Factorial Design Quantifies Effects of Hand Hygiene and Nurse-to-Patient Ratio on MRSA Acquisition

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Objectives

I. To compare the relative effectiveness of increasing the hand hygiene compliance of nurses and increasing the nurse-to-patient ratio (e.g., 1:4 to 1:3) as infection control measures against patient-to-patient transmission of MRSA

II. Evaluate the effectiveness of our methods

Methods

- Two-staged approach:
  1. Stochastic, agent-based model of patient-to-patient transmission in a 20-bed intensive care unit

  2. Apply full 2^k factorial design to the output of the simulation to quantify the effect of each factor on MRSA transmission

Agent-Based Modeling and Simulation

Contemporary simulation technique that models the *interactions* between individual *agents*

- Agents: All have individual characteristics and states
  - Patients
  - Nurses
  - Physicians

  } Health care workers (HCWs)

- Interactions:
  - Patients are admitted to the hospital and are visited by nurses and physicians on a daily basis
  - HCW visits to patients serve as the mechanism for transmission

Key Simulation Parameters

Parameter	Value
Simulation Period	1 year
Beds	20
Number of physicians	2 (1:10 ratio)
Physician hand hygiene compliance	65%
Hand hygiene efficacy	95%
Proportion of admitted MRSA-positive patients	0.10
Transmission probability from patient to HCW	0.20
Transmission probability from HCW to patient	0.05
Patient length of stay	Mean 3.94 days, median 2 days
Visits per day per patient	48
% of patient visits by nurses (vs. physicians)	90%

Full 2^k Factorial Design (k=2)

Design Point	Factor A	Factor B	Response
1	-	-	R_1
2	-	+	R_2
3	+	-	R_3
4	+	+	R_4

Main effects represent the average effect of each factor on the response. For our purposes, this represent the average number of MRSA acquisitions prevented by increasing the factor from its minus- to its plus-level

Main Effects

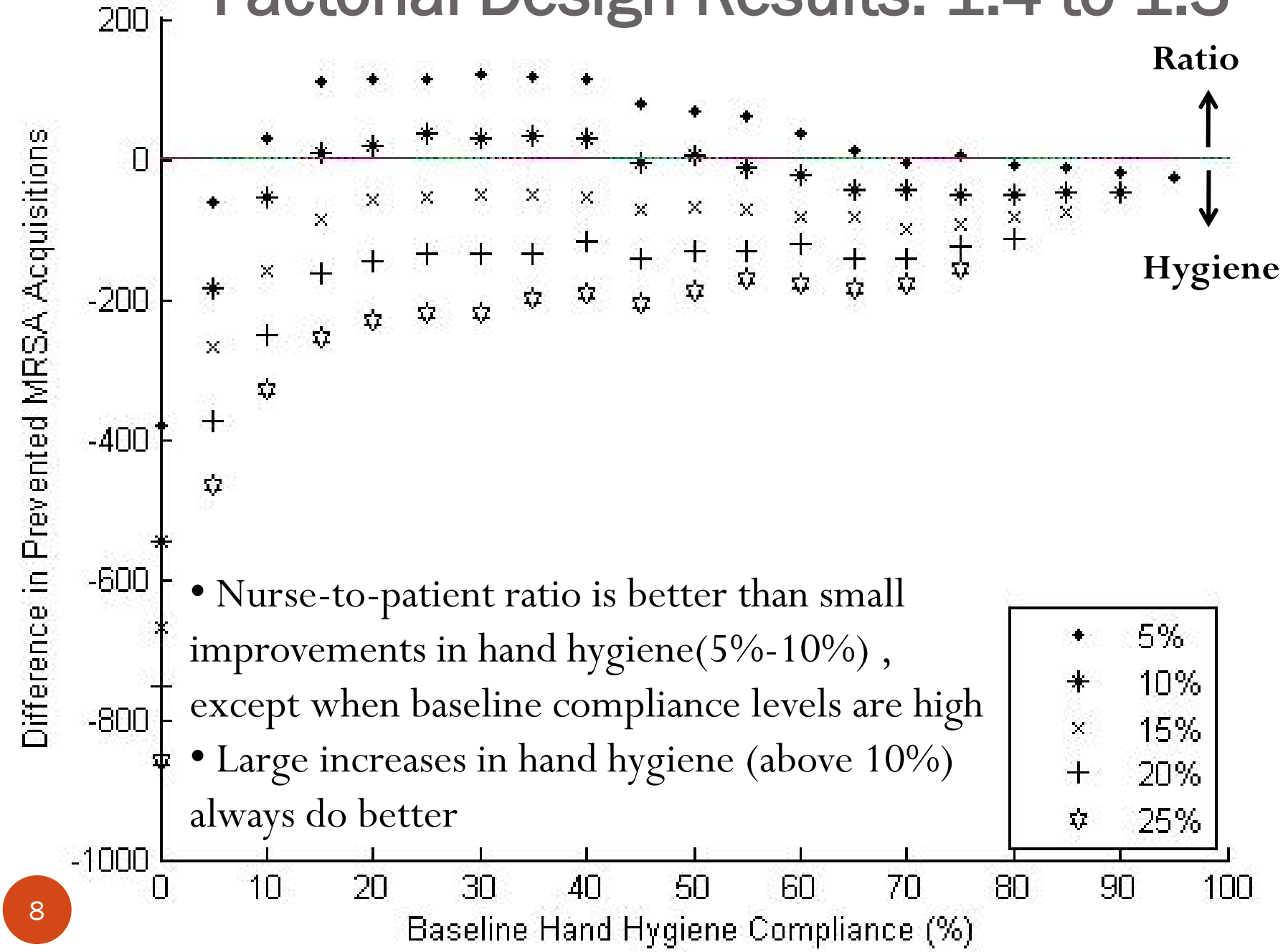
$$e_A = \frac{-R_1 + R_2 - R_3 + R_4}{2}$$

