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Computational Thinking

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Briefing presented to the DACMPT

August 16, 2023

Briefing Agenda

- Background Information
- Phase 1 – Alignment Study
  - Design and Data Collection
  - Preliminary Analyses of SME Data
  - Potential Prediction Models to be Evaluated
- Phase 2 – Empirical Evaluation Study (Year 2)
- For Further Consideration

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Background Information

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Background

William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (HR 6395), Section 594

"Not later than one year after the date of the enactment of this Act, the Secretary of Defense shall establish a special purpose test adjunct to the Armed Services Vocational Aptitude Battery test to address computational thinking skills relevant to military applications, including problem decomposition, abstraction, pattern recognition, analytical ability, the identification of variables involved in data representation, and the ability to create algorithms and solution expressions."

Note: The date for meeting this requirement has been adjusted to October 1, 2024.

What We Know

- A measure of Computational Thinking does not currently exist within ASVAB/military testing
- NDAA timeline does not support creating a new, valid measure of Computational Thinking
- Existing ASVAB/military tests potentially measure the six (6) content domains underlying the Computational Thinking construct
- A means to assess the six (6) content domains of Computational Thinking must be operational by October 1, 2024

Objectives, Assumptions, and Considerations

Objectives

- Develop a Computational Thinking composite score from existing ASVAB subtests/military tests that can be used to inform enlisted decisions
- Deliver composite specifications to DTAC by September 30, 2023, for platform modifications
- Implement operationally by October 1, 2024

Assumptions

- Composite would complement other measures and data that Services use when making decisions during applicant screening, e.g.,
  - AFQT scores
  - Medical, physical, conduct-related data
- Focus is building a composite that will be predictive of first-term enlisted job performance

Considerations

- Intended use of Computational Thinking composite score for selection, classification, or both
- Weighting of Computational Thinking domains
  - Overall vs. occupation-specific
- Ease of implementing requirements
  - Platform modifications
  - Testing time

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Approach Overview

Phase 1—Alignment Study	Phase 2—Empirical Evaluation
▪ Collect SME judgments of estimated correlations between: • Computational Thinking content domains and ASVAB subtests/military tests • Six (6) Computational Thinking content domains • Military tests where empirical correlations do not already exist ▪ Analytically derive equation for estimating Computational Thinking composite scores from existing ASVAB subtests and military tests	▪ Collect data from military applicants/recruits (or a similar population) • Administer ASVAB subtests and military tests comprising Computational Thinking composite score equation • Administer Computational Thinking marker instrument ▪ Evaluate analytically derived equation for estimating Computational Thinking composite scores with respect to: • Score distributions • Subgroup differences • Other pertinent outcomes to be determined

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Phase 1—Alignment Study

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Key Development Steps

- **Step 1:** Define Computational Thinking construct domains from literature
- **Step 2:** Establish composite development and validation strategies
- **Step 3:** Gather ASVAB and military test information and data
  - Test descriptions, sample items, and correlations with other tests
- **Step 4:** Gather observed empirical data and SME data to support composite development
- **Step 5:** Specify potential prediction models
  - Based on operational constraints
  - Based on optimized prediction
- **Step 6:** Generate and evaluate composites from prediction models
  - Determined from Step 5 using strategies identified in Step 2
- **Step 7:** Deliver interim composite by September 30th for integration into ASVAB delivery platform
  - Implementation will occur by October 1, 2024
- **Step 8:** Empirical evaluation of interim composite (Phase 2 during Year 2)

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Step 1: Define 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

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Step 1: Define Computational Thinking Construct Domains

Construct Domains	Descriptions
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

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Step 2: Establish Composite Development and Validation Strategies

