Stress in Graph Drawings: Perception, Preference, and Performance

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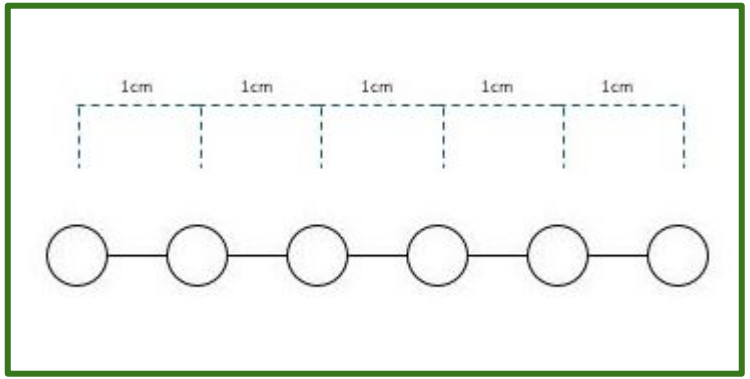
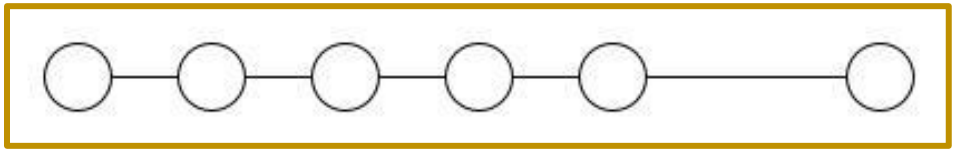
What is stress?

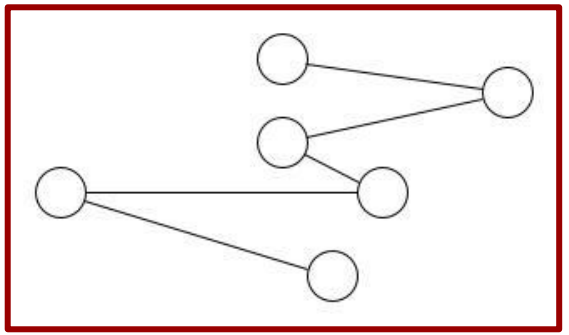
- The extent to which *graph theoretic* distances in a graph line up with *geometric* distances in the graph drawing.

- Formally:

$$\sum_{i<j} \frac{(||X_i - X_j|| - d_{i,j})^2}{d_{i,j}^2}$$







Torgerson, W.S. Multidimensional scaling: I. Theory and method. *Psychometrika* **17**, 401–419 (1952). https://doi.org/10.1007/BF02288916

Kruskal Stress Metric (KSM)

Instead of calculating the exact discrepancy between theoretic and geometric distance:

Maintain the ordering of distances

i.e. from each node, the node that is first, second, and third etc. closest in terms of graph theoretic distance should still be first, second, and third etc. closest in the drawing respectively

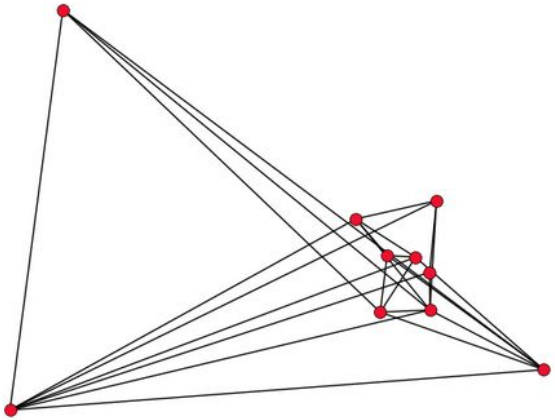
$$\sqrt{\frac{\sum_{i<j}(||X_i - X_j|| - \hat{d}_{i,j})^2}{\sum_{i<j}||X_i - X_j||^2}}$$