$$e_B = \frac{-R_1 - R_2 + R_3 + R_4}{2}$$

Application

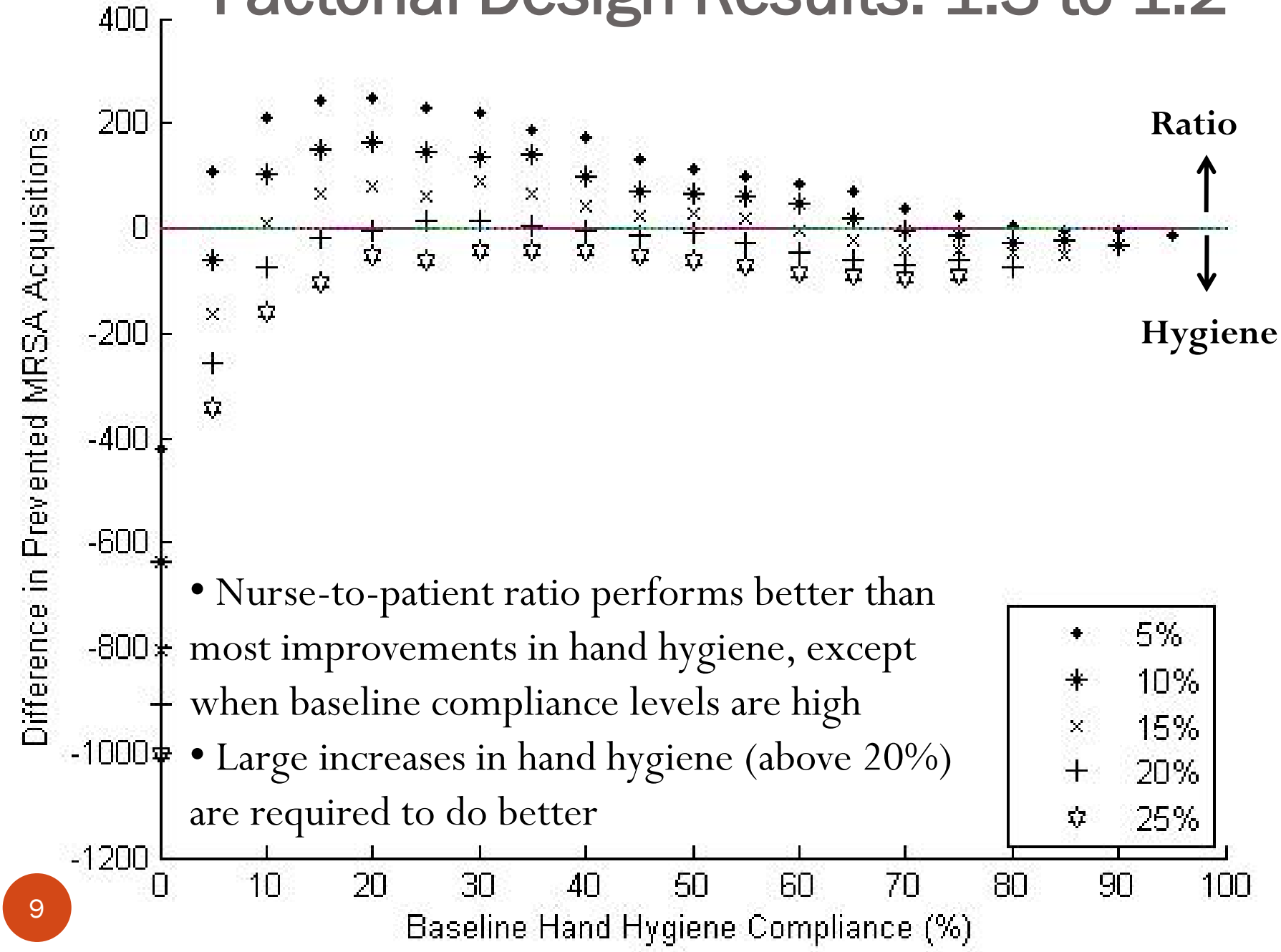
- **Problem**: What happens if we want to examine more than two levels for each factor?
- **Solution**: Apply factorial design methods iteratively across entire parameter space:
  - Hand hygiene compliance: Vary from 0% to 100% in increments of 5%, 10%, 15%, 20%, and 25%
  - Nurse-to-patient ratio: Vary from 1:4 to 1:1 in increments of one and two levels

