

Bom Lee
Hyunkyung Choi

Final Project Presentation

Topic: What Factors Affect
Buldak Sauce Stain Removal Efficiency
on White Cotton Fabric?



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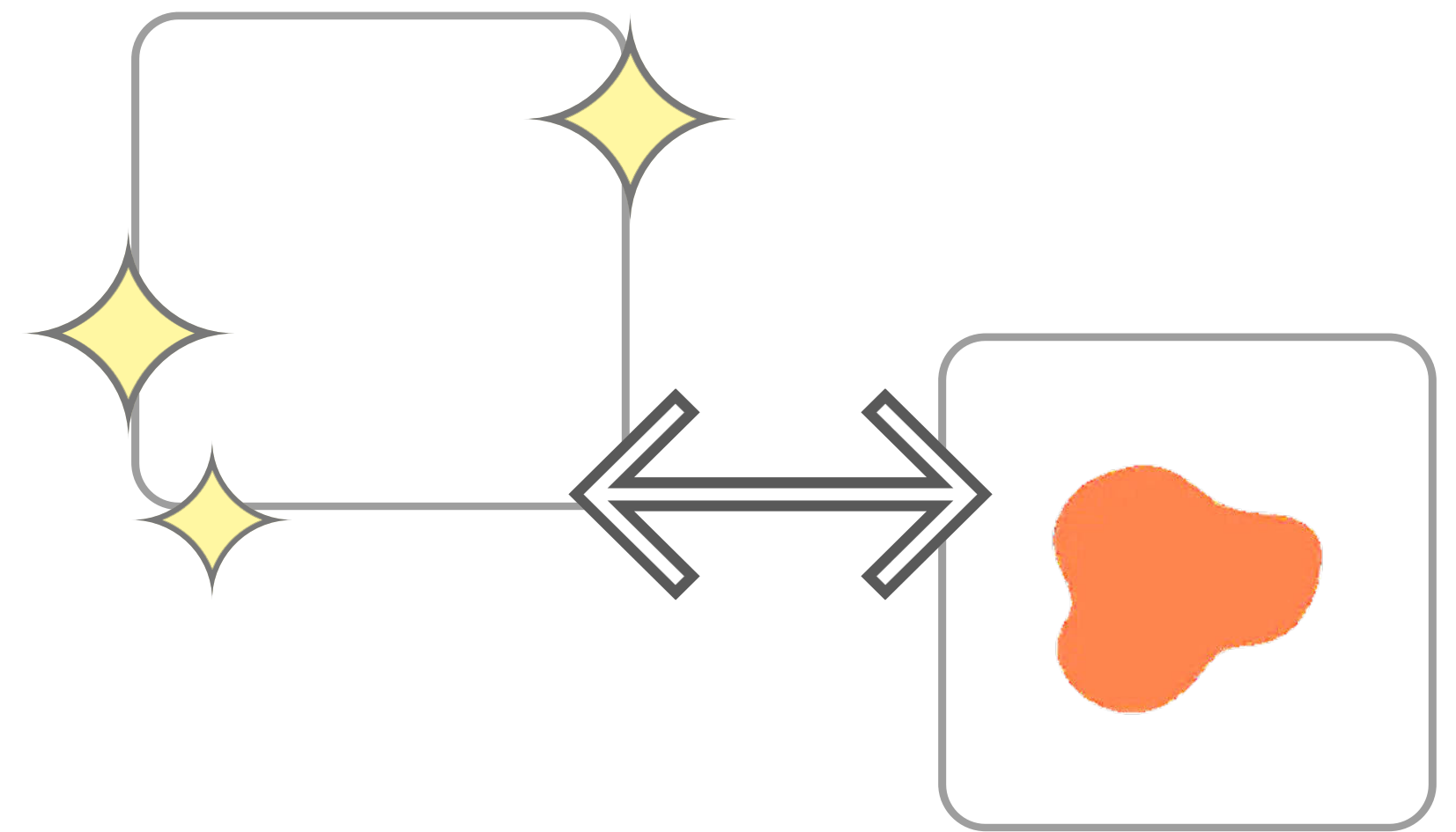
Research Question

Which combination of detergent type, water temperature, and soaking time most effectively removes Buldak sauce stains from white cotton fabric?