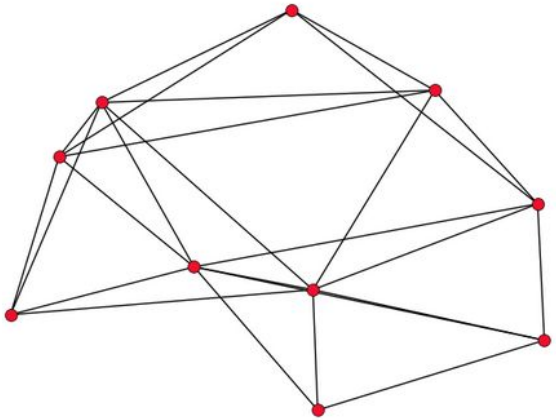
Kruskal, J.B. Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika* **29**, 1–27 (1964). https://doi.org/10.1007/BF02289565

GD 2024: The Perception of Stress in Graph Drawings

RQ: Can people see stress?

*Do the two drawings have the same stress?





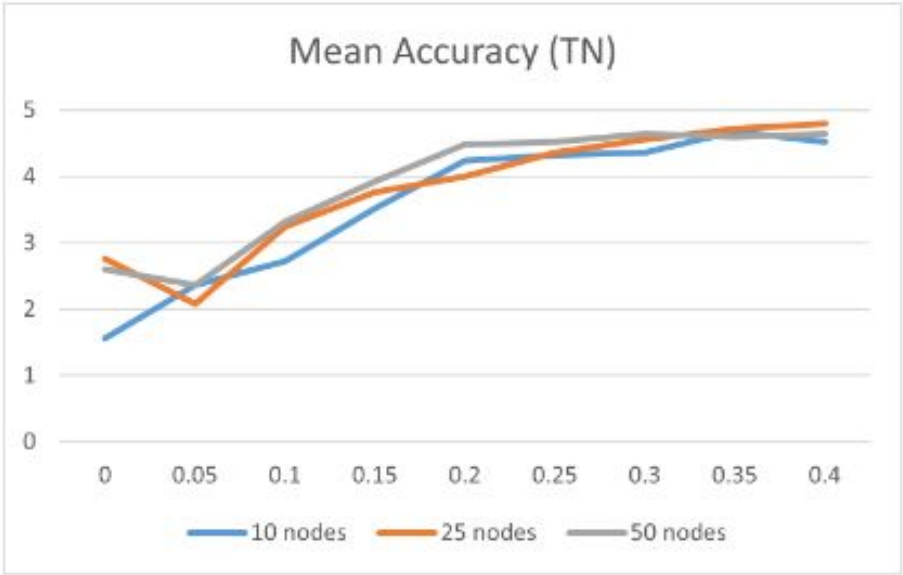
- ◯ The drawing on the **left** has lower stress
- ◯ The drawings have the **same** stress
- ◯ The drawing on the **right** has lower stress

GD 2024: The Perception of Stress in Graph Drawings

RQ: Can people see stress?

Results:

- People can see differences in stress
- Larger differences make this easier
- Graph size does not have a significant impact



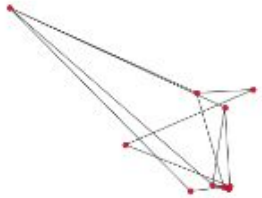
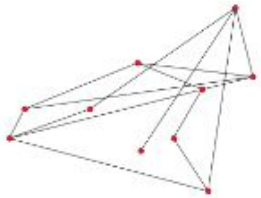
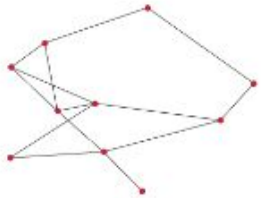
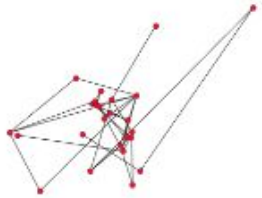
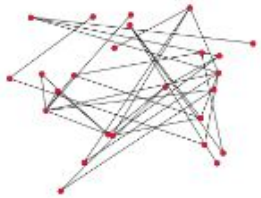
Question: Are people really ‘seeing’ stress, or are they just choosing the ‘better’ drawing?