- Build an intercorrelation matrix among 6 Computational Thinking (CompT) construct domains and a correlation matrix of CompT domains for ASVAB subtests/military tests based on correlation estimates from participating SMEs
- Build a correlation matrix of all ASVAB subtests and military tests of interest based on observed empirical correlation estimates obtained from prior research or correlation estimates from participating SMEs (when empirical data were not available)
- Use these data to simulate n = 1,000 “population” correlation matrices
  - Multiple potential populations that reflect uncertainty due to variation in SME estimates
- Calculate CompT criterion variable by applying unit weights to each CompT construct domain in each sample
- Specify prediction models
  - Ordinary Least Square (OLS)—finds the regression coefficients that minimize sum of squared errors of prediction
  - Non-negative Least Squares (NNLS)—finds the regression coefficients that minimize sum of squared errors of prediction when constraining the coefficients to be non-negative (positive)
  - Least Absolute Shrinkage and Selection Operator (Lasso)—a regularized regression model that performs variable selection
- Run regression models using simulated predictor-criterion correlation data to calculate regression weights with 95% confidence interval
- Compare models with regard to estimated prediction of CompT construct

Step 3: Gather ASVAB and Military Test Information and Data

ASVAB Subtests	Military Tests	New ASVAB Test
Arithmetic Reasoning (AR)	Cyber Test (CT)	Complex Reasoning (CR)**
Mathematical Knowledge (MK)	Coding Speed (CS)	
Paragraph Comprehension (PC)	Mental Counters Test (MCt)	
Word Knowledge (WK)	Electronics Data Processing Test (EDPT)*	
Auto/Shop Information (AS)		
Electronics Information (EI)		
General Science (GS)		
Mechanical Comprehension (MC)		
Assembling Objects (AO)		

* Electronics Data Processing Test (EDPT) is administered by the Air Force. It is not integrated into the ASVAB delivery platform nor are there plans to do so currently.
** Complex Reasoning Test is currently being researched and developed by DTAC/HumRRO team. It has not been integrated into the ASVAB delivery platform to date.

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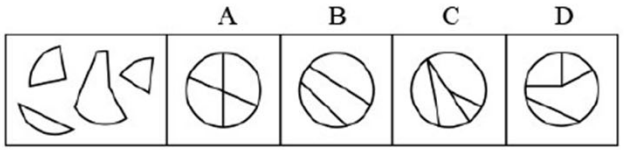
Step 3: Gather ASVAB and Military Test Information and Data

Assembling Objects (AO)		
A measure of spatial orientation that asks participants to determine how an object will look when its parts or connection points are assembled together. Refer to pages 17 and 18 for content areas, descriptions, and sample items.		
Content Area	**Content Description**	**Sample Item**
Puzzles	Determining how an object will look when its parts are assembled together	Which figure best shows how the objects in the left box will appear if they are fit together?  ☐ A ☐ B ☐ C ☐ D

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Step 3: Gather ASVAB and Military Test Information and Data

Cyber Test (CT)		
A measure of basic knowledge in the areas of computer operations, networking and telecommunications, security and compliance and software programming and web design. Refer to pages 19 and 20 for content areas, descriptions, and sample items.		
Content Area	**Content Description**	**Sample Item**
Security and Compliance (SC)	Measures knowledge of telecommunication protocols, vulnerabilities, threats, and encryption methods	What is the name for a malicious program that self-replicates as it spreads to other computers and can be used by hackers to create backdoors? A. Worm B. Trojan horse C. Logic bomb D. Virus
Software Programming & Web Development (SPWD)	Measures knowledge of basic language constructs, and ability to write, modify, execute, and interpret simple scripts	In computer programming, an "if ... then ... else ..." statement supports selection from only two alternatives. Which type of statement can be used to allow selection from many alternatives, where each is linked to a predicate that when evaluated as true, an associated action will be executed? A. Case statement B. Call statement C. Block statement D. Function statement

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Step 4: Gather Observed Empirical Data & SME Data to Support Composite Development

- Obtained empirical correlation estimates for the 91 ASVAB subtest/military test pairings, where data existed (see below regarding missing data)
- Consulted with 11 external Ph.D. researchers with expertise in cognitive ability, job performance relations, and job performance constructs to estimate three sets of correlations
  - Correlations among each of the 6 CompT domains (slide 17)
  - Correlations for the 18 (out of 91) ASVAB subtest/military test pairings that were missing empirical correlation estimates (slide 18)
  - Correlations between the 14 ASVAB subtests/military tests and 6 CompT construct domains (slides 19–22)

