Of the 10 women who actually have a tumor, the mammogram indicates correctly that 9 of them have a tumor and indicates incorrectly that 1 of them does not. Of the 90 women who do not have a tumor, the mammogram indicates correctly that 81 of them do not have a tumor and indicates incorrectly that 9 of them do have a tumor. The table below summarizes all of this information. Imagine that your friend tests positive (as if she had a tumor), what is the likelihood that she actually has a tumor?**
7. **A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?**
8. **In a lake, there is a patch of lilypads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?**

Results- Correlations & Descriptives

Correlations (Means & SD on Diagonal) (N=204)

	Time 1 (2008)	Time 2 (2013)	Time 3 (2015)	Education	Gender	Age	IQ Number	IQ Letter	SNS	SNS-Ability	SNS-Preference
Time 1 (2008)	**4.43 (1.79)**										
Time 2 (2013)	.693**	**3.68 (1.43)**									
Time 3 (2015)	.722**	.627**	**3.79 (1.37)**								
Education	.268**	.268**	.233**	**28% College**							
Gender	.325**	.383**	.343**	.286**	**32% M**						
Age	-.246**	-.291**	-.286**	-.179*	-.357**	**47.5 (12.26)**					
IQ Number	.602**	.598**	.503**	.234**	.139*	-.159*	**3.63 (2.3)**				
IQ Letters	.591**	.479**	.539**	.155*	.080	-.177*	.647**	**4.17 (1.83)**			
SNS	.493**	.411**	.490**	.293**	.348**	-.205**	.436**	.331**	**4.11 (0.82)**		
SNS-Ability	.493**	.393**	.472**	.288**	.347**	-.165*	.455**	.342**	.951**	**4.27 (1.19)**	
SNS- Preference	.355**	.331**	.388**	.222**	.252**	-.223**	.278**	.218**	.811**	.592**	**3.95 (0.62)**

Summary:

- Significant positive correlations between numeracy measurements
- Negative correlations between age and numeracy measurements
- Positive correlation with education, subjective numeracy, IQ, gender (0=female, 1=male)

Results – Modeling

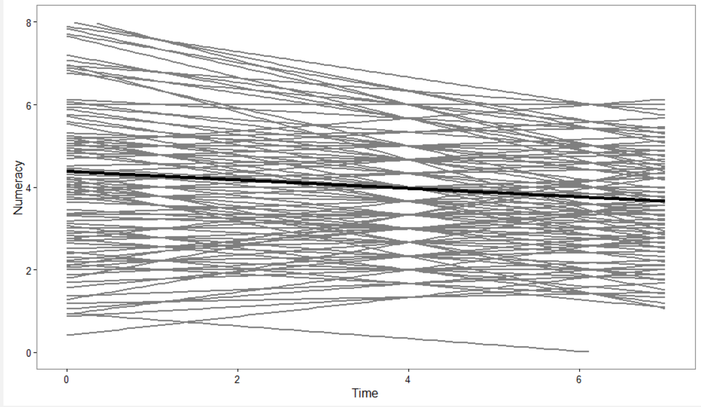
We fit a multi-level model with random intercepts and slopes, predicting baseline numeracy (level-1) and within-person slopes (level-2).

Table II. Multilevel modeling of numeracy over time (N=204)

Variable	UGM	Step 1	Step 2
Fixed effects: Initial Numeracy			
γ_{00} Intercept	4.378 (.124)	4.578 (.542)	4.09 (.098)
γ_{10} Time (years)	-0.102 (.012)***	-0.088 (.078)	-.102 (.012)***
γ_{01} Age		-0.013 (.008)	
γ_{02} Gender		0.542 (.222)*	0.885 (.132)***
γ_{03} Education		0.047 (.065)	
γ_{04} SNS Ability		0.185 (.107)	
γ_{05} SNS Preference		0.165 (.182)	
γ_{06} Math in Job		0.004 (.059)	
γ_{07} IQ-Number Sequence		0.248 (.055)**	0.287 (.051)***
γ_{08} IQ-Letter Sequence		0.295 (.065)**	0.313 (.063)***
Fixed effects: Rate of change			
γ_{11} Age		-0.000 (.001)	
γ_{12} Gender		0.005 (.032)	
γ_{13} Education		-0.004 (.009)	
γ_{14} SNS Ability		0.020 (.015)	
γ_{15} SNS Preference		0.014 (.026)	
γ_{16} Math in Job		0.005 (.009)	
γ_{17} IQ-Number Sequence		-0.011 (.008)	-.015 (.007)*
γ_{18} IQ-Letter Sequence		-0.016 (.009)†	-.016 (.008)†
Variance Components: Level 1			
σ^2_e Within-person	.739	0.745	0.651
Variance components: Level 2			
σ^2_0 In initial risk	2.439	0.801	.467
σ^2_1 In rate of change	0.005	0.002	0.0009
σ^2_{01} Covariance	-0.115	-0.043	0.021

Results – Modeling Cont.

Figure: OLS fitted Individual & Composite slopes/intercepts



- Significant overall negative trend in objective numeracy over time
- Gender was a significant positive predictor of numeracy such that being male predicted a higher initial objective numeracy score
- Numerical and Literacy IQ measures were positive predictors of initial numeracy scores
- IQ was found to be a (marginally) negative predictor of slope- Higher IQ -> Quicker decline

Conclusions

- No known research has examined individuals' objective numeracy skills over several years time
- Over a period of 7 years, we observed a significant linear decline in objective numeracy
- There was little variance in the slopes displayed *between* individuals (figure above)
- Consistent with prior research, men tended to display higher initial numeracy scores than women
- IQ may moderate changes in objective numeracy over time
- We did not find differences in objective numeracy over time related to age nor education, as suggested in other literature
- Further research is needed to determine causal relationships and replicate to these findings

Select References

de Bruin, W. B., McNair, S. J., Taylor, A. L., Summers, B., & Strough, J. (2015). "Thinking about Numbers Is Not My Idea of Fun" Need for Cognition Mediates Age Differences in Numeracy Performance. *Medical Decision Making*, *35*(1), 22-26.

Peters, E., Västfjäll, D., Slovic, P., Mertz, C. K., Mazzocco, K., & Dickert, S. (2006). Numeracy and decision making. *Psychological science*, *17*(5), 407-413.

Peters, E., Dieckmann, N., Dixon, A., Hibbard, J. H., & Mertz, C. K. (2007). Less is more in presenting quality information to consumers. *Medical Care Research and Review*, *64*(2), 169-190..

Weller, J. A., Dieckmann, N. F., Tusler, M., Mertz, C. K., Burns, W. J., & Peters, E. (2013). Development and testing of an abbreviated numeracy scale: A Rasch analysis approach. *Journal of Behavioral Decision Making*, *26*(2), 198-212.

This material is based upon work supported by the National Science Foundation.

Contact: marcus@decisionresearch.org