Our follow up paper answers this question (and more)

Stimuli

- 3 Graph sizes: 10, 25, 50
  - Low density
  - 5 Graphs for each size
  - Randomly generated
- Generated with hill climbing algorithm for 9 distinct KSM values
  - 0.4, 0.45, 0.5... 0.8 (and hence 9 unique differences: 0, 0.05, 0.1, 0.15… 0.4)
  - 15 x 9 = 135 drawings
  - Repeated 3 times
- 3 sizes × 5 graphs × 9 stress values × 3 drawings **= 405 total drawings**

Table 1 Example drawings of different KSM values. Each row consists of different drawings of the same graph. Higher KSM values indicate lower stress.

		KSM		
		0.4	0.6	0.8
Size	10			
	25			
	50			

Experiments

- Same stimuli for all experiments

- Perception (GD’24) (n=159, 25 untrained/trained per size + 9 experts)
  - 2AFC - choose the drawing with lower stress

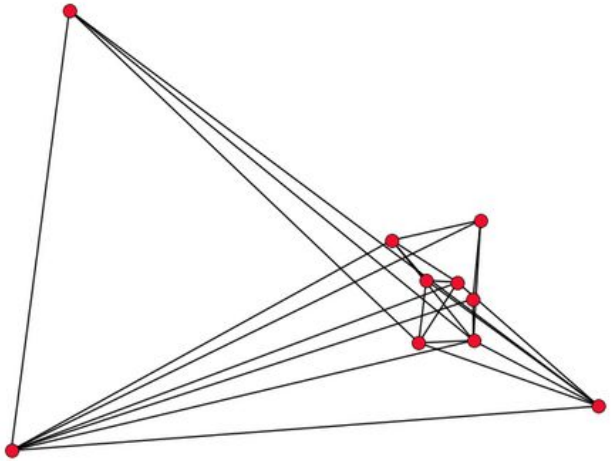
- **Preference** (n=75, 25 per size):
  - 2AFC - choose the drawing you prefer

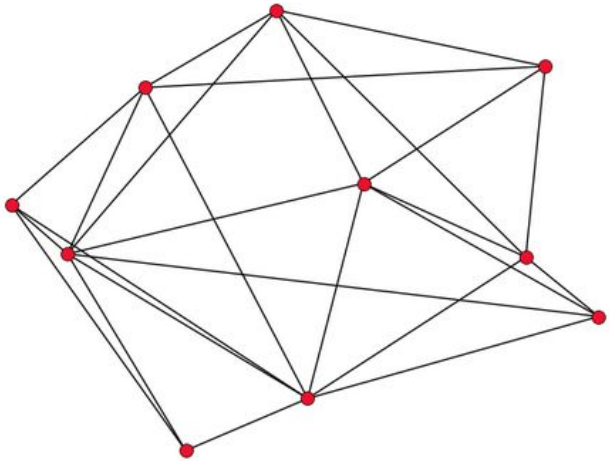
- **Performance** (n=36):
  - Shortest path task experiment

Preference Experiment

(n=75, 25 per size)

*Which drawing do you prefer?





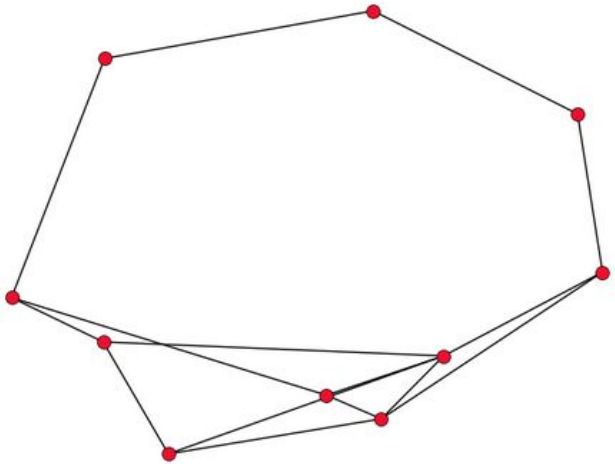
I prefer the drawing on the **left**.