Step 4: SME Estimated Correlations Between CompT Domains

Computational Thinking Domain	1	2	3	4	5	6
1. Problem decomposition						
2. Abstraction	0.61					
3. Pattern recognition	0.56	0.61				
4. Analytical ability	0.60	0.58	0.60			
5. Identifying variables for data representation	0.59	0.54	0.54	0.59		
6. Creating algorithms and solution expressions	0.62	0.51	0.50	0.58	0.61	

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Step 4: Observed and SME-Estimated Correlations Between all ASVAB Subtests and Military Tests

Test	AFQT				Science and Technical					Special Tests				New
	AR	MK	PC	WK	AS	EI	GS	MC	AO	CT	CS	McT	EDPT	CR
Arithmetic Reasoning (AR)	--													
Math Knowledge (MK)	0.74	--												
Paragraph Comprehension (PC)	0.64	0.53	--											
Word Knowledge (WK)	0.56	0.44	0.75	--										
Auto and Shop Information (AS)	0.35	0.10	0.38	0.43	--									
Electronics Information (EI)	0.53	0.35	0.58	0.63	0.71	--								
General Science (GS)	0.61	0.52	0.70	0.76	0.51	0.70	--							
Mechanical Comprehension (MC)	0.66	0.63	0.62	0.60	0.63	0.72	0.70	--						
Assembling Objects (AO)	0.55	0.48	0.45	0.37	0.29	0.41	0.44	0.58	--					
Cyber Test (CT)	0.54	0.45	0.58	0.62	0.38	0.61	0.61	0.56	0.37	--				
Coding Speed (CS)	0.38	0.37	0.39	0.33	0.04	0.15	0.22	0.21	0.27	0.29	--			
Mental Counters (MCt)	0.51	0.43	0.39	0.35	0.27	0.35	0.38	0.47	0.43	0.35	0.35	--		
Electronic Data Processing Test (EDPT)	0.55	0.46	0.37	0.36	0.19	0.27	0.41	0.45	0.38	0.42	0.31	0.46	--	
Complex Reasoning (CR)	0.53	0.49	0.47	0.41	0.31	0.36	0.39	0.52	0.50	0.42	0.31	0.44	0.60*	--

Blue cells = Average correlation estimates across 11 SMEs who participated in the current study (*Average correlation estimate based on 10 SMEs)
White cells = Observed empirical correlation estimates obtained from prior research conducted by DTAC/Services

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Step 4: SME-Estimated Correlations Between Military Tests & CompT Domains

Pair #	AFQT Subtest	Computational Thinking Domain	Estimated Correlation
1-1	Arithmetic Reasoning (AR)	Problem decomposition	0.54
1-2	Arithmetic Reasoning (AR)	Abstraction	0.52
1-3	Arithmetic Reasoning (AR)	Pattern recognition	0.50
1-4	Arithmetic Reasoning (AR)	Analytical ability	0.56
1-5	Arithmetic Reasoning (AR)	Identifying variables for data representation	0.54
1-6	Arithmetic Reasoning (AR)	Creating algorithms and solution expressions	0.54
2-1	Mathematics Knowledge (MK)	Problem decomposition	0.44
2-2	Mathematics Knowledge (MK)	Abstraction	0.50
2-3	Mathematics Knowledge (MK)	Pattern recognition	0.43
2-4	Mathematics Knowledge (MK)	Analytical ability	0.47
2-5	Mathematics Knowledge (MK)	Identifying variables for data representation	0.48
2-6	Mathematics Knowledge (MK)	Creating algorithms and solution expressions	0.46
3-1	Paragraph Comprehension (PC)	Problem decomposition	0.48
3-2	Paragraph Comprehension (PC)	Abstraction	0.50
3-3	Paragraph Comprehension (PC)	Pattern recognition	0.44
3-4	Paragraph Comprehension (PC)	Analytical ability	0.44
3-5	Paragraph Comprehension (PC)	Identifying variables for data representation	0.38
3-6	Paragraph Comprehension (PC)	Creating algorithms and solution expressions	0.37
4-1	Word Knowledge (WK)	Problem decomposition	0.36
4-2	Word Knowledge (WK)	Abstraction	0.40
4-3	Word Knowledge (WK)	Pattern recognition	0.39
4-4	Word Knowledge (WK)	Analytical ability	0.40
4-5	Word Knowledge (WK)	Identifying variables for data representation	0.33
4-6	Word Knowledge (WK)	Creating algorithms and solution expressions	0.33

