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The Effects of the Assessed Perceptions of MBSE on Adoption

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Why Systems Engineering?

- “Modern systems engineering emerged during and immediately following World War II as weapons grew into weapons systems, due to the complexity in design, development and deployability” (Hoban 1993)
- The motivation of SE is to enable the realization, operation, maintenance, and disposal of systems (a collection of components and/or components and their relationships that provide a function that cannot be done by any of the constituent elements individually) that meets stakeholder needs and requirements by completing a series of defined technical and management processes throughout the system life cycle
- **SE is a mature discipline that has evolved over decades of use and refinement**

Systems Engineering Challenges

- Increased complexity due to software-centric nature of modern systems
- Continued systems failures in modern, complex systems are often a result of:
  - Insufficient communication between stakeholders
  - Outdated, incomplete, or inconsistent specifications and requirements
- Immature understanding of underlying systems science
  - What constitutes a good system?
  - Heuristic based vs. Scientific based
- Process overhead in agile world
  - “We are doing too much systems engineering when it isn't needed”
  - “We aren't doing the ‘right type’ of systems engineering”

Model-Based Systems Engineering (MBSE)

"The formalized application of modeling to support system requirements, design, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases"

MBSE Benefits

- MBSE enhances the ability to capture, analyze, share, and manage the information associated with the complete specification of a product, resulting in the following benefits:
  - **Improved communications** facilitated by models that can be evaluated for consistency, completeness, correctness
  - **Improved ability to cope with complexity** in systems and to analyze change impacts
  - **Improved system quality**
  - **Improved knowledge capture and reuse** leading to reduced cycle time and lower maintenance costs
  - **Improve capacity to teach and learn SE**, to integrate new team members, to minimize loss of knowledge as team members leave, to establish shared mental models

MBSE Adoption Challenges

- We are still referring to this approach as “model-based systems engineering” instead of simply “systems engineering”
- Adoption Challenges:
  - Technical
    - Lack of standardization and interoperability amongst tools
    - Challenges integrating tools in legacy environments
  - Cultural
    - Overcoming the perception that MBSE is the latest fad
    - Stakeholders uncomfortable with new technologies
    - Uncomfortable learning curve
  - Economic
    - Initial investment to purchase tools and train people
    - New technology presents unknown perceived and/or actual risks (cost, schedule, and performance)