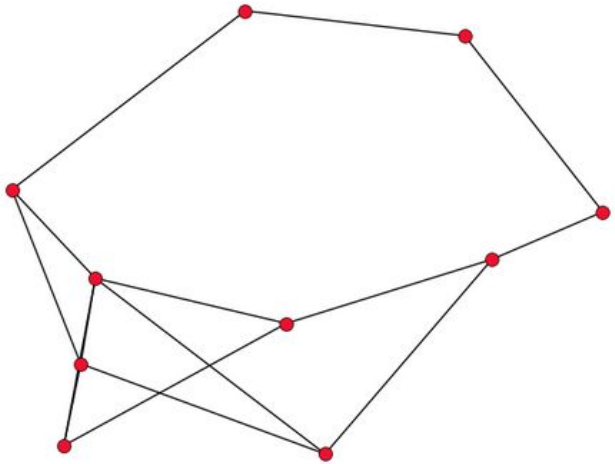
I prefer the drawing on the **right**.

Preference Experiment

Data where the stress is the same are **discarded** from analysis

*Which drawing do you prefer?





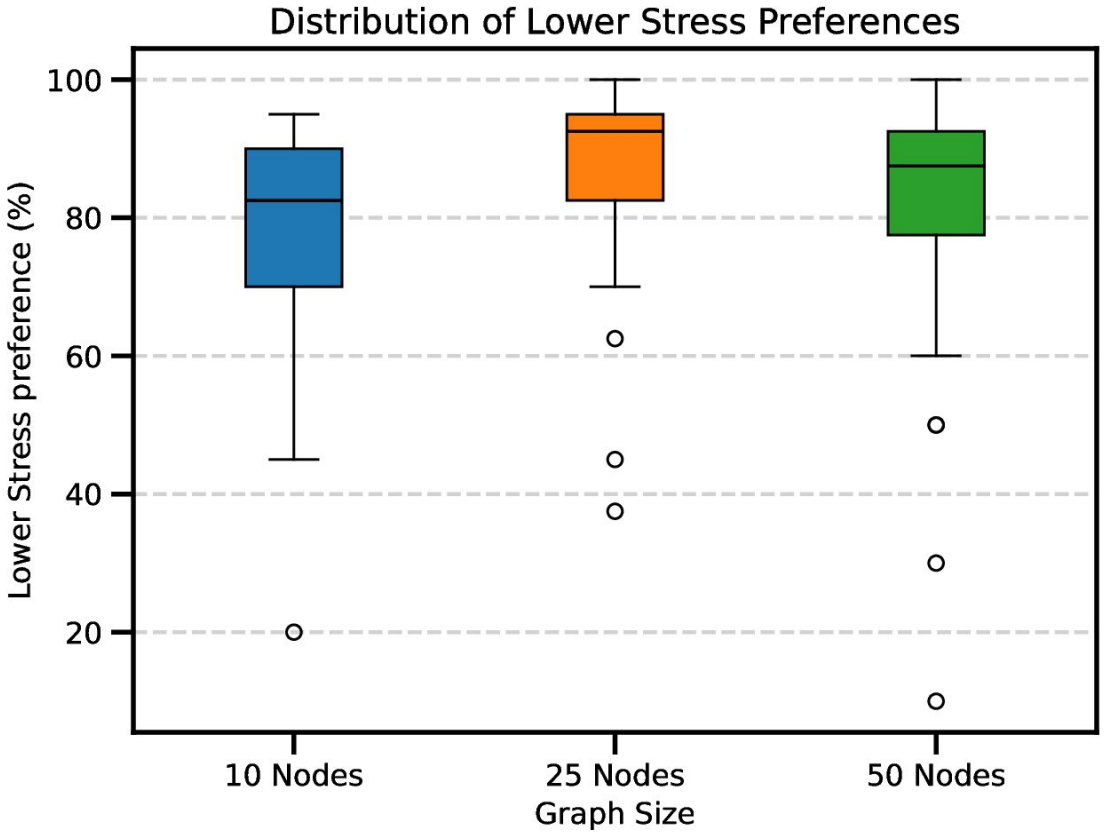
KSM=0.8

I prefer the drawing on the **left**.

I prefer the drawing on the **right**.