$\bar{r}_{AR} = .53$

$\bar{r}_{MK} = .46$

$\bar{r}_{PC} = .44$

$\bar{r}_{WK} = .37$

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Step 4: SME-Estimated Correlations Between Military Tests & CompT Domains

Pair #	Science & Technical Subtest	Computational Thinking Domain	Estimated Correlation
5-1	Auto and Shop Information (AS)	Problem decomposition	0.31
5-2	Auto and Shop Information (AS)	Abstraction	0.30
5-3	Auto and Shop Information (AS)	Pattern recognition	0.29
5-4	Auto and Shop Information (AS)	Analytical ability	0.31
5-5	Auto and Shop Information (AS)	Identifying variables for data representation	0.25
5-6	Auto and Shop Information (AS)	Creating algorithms and solution expressions	0.27
6-1	Electronics Information (EI)	Problem decomposition	0.34
6-2	Electronics Information (EI)	Abstraction	0.33
6-3	Electronics Information (EI)	Pattern recognition	0.32
6-4	Electronics Information (EI)	Analytical ability	0.31
6-5	Electronics Information (EI)	Identifying variables for data representation	0.28
6-6	Electronics Information (EI)	Creating algorithms and solution expressions	0.30
7-1	General Science (GS)	Problem decomposition	0.39
7-2	General Science (GS)	Abstraction	0.39
7-3	General Science (GS)	Pattern recognition	0.37
7-4	General Science (GS)	Analytical ability	0.36
7-5	General Science (GS)	Identifying variables for data representation	0.34
7-6	General Science (GS)	Creating algorithms and solution expressions	0.35
8-1	Mechanical Comprehension (MC)	Problem decomposition	0.44
8-2	Mechanical Comprehension (MC)	Abstraction	0.47
8-3	Mechanical Comprehension (MC)	Pattern recognition	0.43
8-4	Mechanical Comprehension (MC)	Analytical ability	0.42
8-5	Mechanical Comprehension (MC)	Identifying variables for data representation	0.39
8-6	Mechanical Comprehension (MC)	Creating algorithms and solution expressions	0.39
9-1	Assembling Objects (AO)	Problem decomposition	0.45
9-2	Assembling Objects (AO)	Abstraction	0.45
9-3	Assembling Objects (AO)	Pattern recognition	0.55
9-4	Assembling Objects (AO)	Analytical ability	0.47
9-5	Assembling Objects (AO)	Identifying variables for data representation	0.38
9-6	Assembling Objects (AO)	Creating algorithms and solution expressions	0.36

$\bar{r}_{AS} = .29$

$\bar{r}_{EI} = .31$

$\bar{r}_{GS} = .37$

$\bar{r}_{MC} = .42$

$\bar{r}_{AO} = .44$

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Step 4: SME-Estimated Correlations Between Military Tests & CompT Domains

Pair #	Special Test	Computational Thinking Domain	Estimated Correlation
10-1	Cyber Test (CT)	Problem decomposition	0.36
10-2	Cyber Test (CT)	Abstraction	0.39
10-3	Cyber Test (CT)	Pattern recognition	0.33
10-4	Cyber Test (CT)	Analytical ability	0.37
10-5	Cyber Test (CT)	Identifying variables for data representation	0.33
10-6	Cyber Test (CT)	Creating algorithms and solution expressions	0.34
11-1	Coding Speed (CS)	Problem decomposition	0.32
11-2	Coding Speed (CS)	Abstraction	0.29
11-3	Coding Speed (CS)	Pattern recognition	0.38
11-4	Coding Speed (CS)	Analytical ability	0.28
11-5	Coding Speed (CS)	Identifying variables for data representation	0.24
11-6	Coding Speed (CS)	Creating algorithms and solution expressions	0.26
12-1	Mental Counters Test (MCt)	Problem decomposition	0.34
12-2	Mental Counters Test (MCt)	Abstraction	0.34
12-3	Mental Counters Test (MCt)	Pattern recognition	0.38
12-4	Mental Counters Test (MCt)	Analytical ability	0.37
12-5	Mental Counters Test (MCt)	Identifying variables for data representation	0.33
12-6	Mental Counters Test (MCt)	Creating algorithms and solution expressions	0.38
13-1	Electronic Data Processing Test (EDPT)	Problem decomposition	0.58
13-2	Electronic Data Processing Test (EDPT)	Abstraction	0.61
13-3	Electronic Data Processing Test (EDPT)	Pattern recognition	0.63
13-4	Electronic Data Processing Test (EDPT)	Analytical ability	0.63
13-5	Electronic Data Processing Test (EDPT)	Identifying variables for data representation	0.59
13-6	Electronic Data Processing Test (EDPT)	Creating algorithms and solution expressions	0.56