Current Systems Engineering Reality

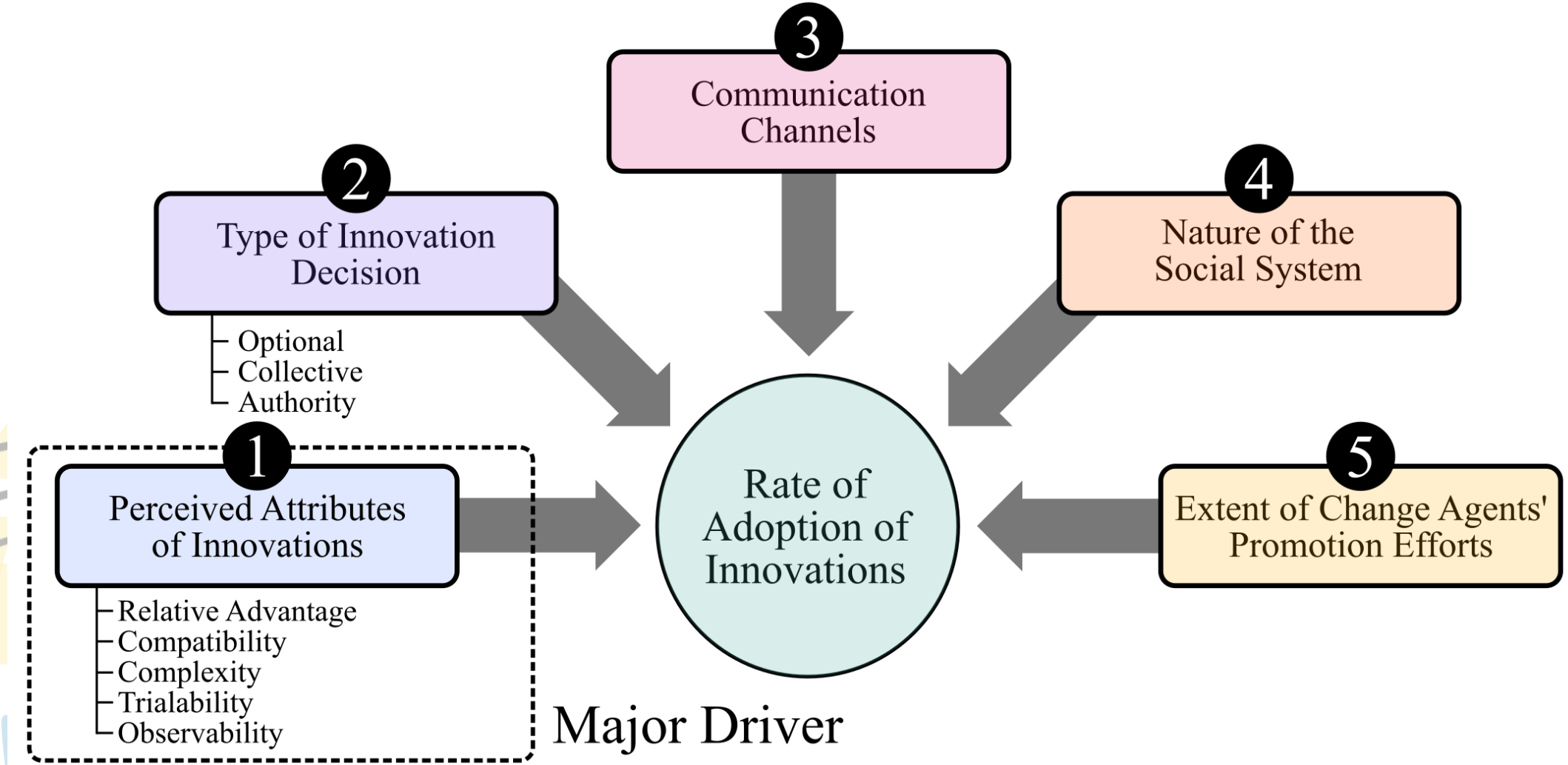
- Systems engineering is important and provides value
- The practice of systems engineering is facing challenges associated with modern, complex systems
- There is ample evidence that MBSE is well-suited to meet systems engineering challenges
- MBSE is not being widely adopted

Now what?

Diffusion of Innovations (DoI) Theory

- First edition of the *Diffusion of Innovations* published in 1962 by rural sociologist Everett Rogers– Fifth edition published in 2003
- Developed to understand why some innovations achieved rapid, widespread adoption while others were adopted more slowly, narrowly, or not at all
- **Innovation-** "an idea, practice, or object that is perceived as new by an individual or other unit of adoption
- **Diffusion-** "the process in which an innovation is communicated through certain channels over time among the members of a social system."

Adoption Rate Variables



Perceived Attributes

Attribute	Definition
Relative Advantage	The degree to which an innovation is perceived as being better than the idea it supersedes
Compatibility	The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters
Complexity	The degree to which an innovation is perceived as relatively difficult to understand and use
Trialability	The degree to which an innovation may be experimented with on a limited basis
Observability	The degree to which the results of an innovation are visible to others

MBSE Attribute Assessment

- Warming up questions
- Perceived attributes of innovations
  - 18 statements with a 5-point Likert scale for response
  - Question breakdown
    - Relative advantage- 5
    - Compatibility- 3
    - Complexity- 5
    - Trialability- 3
    - Observability- 2
- Model-use
  - Based on INCOSE model-based capability matrix (MBCM)
- Demographics
  - Organization Size
  - Formal systems engineering plan (model or document based)
  - Digital engineering mandates
  - Experience

Model-Based Systems Engineering (MBSE) Attribute Assessment

Informed Consent

Dear Participant,
My name is Daniel Call, and I am a researcher from Colorado State University (CSU) in the Systems Engineering department. We are conducting a research study on perceptions of attributes of model-based systems engineering (MBSE). The title of our project is MBSE Attribute Perception Assessment. The Principal Investigator is Daniel Herber, also from the CSU Systems Engineering department, and I am the Co-Principal Investigator.

We would like you to take an anonymous online survey. Participation will take approximately 15 minutes. Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participation at any time without penalty. There are no known risks associated with this study.