Response Variable

**CIEDE2000 Color
Difference**

CIEDE2000 : **international standard**
formula for calculating the
difference between two colors



Factors

This experiment evaluates the main effects and interaction effects of three factors on stain removal efficiency

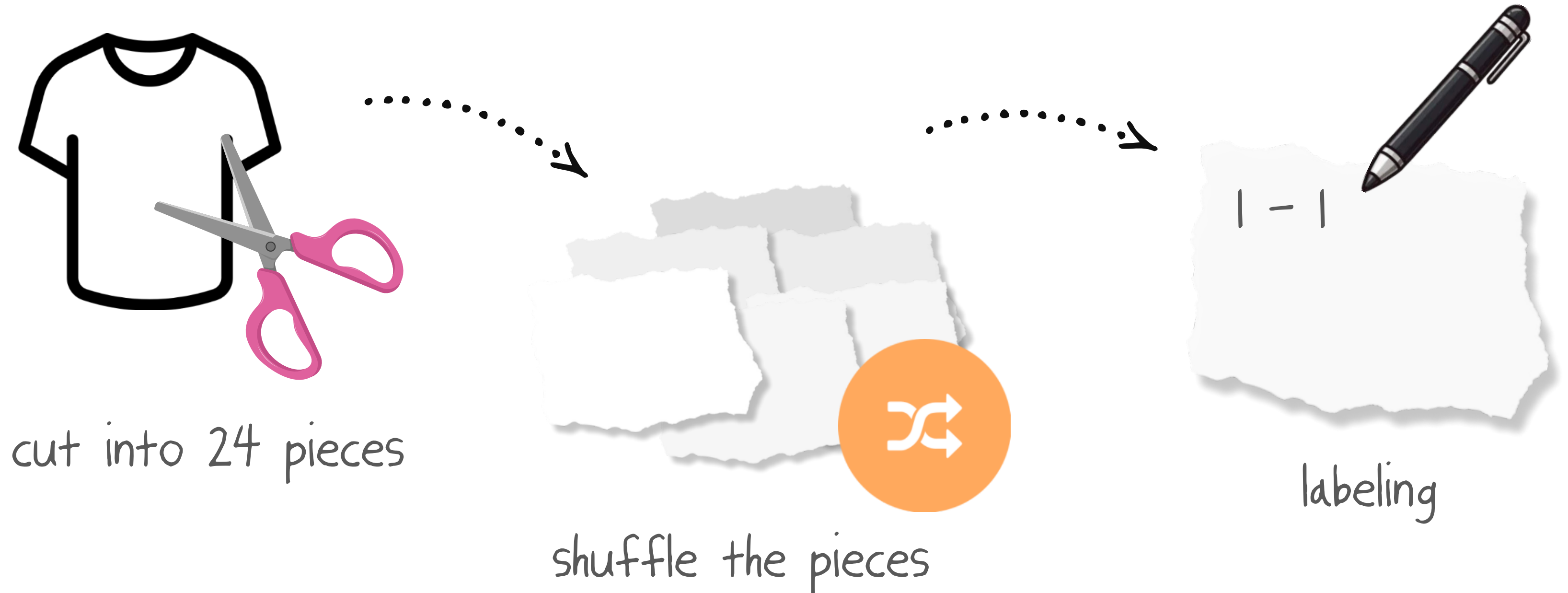
2³ Full Factorial Design

3 two - level factors
8 treatment combinations
6 replicates
 $N = 8 \times 6 = 48$

	Low Level (-1)	High Level (+1)
Detergent	Dishwashing	Laundry
Temperature	25°C	60°C
Soaking Time	5 mins	30 mins