Preference Results

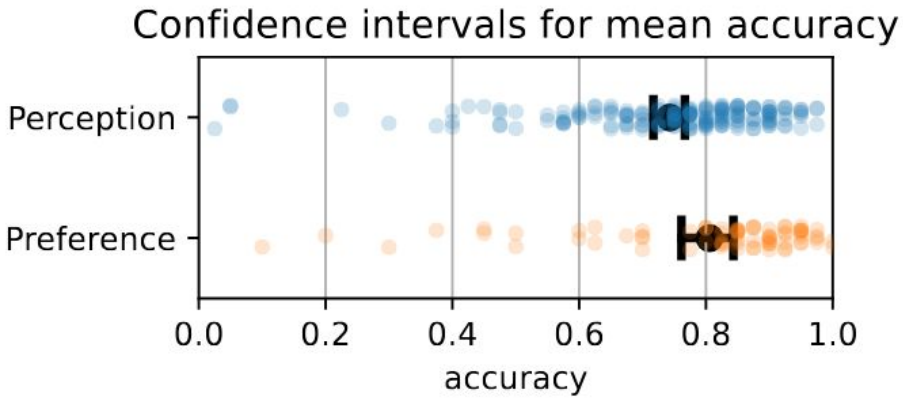
- People prefer lower stress drawings

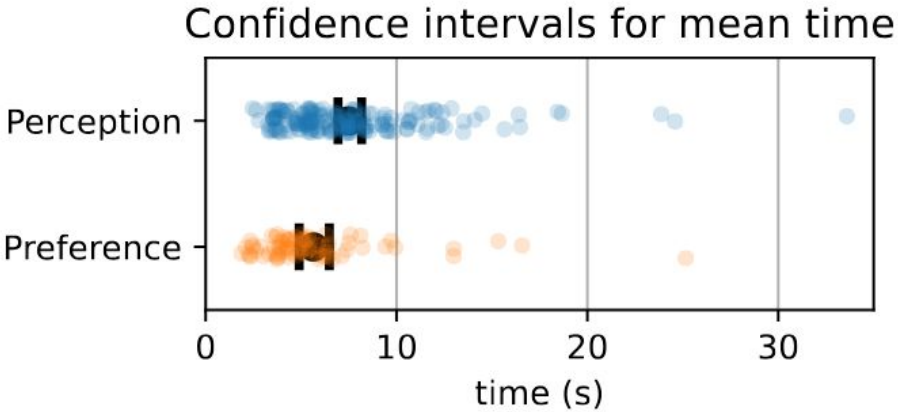


Boxplot: Percentage of times each participant preferred the lower stress drawing

Preference Results

- Being correct in the perception task is **not** the same as preferring lower-stress drawings - distributions are significantly different

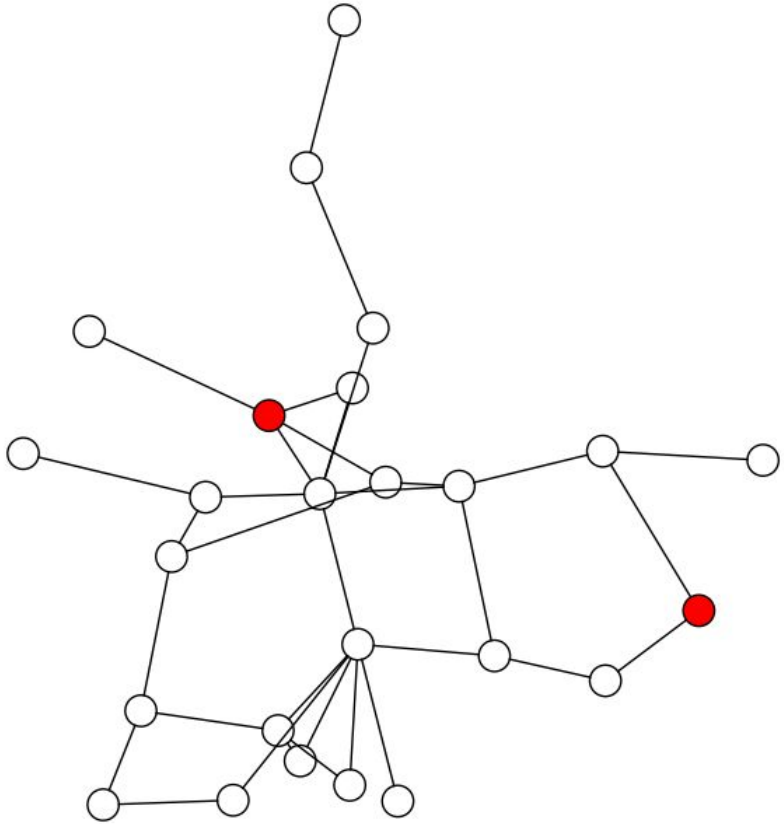




Performance Experiment

(n=36)