Factorial Design Results: 1:4 to 1:3



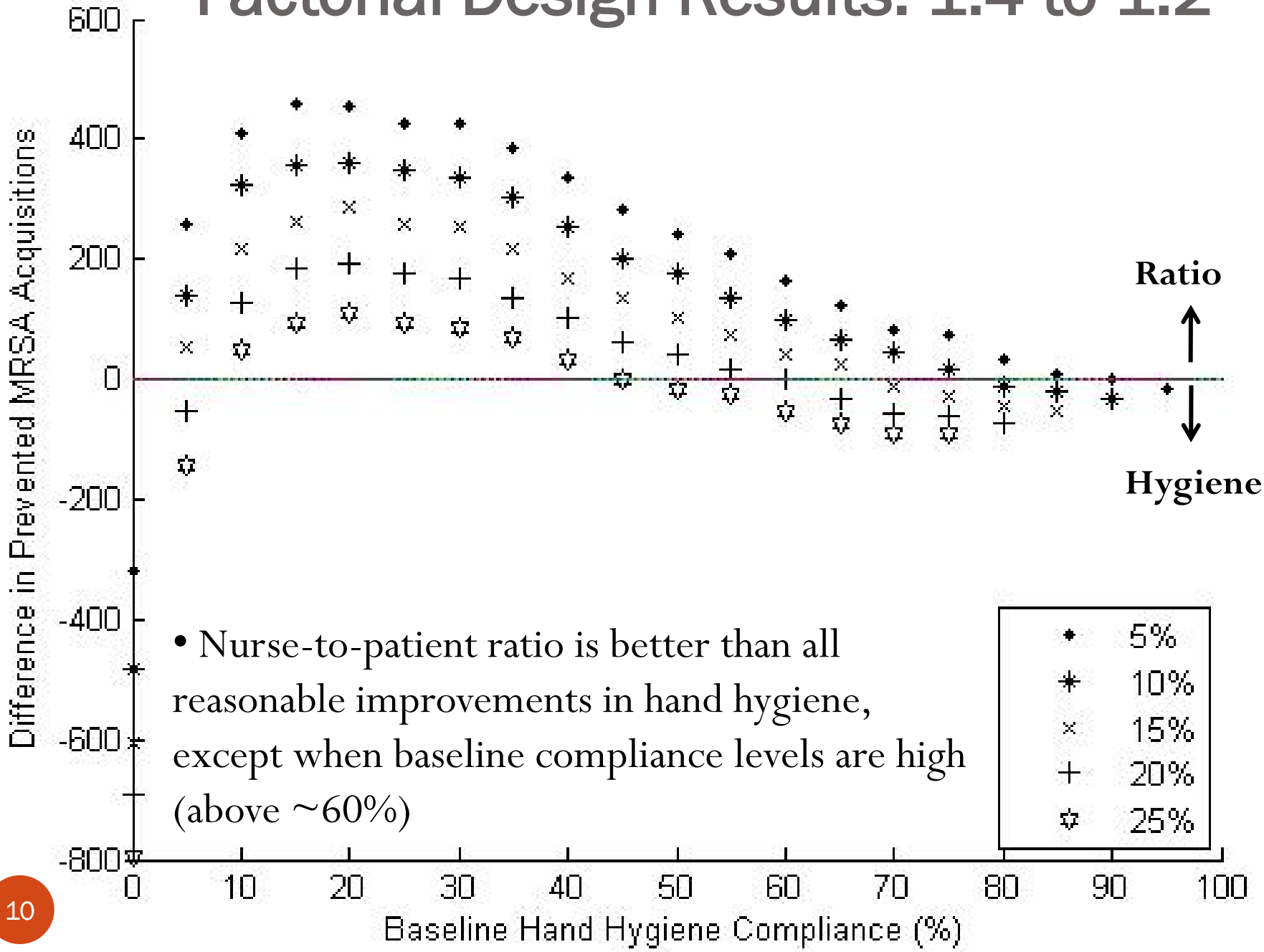
- Nurse-to-patient ratio is better than small improvements in hand hygiene(5%-10%) , except when baseline compliance levels are high
- Large increases in hand hygiene (above 10%) always do better