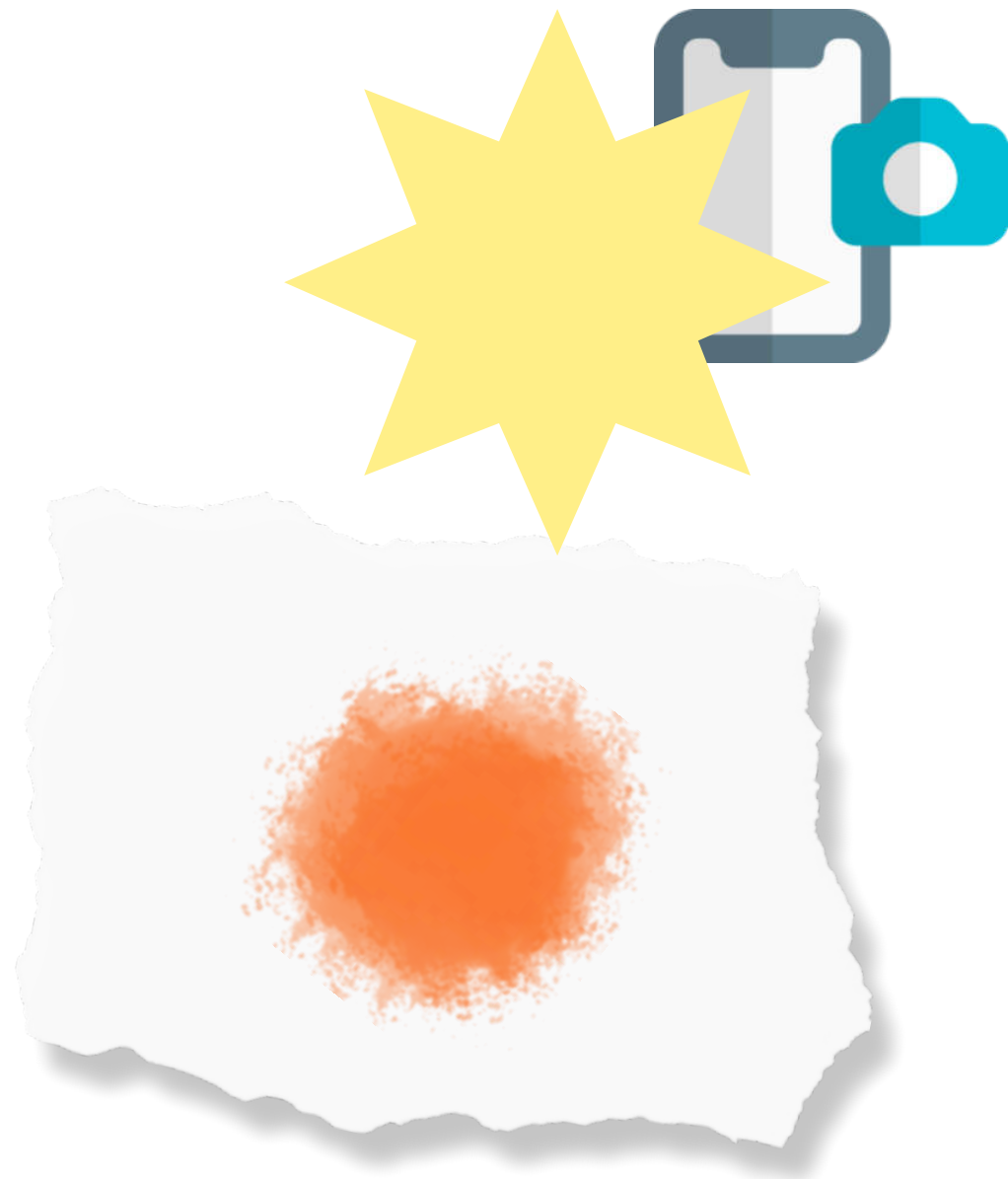
Procedures

1. Cut the T-shirt into 24 pieces of 5cm * 5cm; shuffle and number



Procedures