We will not collect your name or personal identifiers. Anonymous data collected as a part of this survey may be used in future research studies or distributed to another investigator without additional consent. When we report and share the data to others, we will combine the data from all participants. While there are no direct benefits to you, we hope to gain more knowledge on the factors that affect the adoption rate of MBSE.

To indicate your consent to participate in this research and to continue to the survey, please click "Next Page" button below.

If you have any questions about the research, please contact Daniel Call at daniel.call@colostate.edu. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: CSU_IRB@colostate.edu; 970-491-1553.

Thank you for your participation in this research-- your help is greatly appreciated!

Daniel Call	Daniel Herber
Co-Principal Investigator	Principal Investigator

Survey Results

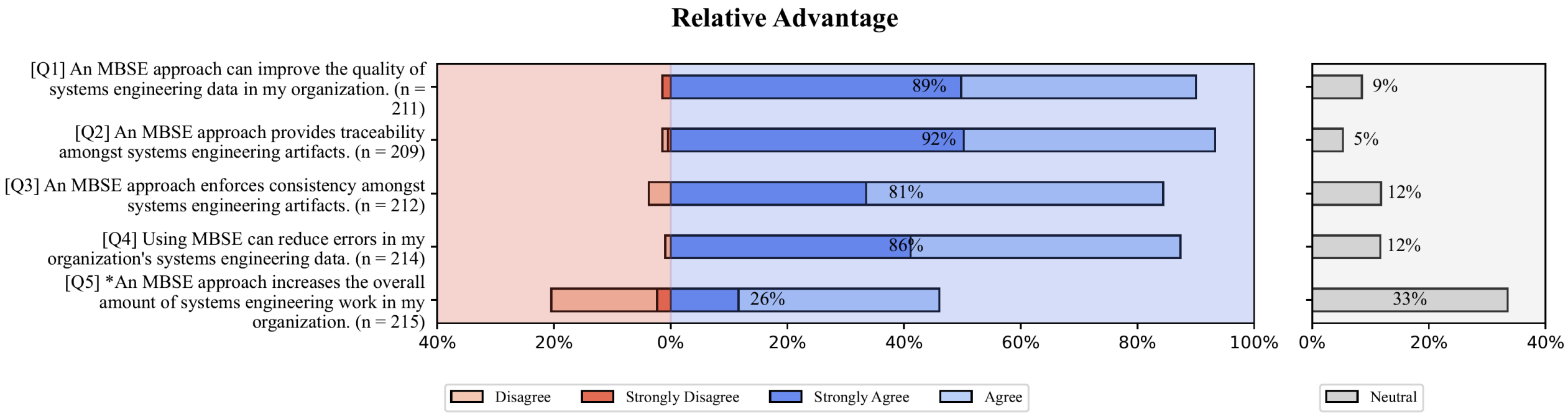
- The survey was open for responses from June 15, 2023, to September 15, 2023
  - Link and QR code were distributed via email, social media, posts in collaboration channels (MS Teams), and shared in person
- Received 270 responses, of which 193 were complete responses

Please consider assisting in my research by using this QR code to complete and share a brief survey on the perceptions of model-based systems engineering (MBSE).

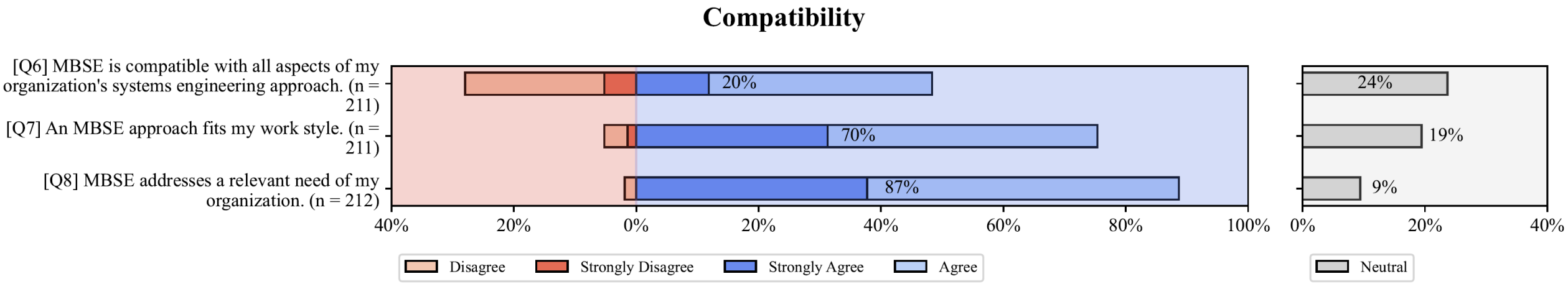
Net Agreement Score (NAS)