Factorial Design Results: 1:3 to 1:2



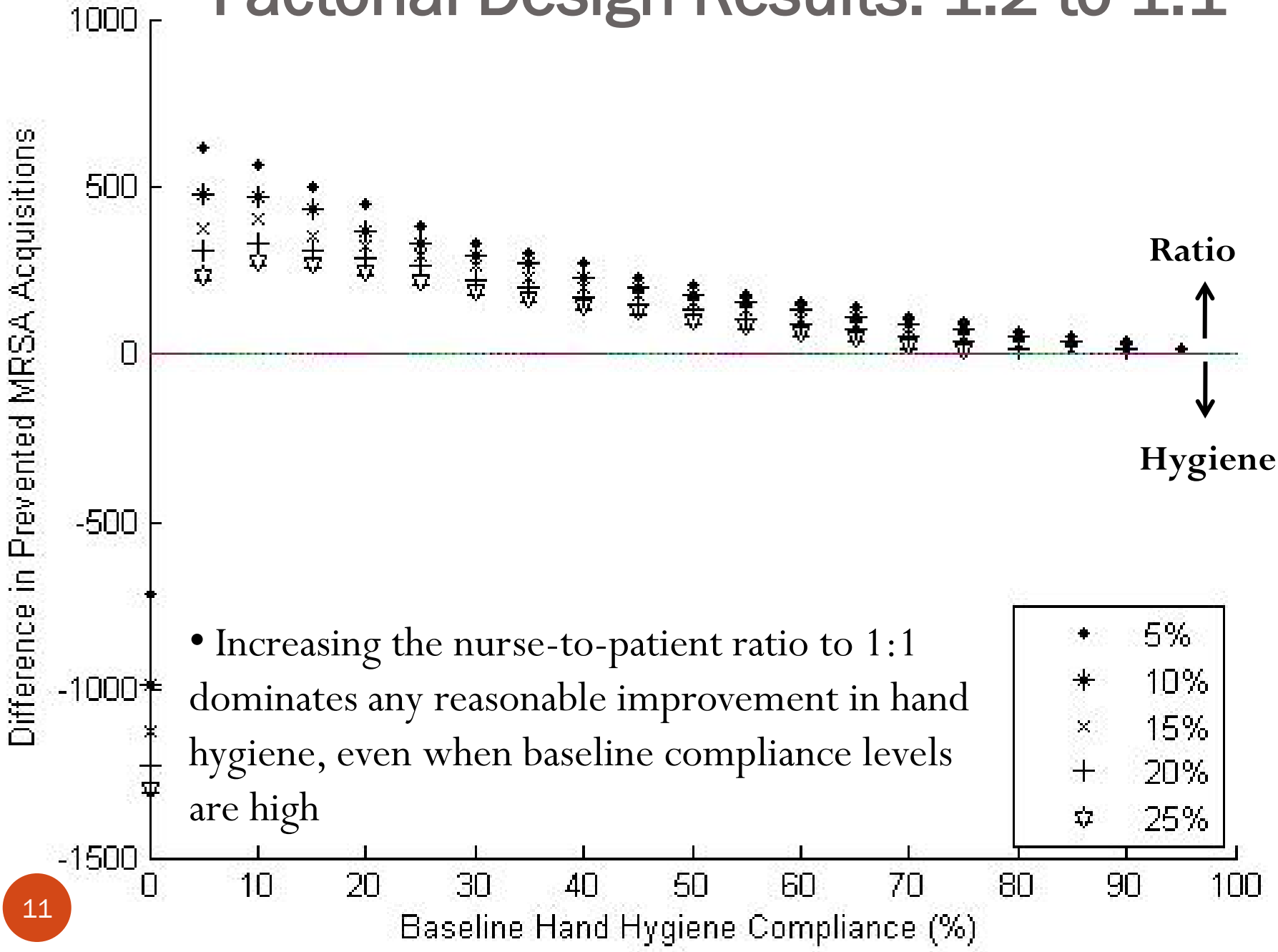
- Nurse-to-patient ratio performs better than most improvements in hand hygiene, except when baseline compliance levels are high
- Large increases in hand hygiene (above 20%) are required to do better

