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Computational Thinking

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Briefing Agenda

- Background and Project Overview
  - Phase 1: Computational Thinking Score
  - Phase 2: Computational Thinking Score Validation
- Predictors and Criterion
- Phase 2 Results
- Closing

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Congressional Mandate

- William M. (Mac) Thornberry National Defense Authorization Act (NDAA) for Fiscal Year 2021 (HR 6395), Section 594
  - Must assess six (6) computational thinking construct domains
    - Problem Decomposition
    - Abstraction
    - Pattern Recognition
    - Analytical Ability
    - Identifying Variables for Data Representation
    - Creating Algorithms and Solution Expressions
  - Must be available for operational use by October 1, 2024

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Computational Thinking Construct Domains

Construct Domains	Descriptions
1. Problem decomposition	▪ Break down a problem/task into smaller/easier components (e.g., describe a system as a sequence of processes)
2. Abstraction	▪ Focus on the most relevant information and ignore extraneous information to interpret meaning and reduce complexity of a problem/task
3. Pattern recognition	▪ Identify and use repeated information or patterns to predict outcomes or determine actions for a problem/task
4. Analytical ability	▪ Inspect, cleanse, transform, and model data with the goal of discovering useful information for a problem/task
5. Identifying variables for data representation	▪ Recognize how parts of a solution may be reapplied to, or eliminated from, similar or unique problems/tasks
6. Creating algorithms and solution expressions	▪ Recognize and evaluate options against outcomes to simplify or automate processes for efficiency and resource utilization improvements

Where We Started

- Existing measures of computational thinking were not viable
  - Those used for selection require specific programming language skills
  - Those used for skill acquisition are developed for the K–12 classroom environment, which are free on the internet (lack test security)
- NDAA-specified deadline of 01 October 2024 did not support creating a new, valid measure of computational thinking
- Belief that the Complex Reasoning Test (CR) already under development, and possibly some of the ASVAB subtests [e.g., Arithmetic Reasoning (AR), Assembling Objects (AO)] and other special tests [e.g., Cyber (CT), Coding Speed (CS), Mental Counters (MCt)] were likely assessing the computational thinking construct domains

Project Overview

Phase 1: Define Computational Thinking Score Equation

- Gather empirical & SME-estimated correlations
- Specify & analyze prediction models
- Generate, evaluate, finalize synthetic CompT score equations
- Submit software requirements & specifications

Phase 2: Verify Validity of Computational Thinking Scores

- Select computational thinking marker test
- Develop & implement data collection plan at MEPS
- Match shippers' ASVAB & CT scores to study data & clean
- Conduct analyses & summarize results

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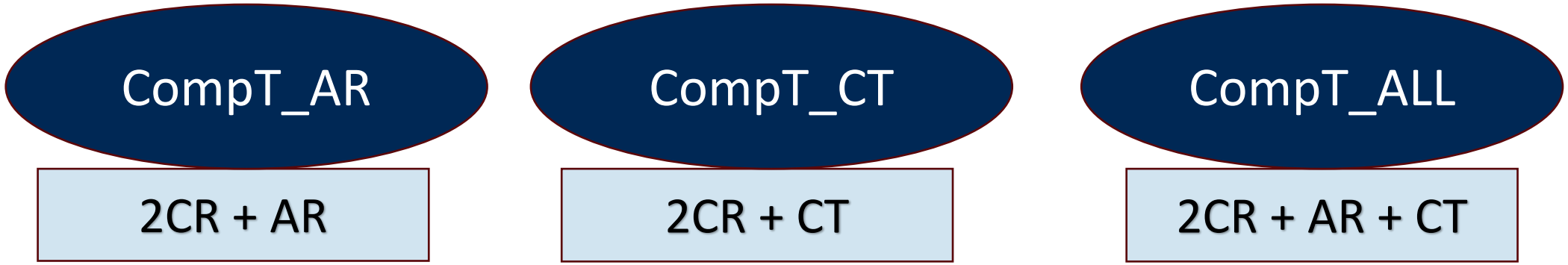
Computational Thinking Score Equations



Note: Scores are a weighted sum of CR, AR, and CT standard (T) scores with X = 50, std = 10. The AR, CR, and CT standard (T) scores are normed to the PAY97 sample.