2. Photograph all pieces in the standardized setting

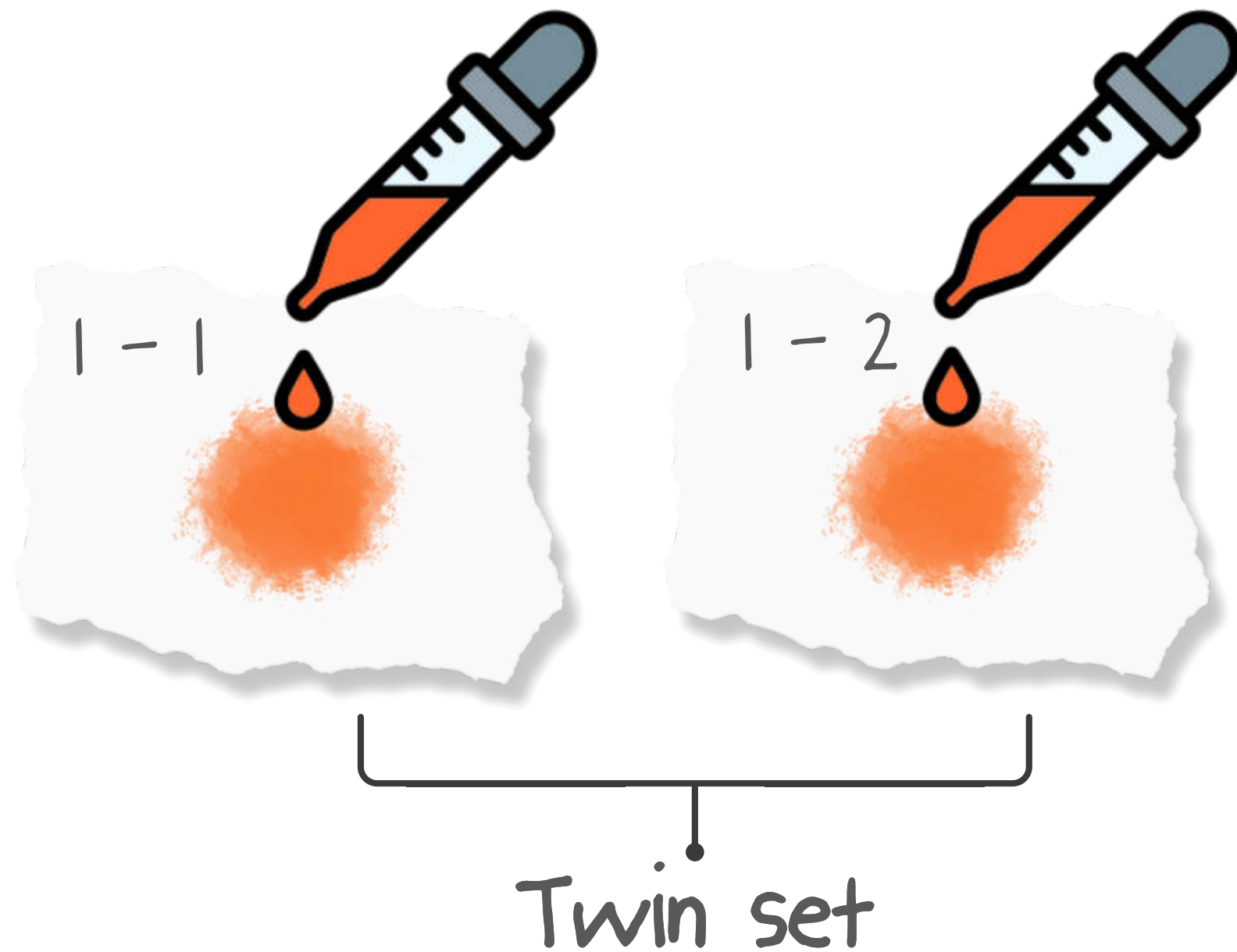
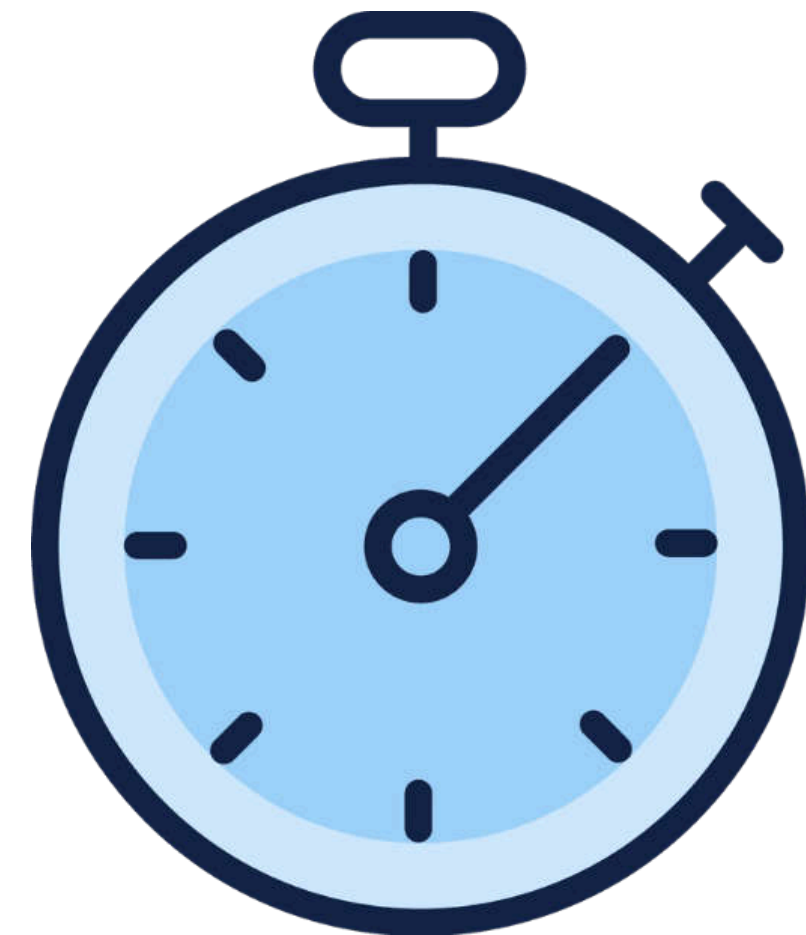


