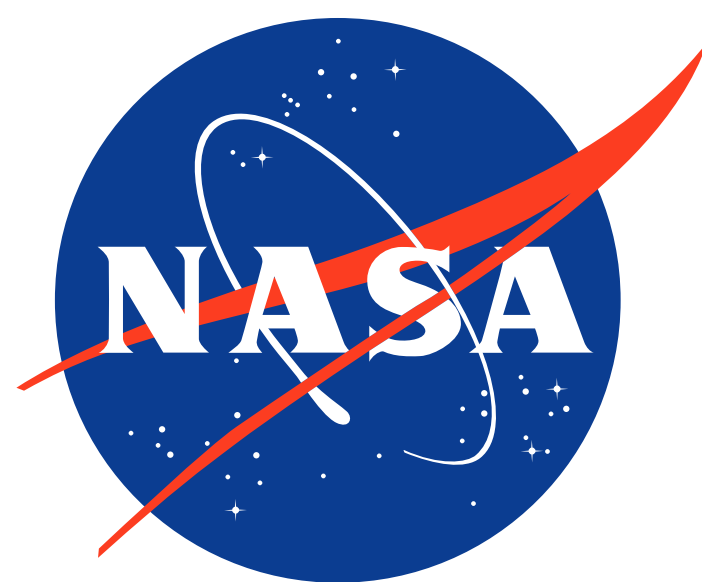




Pathfinder Networks for Measuring Operator Mental Model Structure with a Simple Autopilot System

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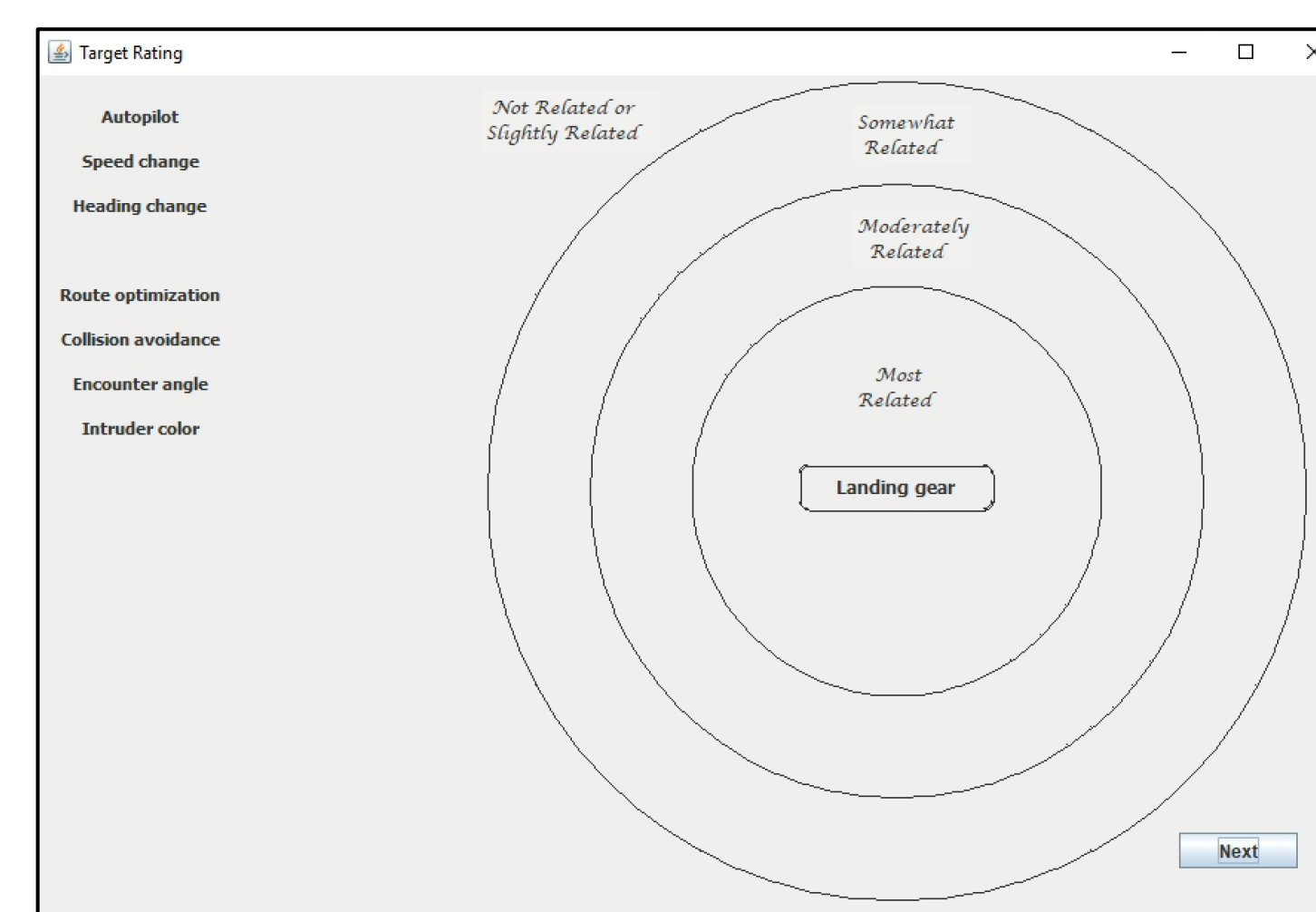
Introduction