Factorial Design Results: 1:4 to 1:2



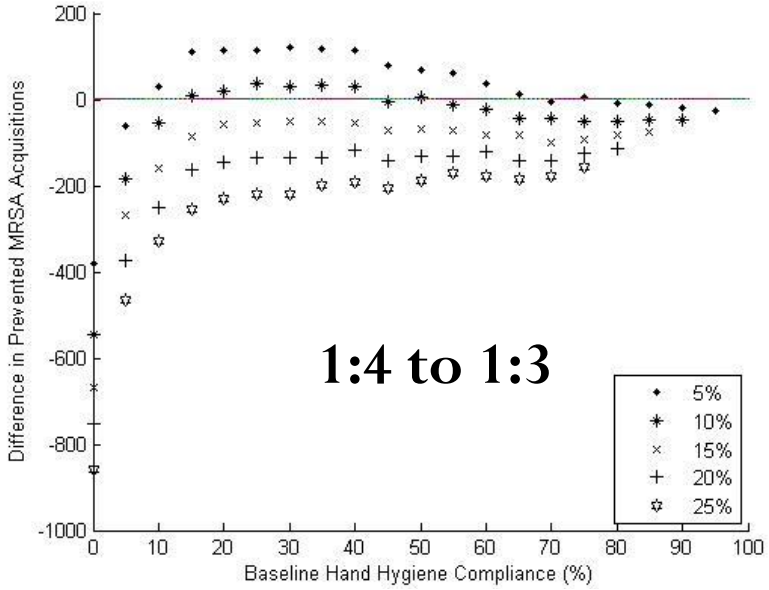
- Nurse-to-patient ratio is better than all reasonable improvements in hand hygiene, except when baseline compliance levels are high (above ~60%)