Photography protocol

- Camera: Smartphone in Pro mode with white balance and exposure locked
- Location: Closed room to block external light
- Distance: Distance fixed at 100 cm
- Timing : Photos taken
 - (i) Before stain application (pre-wash)
 - (ii) After drying (post-wash)

Procedures

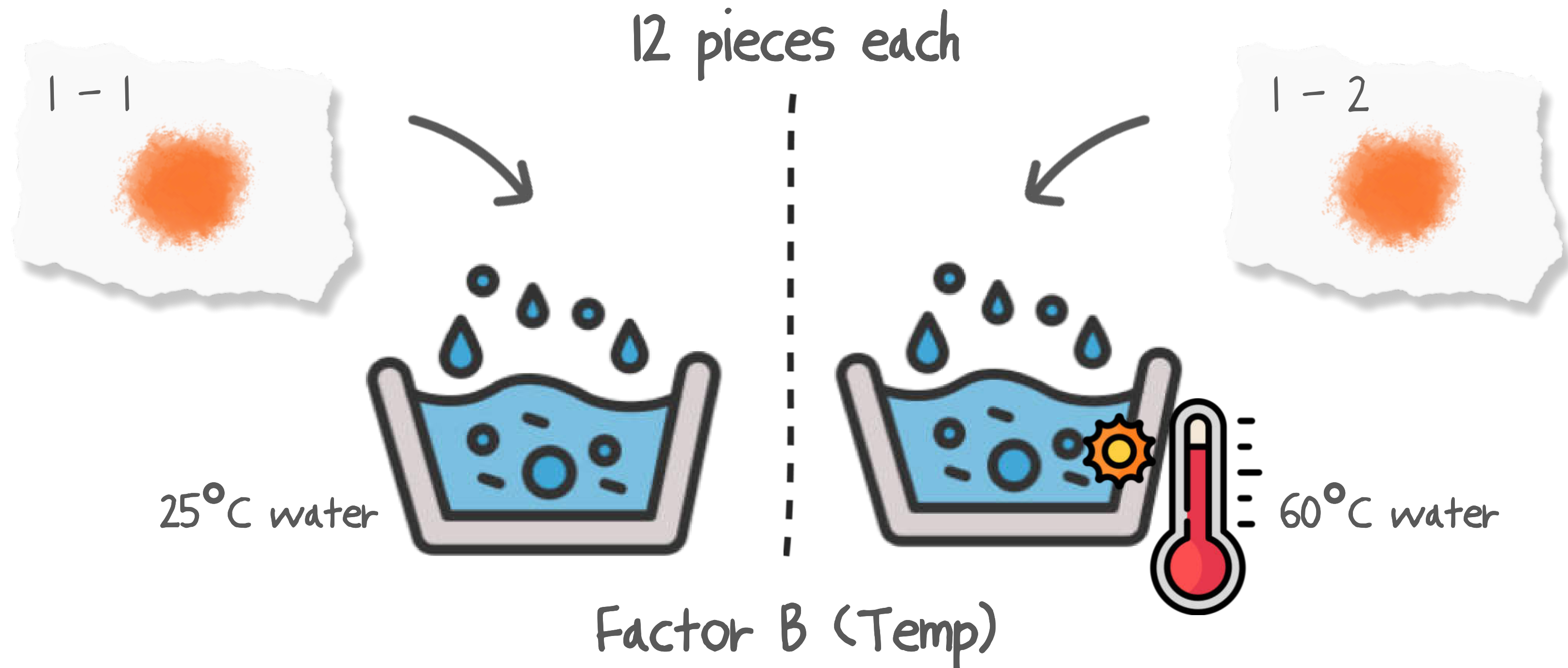
3 & 4. Apply 5 g of sauce and wait for 30 mins