- **Task**: Determine the **shortest-path length** between two highlighted nodes
  - Response options: 2, 3, 4, 5, don't know
- Brief explanation of paths and shortest paths before trials
- Target nodes chosen algorithmically and highlighted in red
  - selected to evenly distribute SPLs across graph sizes* and stress levels (to avoid bias)

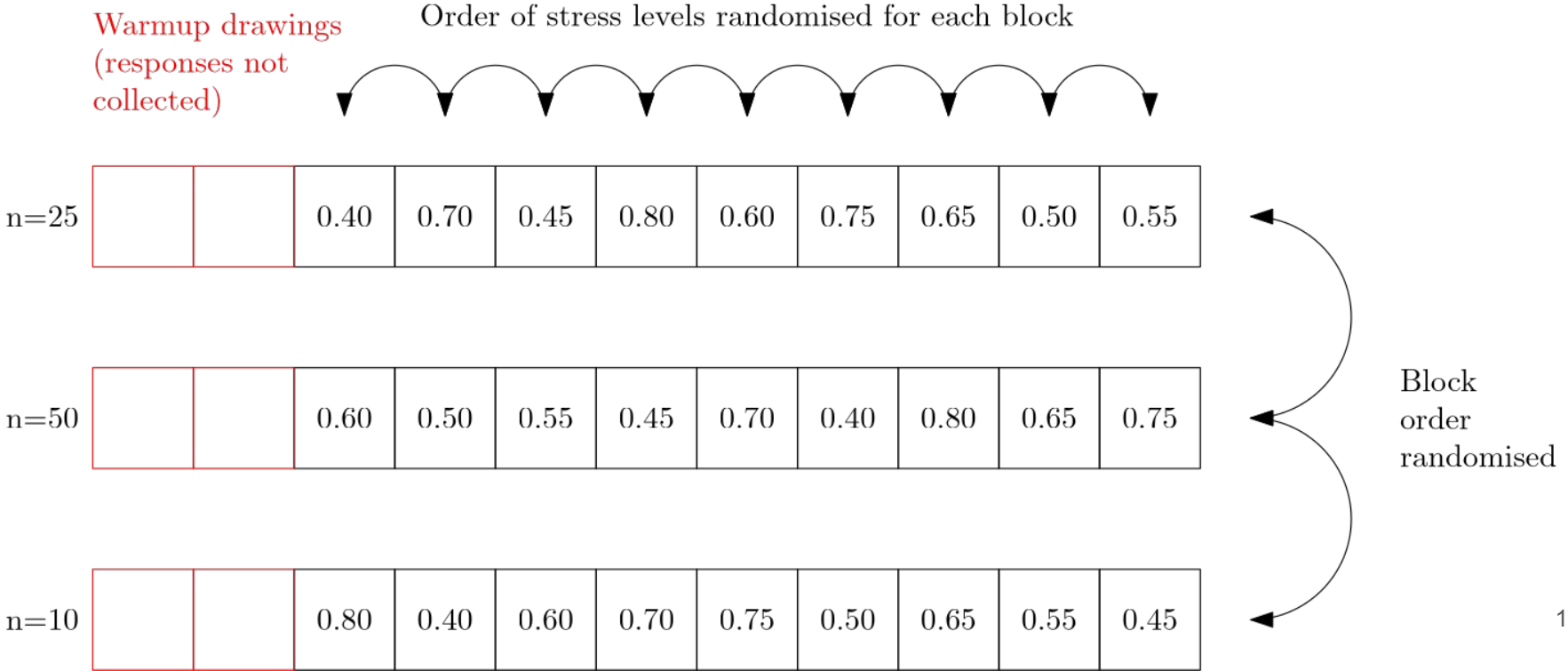


*10 node graphs only contain shortest paths up to length 4

Performance Experiment

(n=36)