$\bar{r}_{CT} = .35$

$\bar{r}_{CS} = .29$

$\bar{r}_{MCt} = .36$

$\bar{r}_{EDPT} = .60$

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Step 4: SME-Estimated Correlations Between Military Tests & CompT Domains

Pair #	New Test	Computational Thinking Domain	Estimated Correlation
14-1	Complex Reasoning (CR)	Problem decomposition	0.56
14-2	Complex Reasoning (CR)	Abstraction	0.59
14-3	Complex Reasoning (CR)	Pattern recognition	0.64
14-4	Complex Reasoning (CR)	Analytical ability	0.57
14-5	Complex Reasoning (CR)	Identifying variables for data representation	0.53
14-6	Complex Reasoning (CR)	Creating algorithms and solution expressions	0.54

$\bar{r}_{CR} = .57$

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Step 5: Specify Potential Prediction Models

Model	AR	MK	PC	WK	AS	EI	GS	MC	AO	CT	McT	CS	EDPT	CR
Model 1 (All tests included) a. OLS b. NNLS	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Model 2 (All tests except EDPT) a. OLS b. NNLS	X	X	X	X	X	X	X	X	X	X	X	X		X

Note: Given that EDPT is not currently on the ASVAB delivery platform nor are there plans to administer the test through the ASVAB platform, a comparison of models with and without EDPT seems important.
OLS = Ordinary Least Squares regression; NNLS = Non-Negative Least Squares regression

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Step 5: Specify Potential Prediction Models

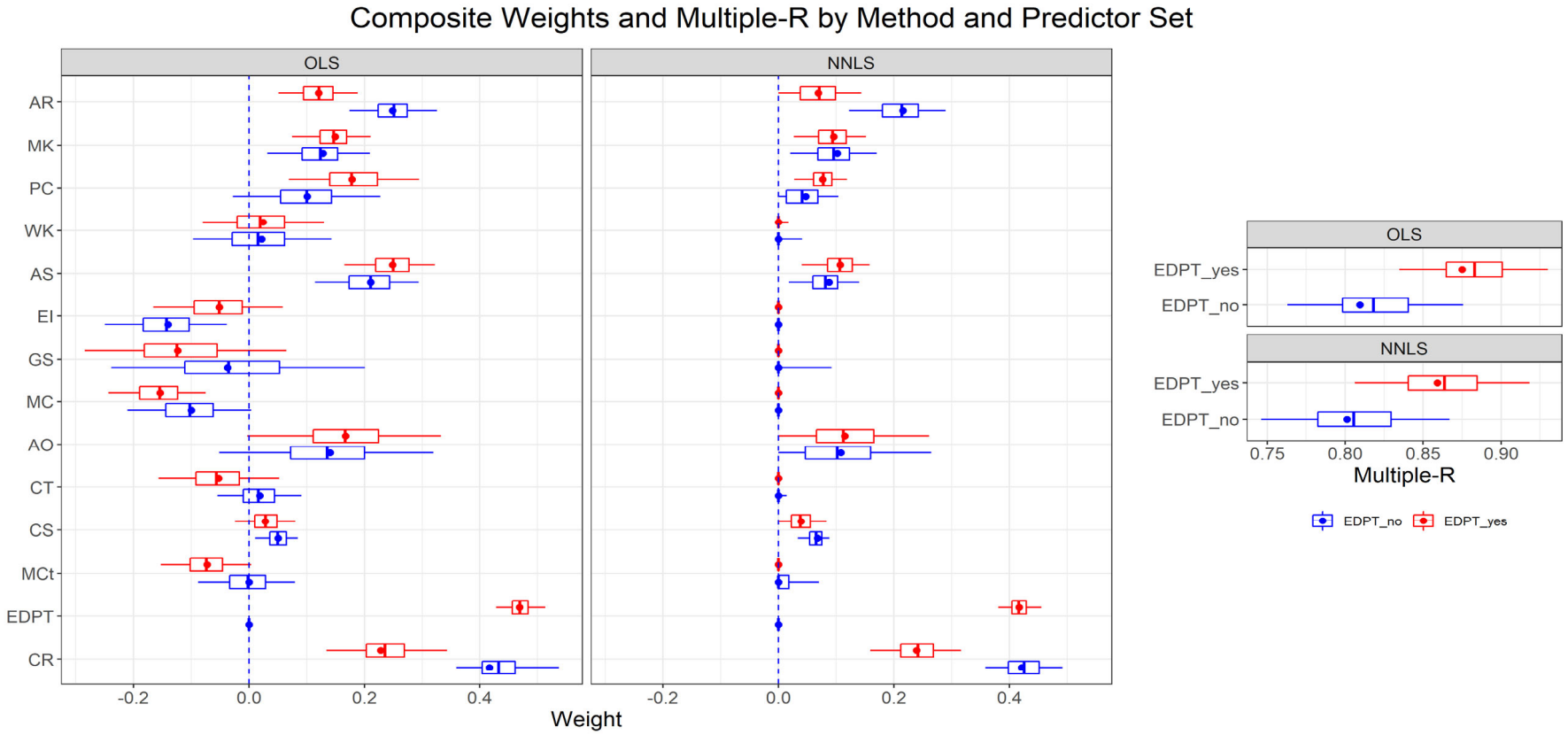
- Data-driven selection of predictors specified using lasso regression to establish a parsimonious equation for estimating CompT composite scores
  - Start with 13 predictors (all tests except EDPT) specified in Model 2
  - Potential to run “constrained” lasso models based on policy-type decisions, as appropriate (e.g., include a particular predictor to be included or excluded in the model)