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Validation Data Collection

Collected Data	Matched Data	Cleaned Data
▪ MEPS administered the Qualtrics data collection tool between 4/15 – 5/20 ✓Complex Reasoning (CR) ✓Computational Thinking Assessment for Middle Schoolers (CTA-M) ✓Background questions ▪ Shippers = 1,044	▪ HumRRO sent DTAC participant IDs from Qualtrics on weekly basis ▪ DTAC used participant IDs and MEPS rosters to pull ASVAB and CT scores into a de-identified dataset ▪ HumRRO appended with responses on CR, CTA-M, and background questions ▪ Shippers = 922	▪ Removed any that showed a lack of motivation using: ✓Two CR attention-check items ✓Self-report question at end ✓Time spent on CR and CTA-M (no more than 2 standard deviations below the mean for time spent) ✓Checks for careless response patterns ✓Checks for CR and CTA-M scores that were at or below chance ▪ Removed any that left study early for transportation ▪ Shippers = 722

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Sample by Demographic Group

Gender		Race-Ethnicity		Service*	
Female	106	Hispanic White (HW)	166	Air Force	232
Male	608	Non-Hispanic Asian (NHA)	35	Army	22
NA	8	Non-Hispanic Black (NHB)	172	Coast Guard	0
		Non-Hispanic White (NHW)	291	Marine Corps	214
		Other or NA	58	Navy	238
				Space Force	16
Total	722		722		722

*Participation was limited to Shippers with a pre-enlistment CT score. Therefore, an equal distribution across Services was not expected given Services have different policies for administering CT to applicants.

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Sample by Type of Service and Component

Component	Service						
	Army	Air Force	Coast Guard	Marine Corps	Navy	Space Force	Total
Active Duty	21	232	0	205	235	16	709
Guard	1	0	0	9	3	0	13
Reserve	0	0	0	0	0	0	0
Total	**22**	**232**	**0**	**214**	**238**	**16**	**722**

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Predictors and Criterion

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Overview of Predictors

- Components of operational equation-based Computational Thinking scores
  - AR
  - CT
  - CR
- Operational equation-based Computational Thinking scores derived from Phase 1 study
  - CompT_AR = 2CR + AR
  - CompT_CT = 2CR + CT
  - CompT_ALL = 2 CR + AR + CT

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Overview of Criterion

- Computational Thinking Abilities – Middle Grades Assessment (CTA-M)
  - Developed by Wiebe et al, 2019
  - Designed for classroom use with middle school students
- Consists of 23 items administered with a 45-minute time limit
  - 15 Computational Thinking Test (CTt) items (Gonzalez et al., 2015)
  - 8 Bebras items (2016 UK Bebras Challenge)
- Items map to two or three of the six construct domains based on consensus judgments by HumRRO team members
  - Problem Decomposition
  - Solving for Algorithms
  - Analytical Ability

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Predictor and Criterion Analyses

- Calculated score for each Shipper on:
  - CTA-M (criterion)
  - CR (predictor)
- Calculated the three CompT scores using the operational equations from Phase 1
  - CompT_AR
  - CompT_CT
  - CompT_ALL
- Computed predictor and criterion descriptive statistics
- Computed predictor and criterion reliability estimates (except AR and CT*)
- Computed predictor and criterion subgroup differences (except AR and CT*)

*For AR and CT, used existing estimates of reliability documented in psychometric checklists (Sinclair et al., 2003) and current estimates of subgroup differences for FY23 applicant data (Johnston-Fisher et al., 2024).

Predictor and Criterion Descriptives

Variable	Variable Type	Mean	Median	SD	Min	Max
CTA-M	Criterion	13.8	14.0	4.1	6	23
AR	Predictor	52.8	52.5	7.9	30	72
CT	Predictor	51.6	52.0	8.9	22	76
CR	Predictor	55.0	57.0	8.1	35	67
CompT_AR	Equation Score	162.8	167.0	20.8	103	202
CompT_CT	Equation Score	161.5	164.0	20.5	104	202
CompT_ALL	Equation Score	214.3	217.0	25.6	141	271

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Predictor and Criterion Reliabilities

Variable	Type of Variable	Reliability	
		Cronbach's Alpha	Mosier's Composite Formula
CTA-M	Criterion	0.73	—
AR*	Predictor	0.89	—
CT*	Predictor	0.70	—
CR	Predictor	0.82	—
CompT_AR	Equation Score	—	0.88
CompT_CT	Equation Score	—	0.83
CompT_ALL	Equation Score	—	0.88

*Cronbach's alpha obtained from Psychometrics Checklists as reported in Sinclair et al. (2023).

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Predictor and Criterion Subgroup Differences

Variable	Type of Variable	Cohen's *d* Effect Size			
		M-F	NHW-NHB	NHW-HW	NHW-NHA*
CTA-M	Criterion	0.28	0.54	0.19	0.35
AR	Predictor	0.25	0.43	0.10	-0.01
CT	Predictor	0.44	0.36	0.21	0.18
CR	Predictor	0.07	0.23	0.11	-0.01
CompT_AR	Equation Score	0.15	0.34	0.12	-0.01
CompT_CT	Equation Score	0.25	0.34	0.18	0.08
CompT_ALL	Equation Score	0.28	0.41	0.17	0.06

Effect Size Category	
Less than Small	<0.20
Small	0.20 – 0.49
Moderate	0.50 – 0.79

*Sample size for Non-Hispanic Asian subgroup is too small to support interpretation of effect sizes.