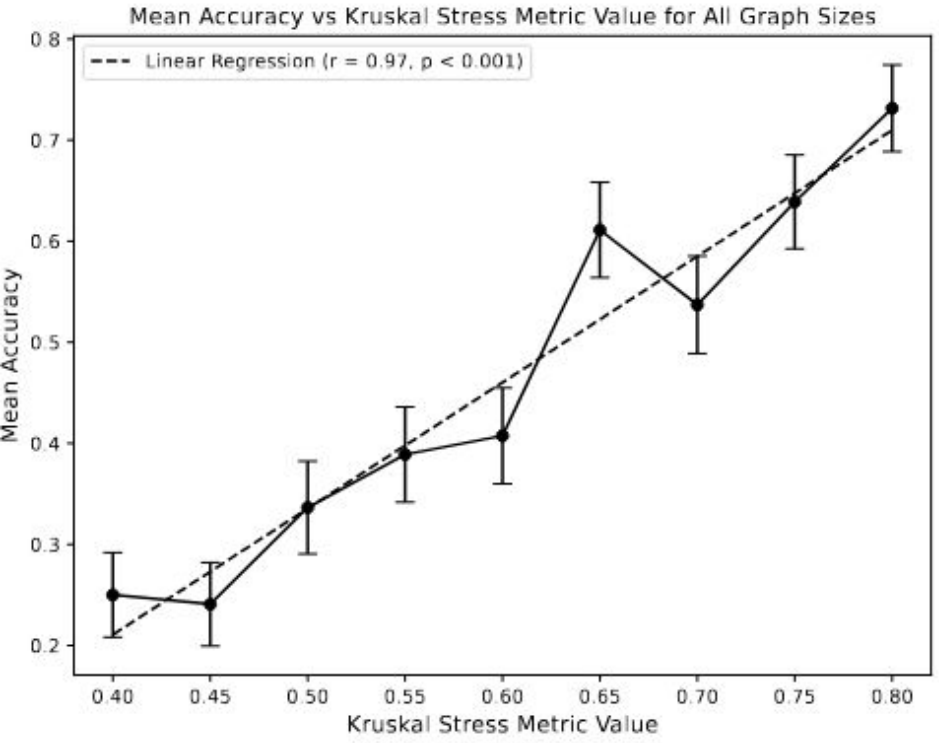
- 9 participant groups: Latin square ensures same number of responses per drawing