- Humans may not fully understand functions of *increasingly autonomous systems* such as aircraft automation for **Advanced Air Mobility** (National Academies of Sciences, Engineering, and Medicine, 2020).
- Mental models** represent operators' internal knowledge of complex systems. Mental models can be defined as:
 - "the mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" (Rouse & Morris, 1986, p. 351).
- Pathfinder network analysis** is one method that allows researchers to externalize mental models by visualizing and analyzing networks of elicited concepts based on proximity data (Schvaneveldt et al., 1989).
 - Pathfinder network analysis uses subjective pairwise comparison ratings as proximity data. The **Target Rating method** is a method for efficiently collecting comparison ratings (Tossell et al., 2010).

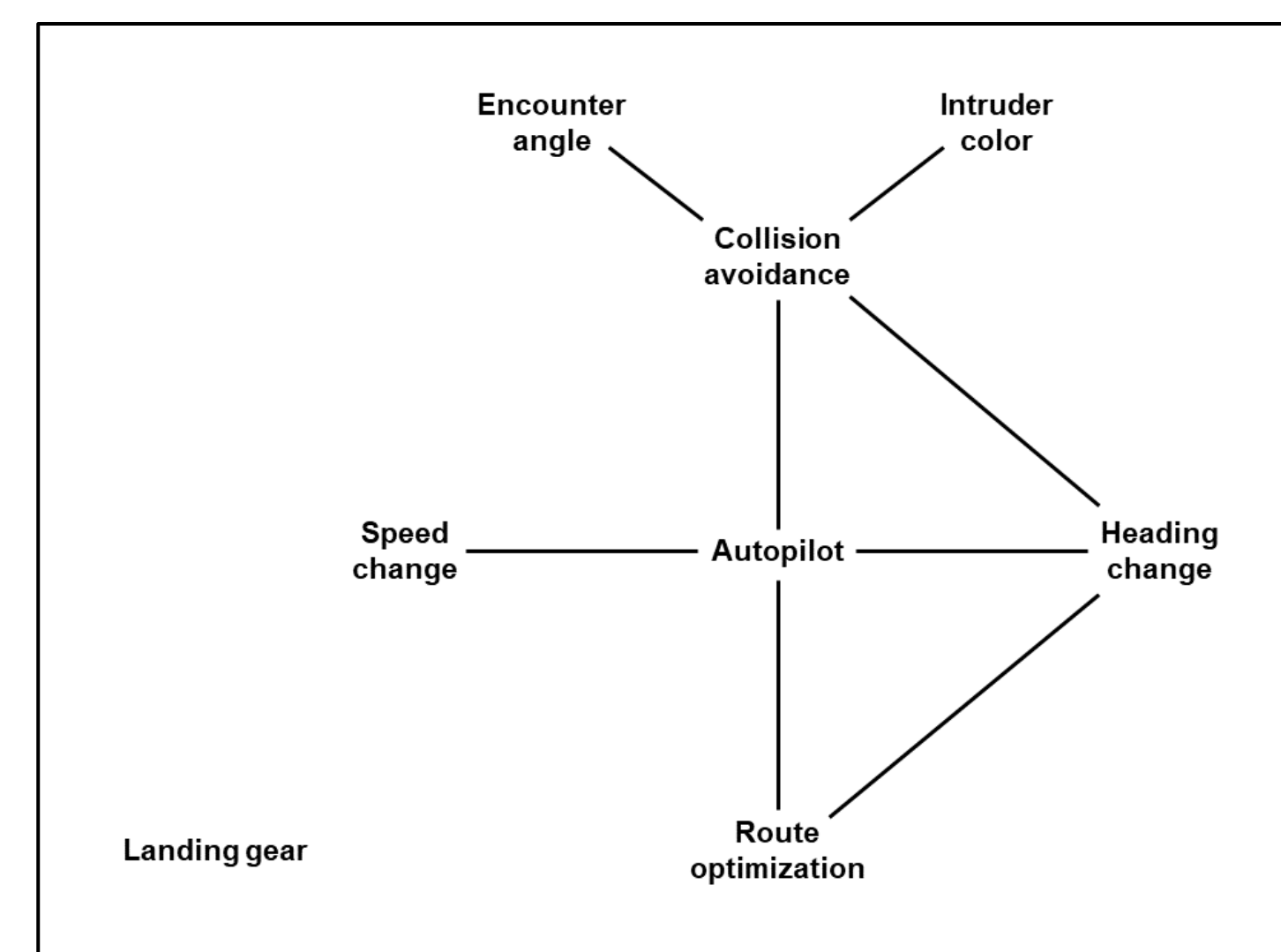
Purpose

This experiment examines the effectiveness of a mock training program for the functionality of a simple autopilot system on participants' mental models using Pathfinder network analysis.

Method



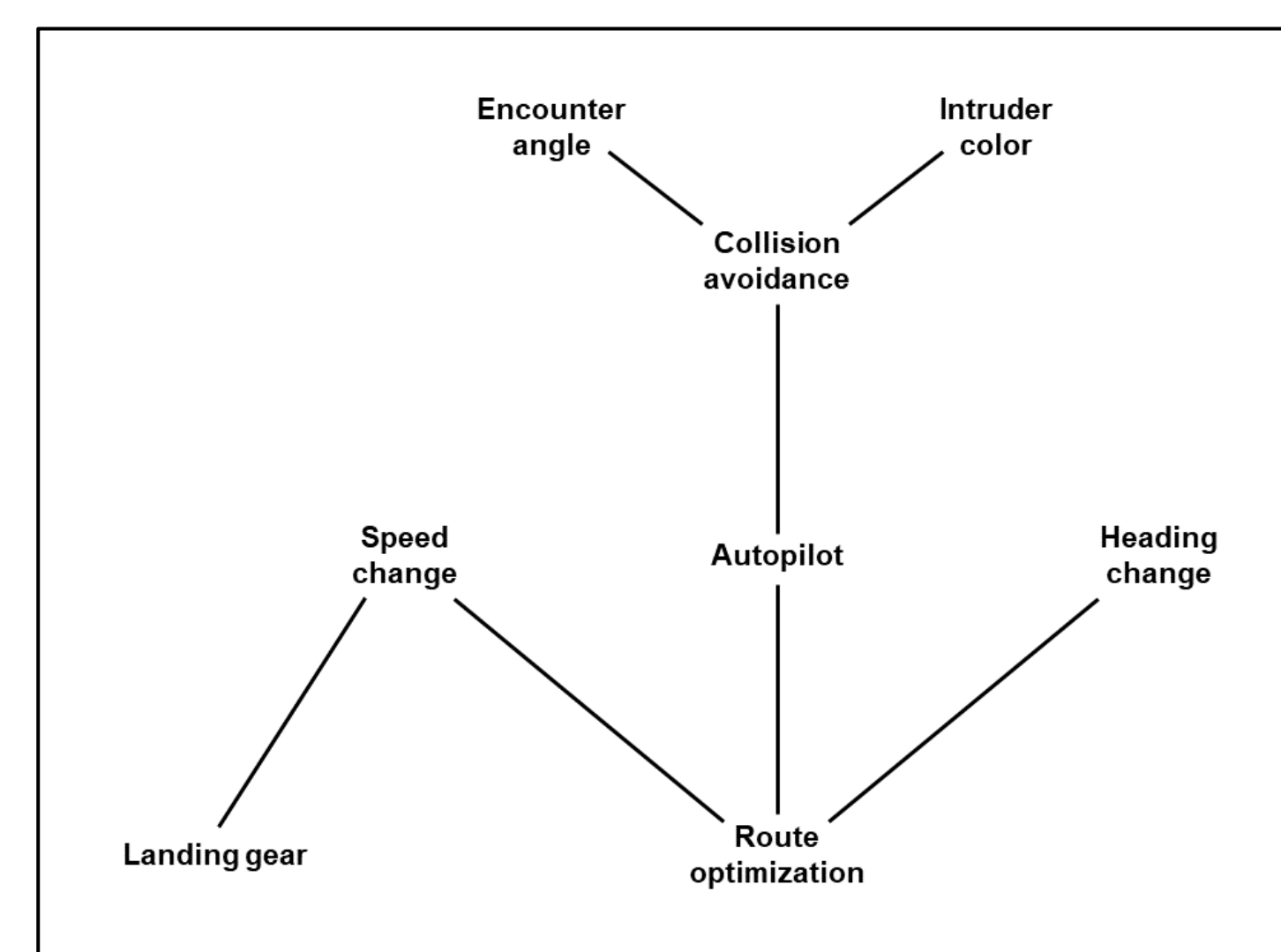
Target Rating method user interface (JRating software)