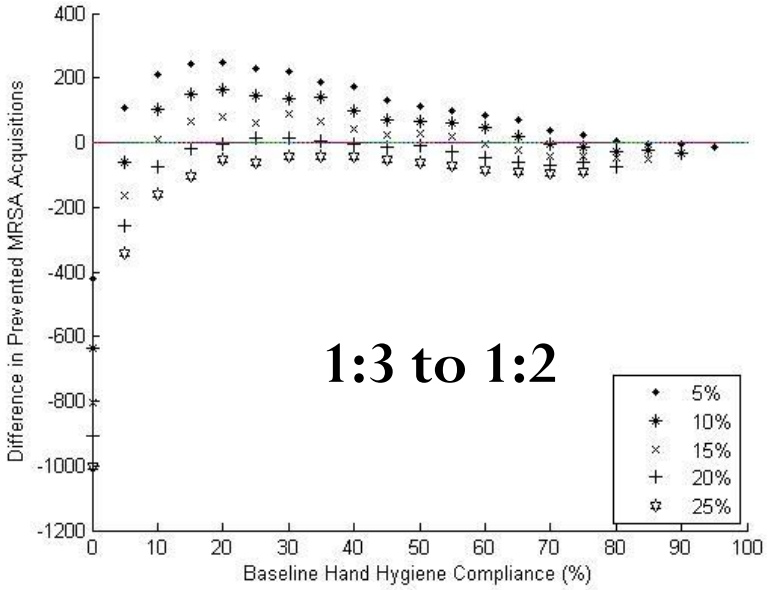
Factorial Design Results: 1:2 to 1:1

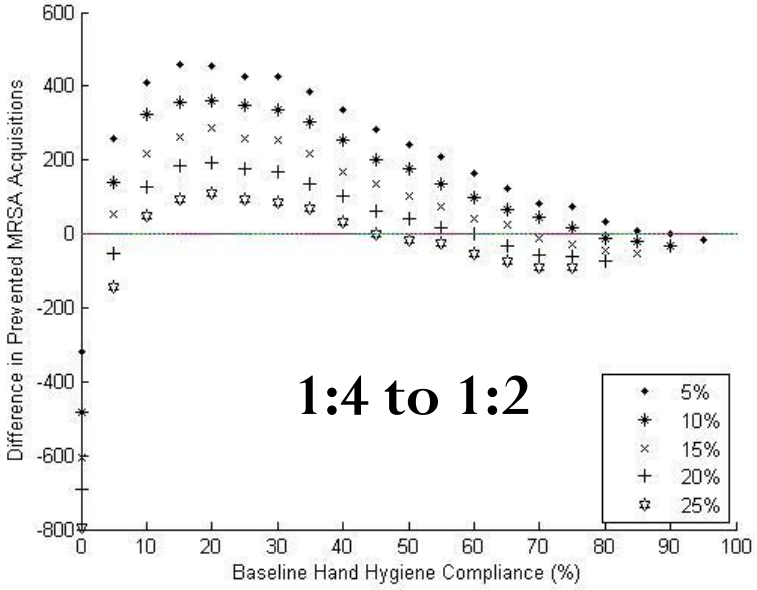


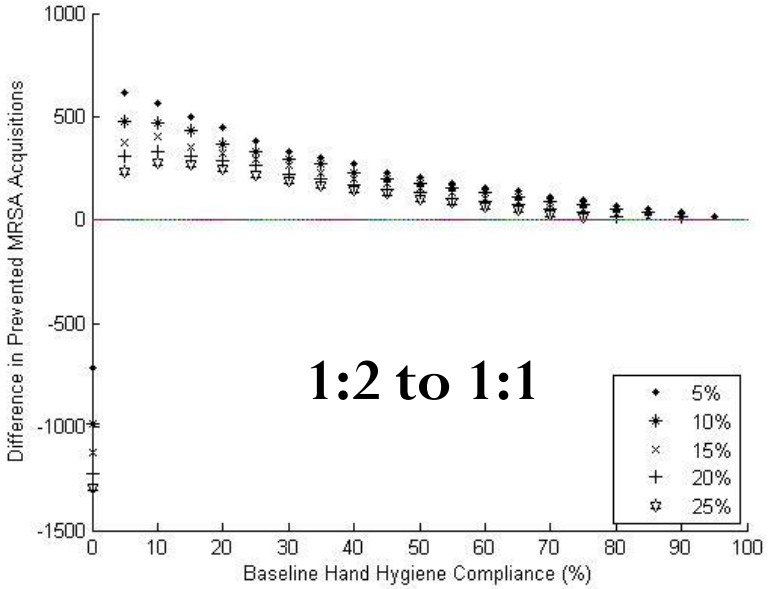
- Increasing the nurse-to-patient ratio to 1:1 dominates any reasonable improvement in hand hygiene, even when baseline compliance levels are high

Factorial Design Results: Comparison









Conclusions

- Both factors have a significant effect on the response, but the effectiveness of each factor depends on the level of the other
  - **Nurse-to-patient ratio** typically performs better than hand hygiene in the 10%-60% range and **presents a viable option while efforts to improve hand hygiene are ongoing**
  - Hand hygiene performs better at higher baseline levels, suggesting that **hospitals that have been successful at increasing compliance should continue to focus on improving hygiene further**
  - **Nurse-to-patient ratios of 1:1 always do better**
- ABMS combined with factorial design provides a powerful engine for determining the effectiveness of infection control measures

Questions???

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