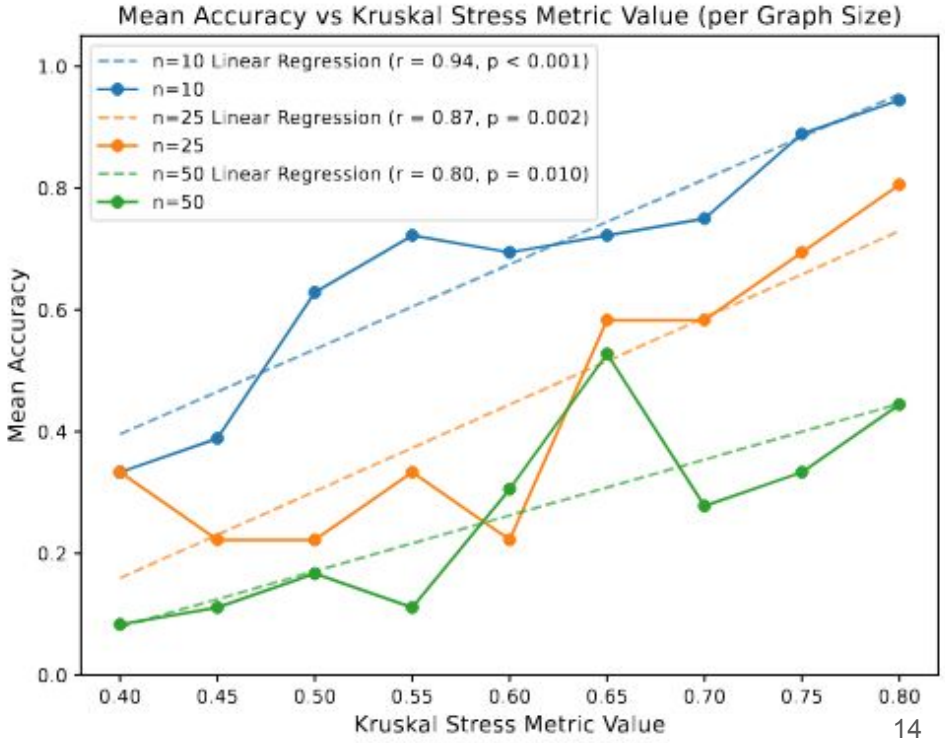


Performance Results

- Lower stress -> higher accuracy

High KSM = low stress!

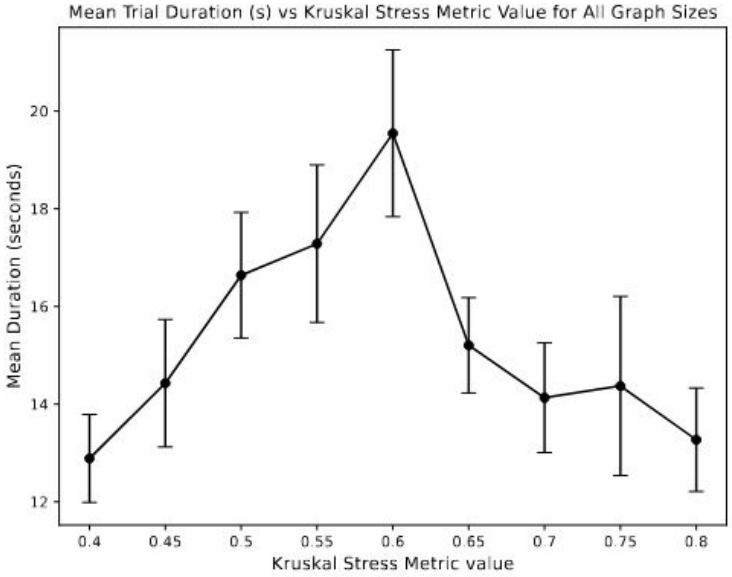


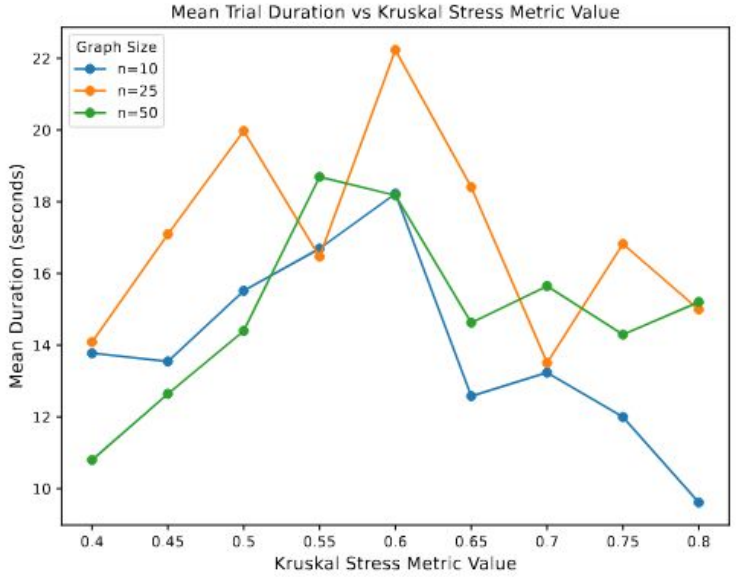


Performance Results

High KSM = low stress!

- **Task time:** No clear monotonic trend
  - Extremes are fast:
    - High stress: hard -> participants often give up quickly
    - Low stress: easy -> participants find answers quickly
  - Middle stress: longest times (hard-but-solvable)





Conclusion

Perception:

- People can be taught to ‘see’ stress
- Graph size doesn’t affect perception

Preference:

- People prefer lower stress drawings
- The task of identifying lower stress is not the same as preference

Performance:

- Lower stress improves accuracy for shortest path tasks, diminishing for larger graphs

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