30 mins

Procedures

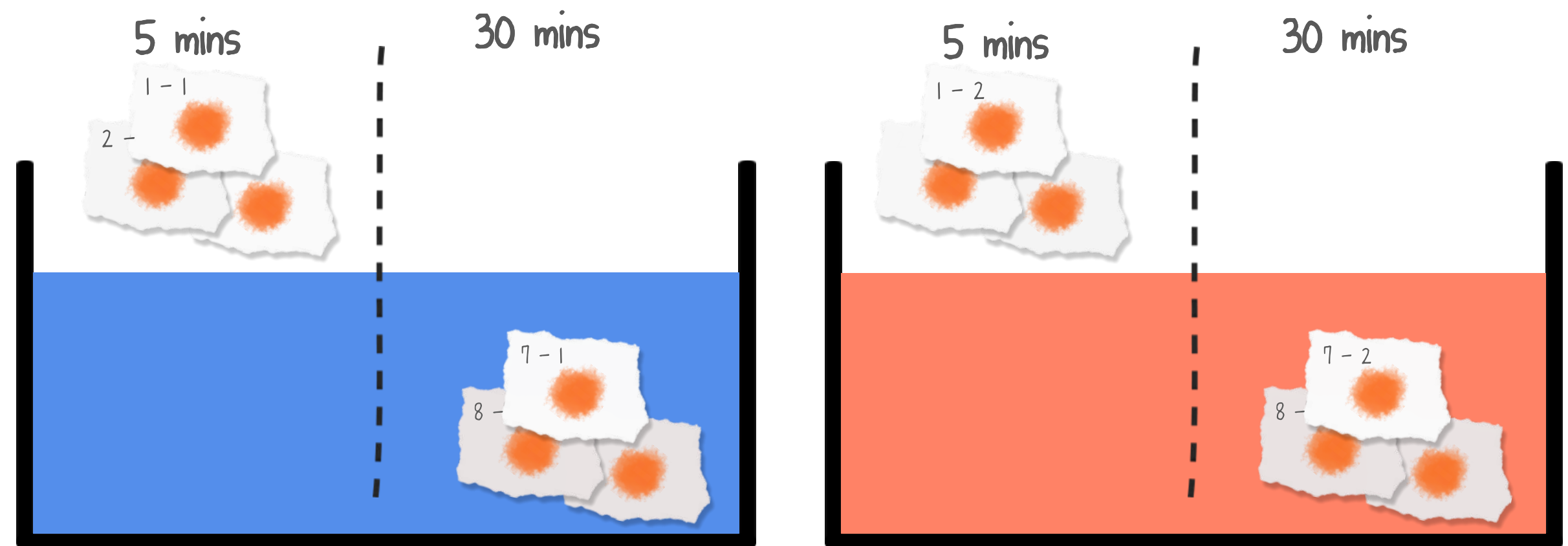
5. After 30 mins, immerse the n - 1 to 25°C water / n - 2 to 60°C