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Phase 2 Results

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Data Analysis Plan

- Calculate zero-order correlations between CTA-M and the three components (AR, CT, CR) in the three Computational Thinking score equations
  - Correct results for range restriction
  - Disattenuate results for criterion unreliability
- Calculate zero-order correlations between CTA-M and the three operational equation-based Computational Thinking scores developed in Phase 1
  - Correct results for range restriction
  - Disattenuate results for criterion unreliability
- Estimate empirical validity of non-negative least square (NNLS) regression equations using data from Phase 2 validation study
  - Correct results for range restriction
  - Disattenuate results for criterion unreliability
  - Adjust results for shrinkage
- Conduct post-hoc analysis to recompute estimates using all 9 ASVAB subtests, CT, and CR

Correlation of Equation Component Tests with CTA-M

Equation Component Test	Correlation with CTA-M	
	Observed	Corrected*
AR	0.48	0.71
CT	0.40	0.61
CR	0.54	0.73

*Results are corrected for multivariate range restriction and disattenuated for criterion unreliability.

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Correlation of Operational Equation-based Scores with CTA-M

Operational Equation-Based Score	Correlation with CTA-M	
	Observed	Corrected*
CompT_AR	0.61	0.81
CompT_CT	0.60	0.80
CompT_ALL	0.63	0.83

*Results are corrected for multivariate range restriction and disattenuated for criterion unreliability.

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NNLS Regression Results by Operational Equation Scores

Regression Coefficient/ Multiple R	CompT_AR		CompT_CT		CompT_ALL	
	Observed	Corrected*	Observed	Corrected*	Observed	Corrected*
AR	0.15	0.18	—	—	0.11	0.13
CT	—	—	0.12	0.15	0.09	0.09
CR	0.2	0.23	0.23	0.27	0.20	0.22
Multiple R	0.61	0.81	0.60	0.80	0.63	0.83
R Shrinkage	0.61	0.81	0.60	0.80	0.63	0.83

*Results are corrected for multivariate range restriction and disattenuated for criterion unreliability.

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Operational vs. NNLS Regression Validity Results

Computational Thinking Score	Validity Estimates			
	Operational Equations Based on Phase 1 Synthetic Validity Study		NNLS Regression Equations Based on Phase 2 Criterion-Related Validity Study	
	Observed	Corrected*	Observed	Corrected*
CompT_AR	0.61	0.81	0.61	0.81
CompT_CT	0.60	0.80	0.60	0.80
CompT_ALL	0.63	0.83	0.63	0.83

*Results are corrected for multivariate range restriction and disattenuated for criterion unreliability.

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Post-Hoc Validity Estimates with All ASVAB Subtests + CT + CR

Computational Thinking Score	Validity Estimates			
	Operational Equations Based on Phase 1 Synthetic Validity Study		NNLS Regression Equations Based on Phase 2 Criterion-Related Validity Study	
	Observed	Corrected*	Observed	Corrected*
CompT_AR	0.61	0.81	0.61	0.81
CompT_CT	0.60	0.80	0.60	0.80
CompT_ALL	0.63	0.83	0.63	0.83
Post-hoc = All ASVAB subtests + CT + CR	--	--	0.67	0.87

*Results are corrected for multivariate range restriction and disattenuated for criterion unreliability. Yellow highlights identify post-hoc results to use for comparison to empirical results for computational thinking scores (same as slide 23).

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Results Conclusion

- All three equation-based scores (CompT_AR, CompT_CT, CompT_ALL) were strong predictors of the computation thinking construct, at least as it was operationalized in the Phase 2 validity study (i.e., CTA-M)
- Empirical weights for the score components (AR, CT, CR) derived from the Phase 2 validity study did not outperform the operational weights derived from the Phase 1 synthetic validity study
- Empirical validity estimates using all ASVAB subtests, CT, and CR resulted in relatively small increases (delta R = 0.04) in prediction in CTA-M scores

Closing

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Software Updates (Completed)

- CR is available for administration on the iCAT platform
- Applicant's completion of CR triggers calculation of CompT scores
  - Requires an AR and/or CT score within the last 2 years
  - Uses most recent AR and/or CT score when multiple records are found
  - Submits a blank score if an eligible AR and/or CT score is not found
- Saves each CompT score within the applicant's CR record
- MEPCOM receives all 4 scores: CR as well as 3 CompT scores

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Questions?

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Response to June 2024 DAC Recommendation

- In process of preparing research designs for CR and CompT that DTAC may consider for future research
  - Applicant data containing one to three of the CompT scores is slowly accumulating, which will support additional analyses
    - Demographic information will likely be available for future subgroup differences research
    - Shippers' occupational training criteria may be useful for future research, should it be made available
    - ASVAB Training Relevance Survey results may be used to identify military occupations with high computational thinking relevance results to further research

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Questions to DAC

- Does the DAC have any suggestions for conducting additional research on fairness issues and/or validity?

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Thank you!

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