Step 6: Generate and Evaluate Composites from Prediction Models

- Generate and evaluate CompT composite scores estimated from prediction models specified in Step 5
  - Identify ASVAB subtests/military tests that tend to remain in the model as lasso constraint becomes more stringent
  - Compare tradeoffs between number of tests and level of prediction, taking into consideration questions such as:
    - Are tests within most predictive model(s) administered to all applicants?
    - Are tests within most predictive model(s) used by all Services for enlistment/classification?
    - Are tests within most predictive model administered within ETP and CEP (vs. ETP only)?
    - Are there policy changes to be considered?

Note: The work described on this slide will be conducted during the summer of 2023. Therefore, the results from the analyses above are not available for inclusion in this slide presentation.

Step 6: Preliminary Findings for Models 1 and 2*



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*Model 1 = all tests included. Model 2 = all tests except EDPT.

Step 7: Deliver, Integrate, and Implement Composite

Deliver interim composite	September 30, 2023
Integrate into ASVAB delivery platform	October 1, 2023 – September 30, 2024
Operational implementation	October 1, 2024

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Step 8: Empirical Evaluation of Interim Composite (Phase 2)

- Validate CompT composite scores estimated from the analytically derived equation developed in Alignment Study (Phase 1) against Computational Thinking marker instrument(s)
  - Using military applicants/recruits (or similar population)
- Evaluate the CompT composite score with respect to:
  - Score distributions
  - Subgroup differences
  - Other pertinent outcomes to be determined

Note: Empirical evaluation of interim composite is Phase 2 of this project and is scheduled to begin after the Alignment Study (Phase 1) is completed at the end of September 2023.

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For Further Consideration

- Perspectives regarding potential tradeoffs between OLS (positive and negative) regression weights for predictors versus constraining regression weights to be positive (i.e., NNLS), taking into consideration:
  - Multicollinearity among predictors
  - Stakeholder perceptions associated with having negative weight(s) applied to test score(s)
- Perspectives regarding potential tradeoffs between administering the Complex Reasoning test in the battery versus as a special test, taking into consideration:
  - Testing time
  - Uses of test by Services

Thank you!

For more information
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