NAS = (% Strongly Agree + % Agree) − (% Strongly Disagree + % Disagree)

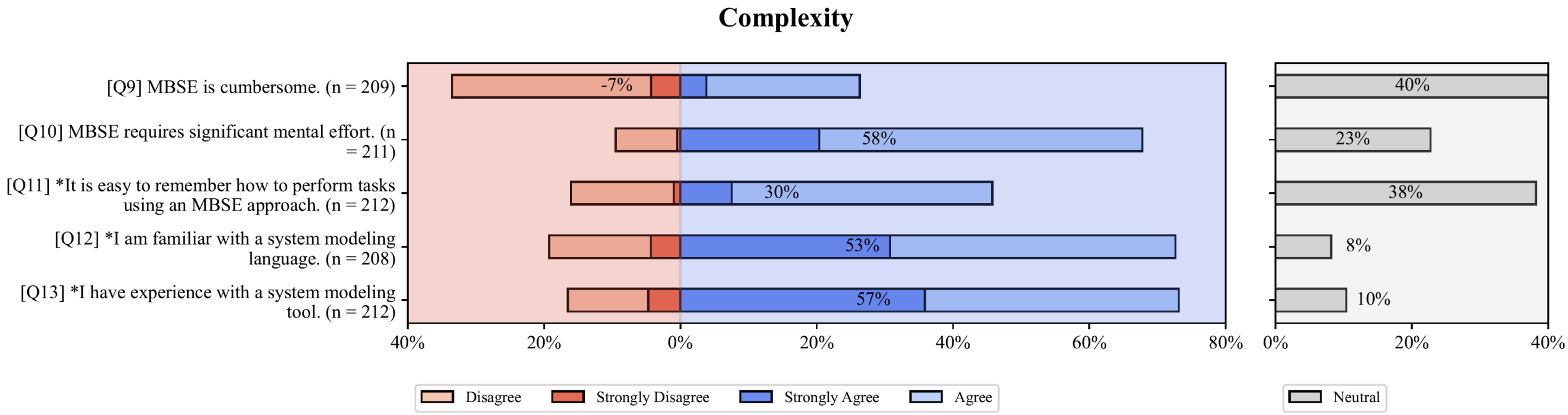
Attributes- Relative Advantage



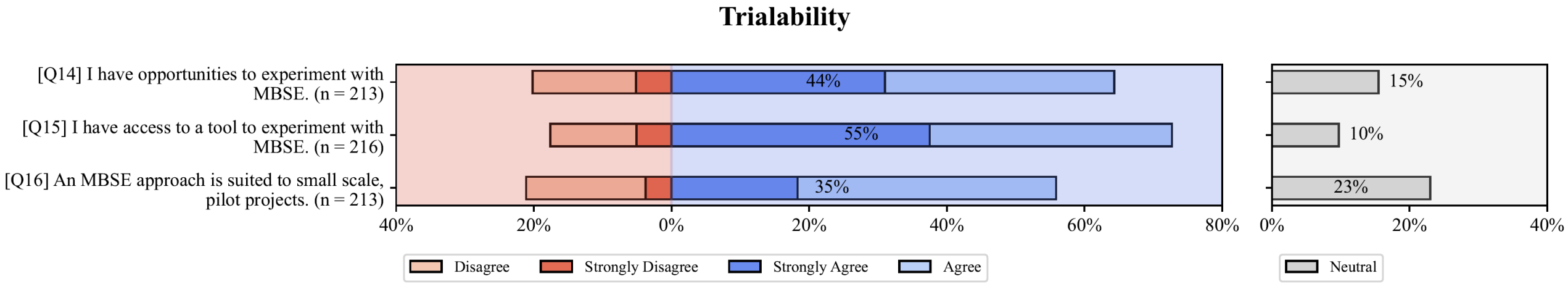
Attributes- Compatibility



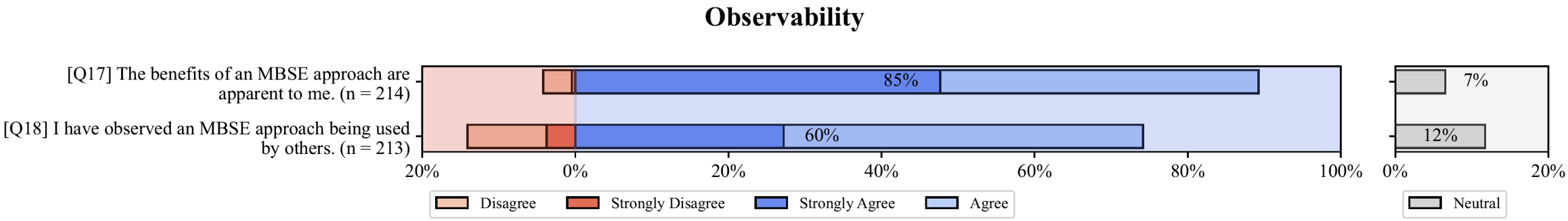
Attributes- Complexity



Attributes- Trialability



Attributes- Observability



Subpopulation- MBSE Involvement