Procedures

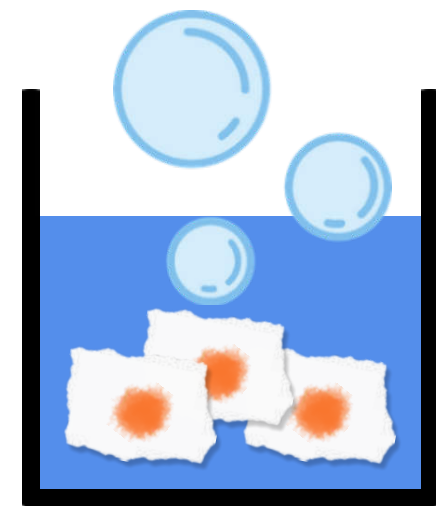
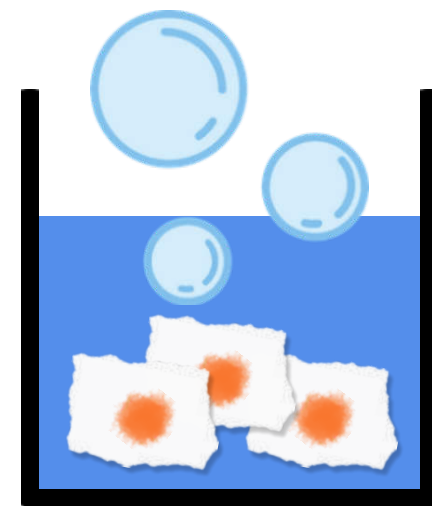
6. Per the random-number table: take 1-6 out in 5 mins, take 7-12 out in 30 mins

	A	B	C
1	난수 함수	매칭될 세트 번호	
2	0.639409	9	1
3	0.088083	11	2
4	0.73996	2	3
5	0.766828	4	4
6	0.530867	12	5
7	0.08196	1	6
8	0.147773	8	7
9	0.951466	6	8
10	0.524375	3	9
11	0.622492	10	10
12	0.296494	5	11
13	0.265388	7	12

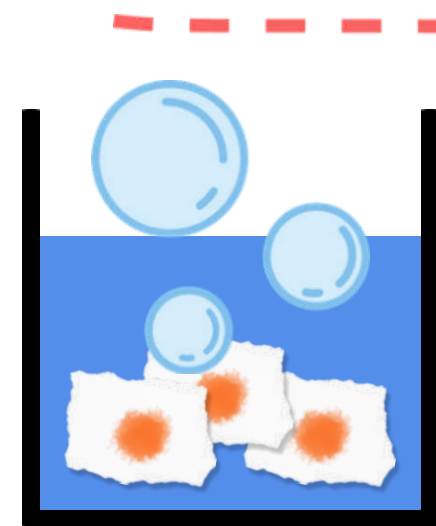
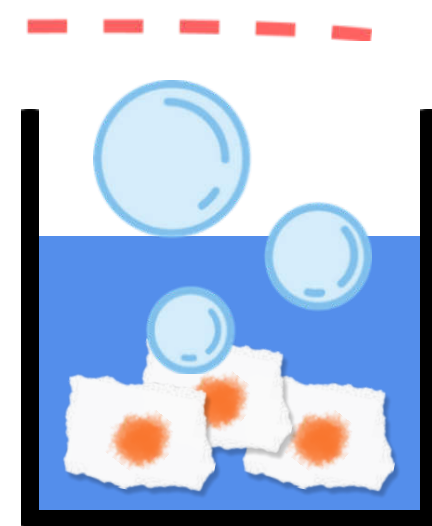


Factor C (Time)