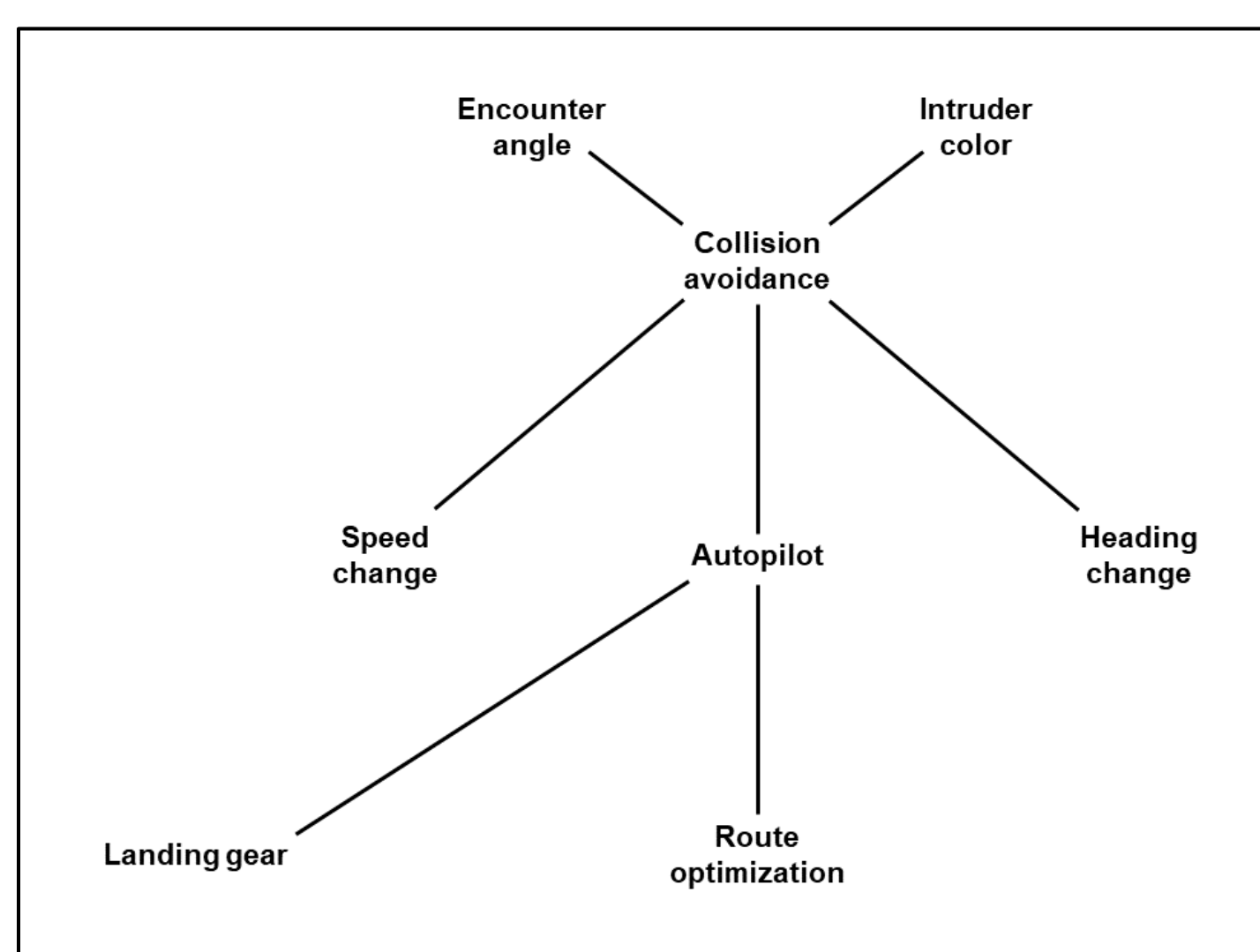
Expected mental model

- Forty-eight undergraduate students ($M = 20.3$ years; $SD = 3.92$) participated in the study.
- Participants read 13 training slides *with* (**Advanced Mental Model**) or *without* (**Basic Mental Model**) explicit information on the functionality of a simple, fictional autopilot system.
 - Training took approximately 4 minutes to complete.
 - Both groups were exposed to the concept of Advanced Air Mobility and the following autopilot concepts: *heading change*, *route optimization*, and *collision avoidance*.
 - The Advanced Mental Model group was additionally exposed to *speed change*, *intruder color*, and *encounter angle* for the last three slides.
 - The Basic Mental Model group was exposed to irrelevant details about Advanced Air Mobility for the last three slides.
- Participants provided pairwise relatedness ratings of autopilot concepts using the Target Rating software (JTarget; Interlink, 2017).
 - The autopilot concepts (i.e., Pathfinder nodes) were generated based on concepts in the training materials.
 - An "expected" mental model representation was generated by the first and third authors to reflect the design model portrayed in the Advanced training materials.
- Participants completed a comprehension test of the autopilot functionality.

Results



Basic Mental Model group mean aggregate network



Advanced Mental Model group mean aggregate network

Dependent Measure	Basic		Advanced		<i>t</i>	<i>p</i>	Cohen's <i>d</i>
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)			