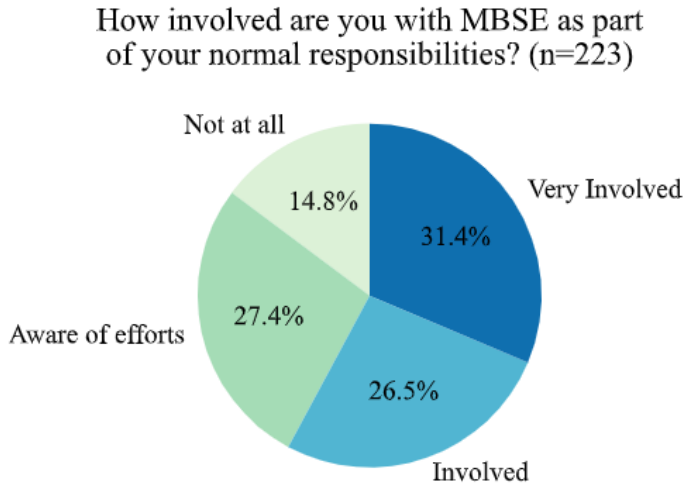
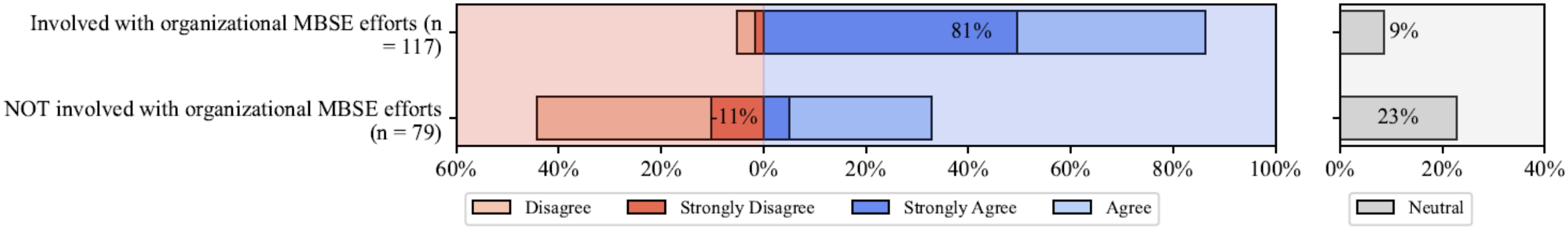


Table 6. Significant results ($p < 0.05$) of the comparison of the subpopulations "Involved with organizational MBSE efforts" and "NOT involved with organizational MBSE efforts" (sorted by the delta between the net agreement score (NAS) of the populations, largest to smallest).

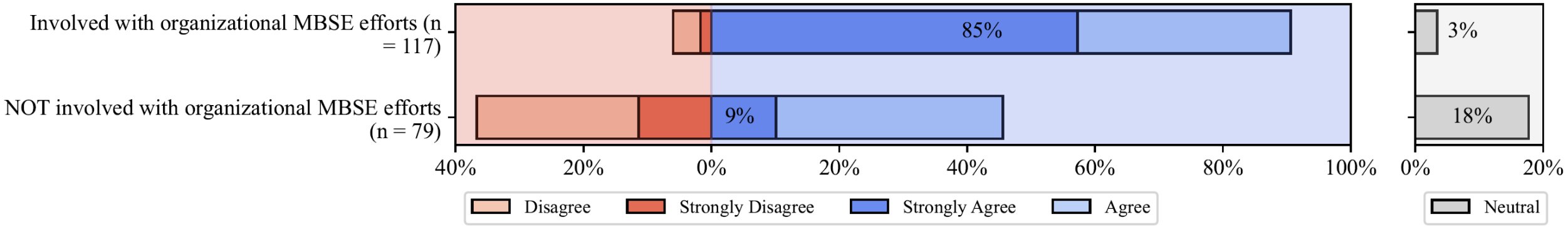
Question Tag	"Involved with organizational MBSE efforts" NAS	"NOT involved with organizational MBSE efforts" NAS	Delta NAS	Test	p-Value
Q14	81.2%	-11.4%	92.6%	χ^2	0.000
Q15	84.6%	8.9%	75.8%	χ^2	0.000
Q13	87.2%	12.7%	74.5%	χ^2	0.000
Q12	82.9%	11.4%	71.5%	χ^2	0.000
Q18	80.3%	30.4%	50.0%	χ^2	0.000
Q6	35.9%	- 5.1%	41.0%	χ^2	0.000
Q7	84.6%	46.8%	37.8%	FE	0.003
Q11	39.3%	12.7%	26.7%	χ^2	0.001
Q17	93.2%	70.9%	22.3%	FE	0.028
Q16	41.9%	21.5%	20.4%	χ^2	0.011
Q8	93.2%	77.2%	15.9%	FE	0.021

Subpopulation- MBSE Involvement

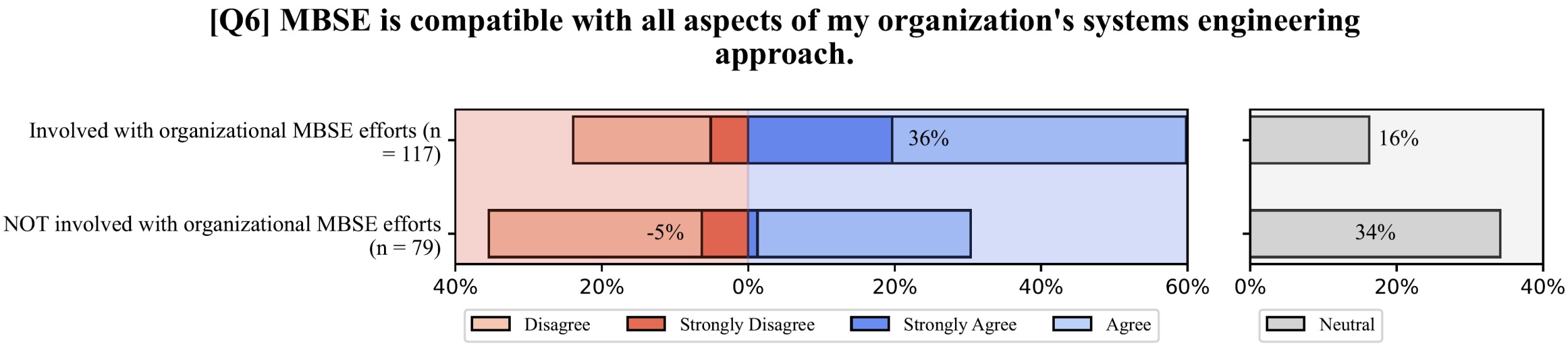
[Q14] I have opportunities to experiment with MBSE.



[Q15] I have access to a tool to experiment with MBSE.



Subpopulation- MBSE Involvement



Major Takeaways

- Potential adopters recognize the **relative advantage** of a model-based systems engineering approach– the DoI theory suggests that further emphasis of this point is not likely to substantially improve MBSE adoption
- The DoI theory suggests that an emphasis on improving the perceived **complexity**, **compatibility**, and **trialability** of MBSE is more likely to drive an improvement in MBSE adoption
- The imminent release of SysML v2 presents a prime opportunity to reframe perceptions of MBSE generally and should be leveraged to improve MBSE adoption

Want to know more?

- “Characterizing and Improving the Adoption Rate of Model-Based Systems Engineering through an Application of the Diffusion of Innovations Theory”

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