Mental Model Assessment Score	5.33	(1.63)	6.33	(1.55)	2.18	.035*	0.63
Coherence	0.25	(0.37)	0.37	(0.32)	1.20	.238	0.35
Similarity (within-group)	0.30	(0.04)	0.35	(0.05)	3.51	.001*	1.01
Similarity (to expected)	0.32	(0.11)	0.37	(0.10)	1.75	.087	0.50
Common Link (w/ expected)	4.42	(1.21)	5.21	(1.25)	2.23	.031*	0.64
Total Links	10.54	(2.30)	11.50	(2.67)	1.33	.190	0.38
Double Rating Mismatch %	0.52	(0.10)	0.53	(0.16)	0.16	.877	0.05
Double Rating Avg Difference	0.82	(0.19)	0.80	(0.27)	0.22	.829	0.06

Note. For all *t*-tests, *df* = 46. For both groups, *n* = 24. **p* < .050.

T-test (two-tailed) results for all dependent measures

Discussion

- On generated Pathfinder networks, the training manipulation produced significant differences on two measures:
 - Within-group similarity
 - Common links with expected model
- Results indicate that the Advanced Mental Model group may have had a better understanding of the autopilot but was not necessarily similar to the expected mental model structure any more than the Basic group.
- However, mental models of the Advanced group converged to a similar model while those of the Basic group were substantially more varied.
- The training manipulation was effective, confirmed by significantly higher mental model assessment scores for the Advanced group than the Basic group.

Future Directions

- The present methodology to measure operator mental models could be used to examine the effects of existing and future training programs on development of mental models and attentional performance in Advanced Air Mobility.

References

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