Procedures

7. Prepare detergent solutions. Hand launder for 3 mins total

5 mins



30 mins

Dish

Laundry

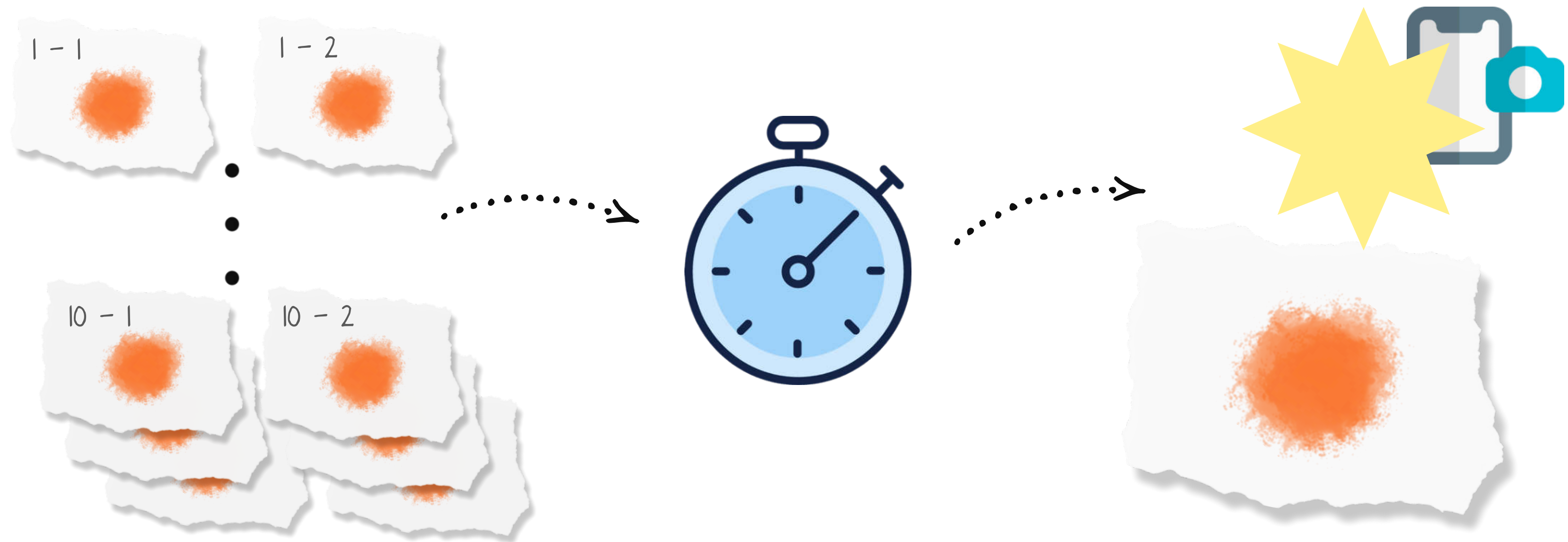
Factor A (Detergent)



80 bpm

1:30 + 1:30

Procedures

8. Dry the whole pieces overnight and take a photo

Sample Size and Power Analysis

MDE (ΔE^*_{00})	Perceptual meaning	λ	Power (N=48, $\alpha=0.05$)
1.0	Barely perceptible	4.23	0.518
1.5	Intermediate	9.51	0.852
2.0 (target)	Clearly perceptible	16.90	0.980

Residual standard deviation : $\sigma = 1.685 \Delta E^*_{00}$

Under the blocked model, the design achieves
power = 0.980 ($\alpha = 0.05$, N = 48)

Data Analysis

Factor	Level	Marginal Mean ΔE^*_{00} (N=48)	Interpretation
Detergent (A)	Dishwashing (D)	22.49	Higher (less effective)
Detergent (A)	Laundry (L)	21.77	Lower (more effective)
Temperature (B)	25°C (ambient)	22.44	Higher (less effective)
Temperature (B)	60°C (heated)	21.81	Lower (more effective)
Soaking Time (C)	5 min	21.92	Lower (more effective)
Soaking Time (C)	30 min	22.33	Higher (less effective)
Block	Day 1	22.64	
Block	Day 2	21.62	

Overall Mean

22.1 ΔE^*_{00}

Statistical Model

$$\Delta E_{*00} = \mu + \delta_{Day} + \alpha_A + \beta_B + \gamma_C + (\alpha\beta)_{AB} + (\alpha\gamma)_{AC} + (\beta\gamma)_{BC} + (\alpha\beta\gamma)_{ABC} + \varepsilon$$

$\varepsilon \sim N(0, \sigma^2)$ i.i.d., Block Effect (RE = 1.084)

δ_{Day} is the block effect, and all treatment factors are fixed effects at two levels.

Twin-set pairing is not represented as a separate term in the model
-> each pair spans only 2 out of 8 cells
(Not a complete block)

B×C interaction term proved statistically significant in the **full factorial model**
(Additive model was judged insufficient)

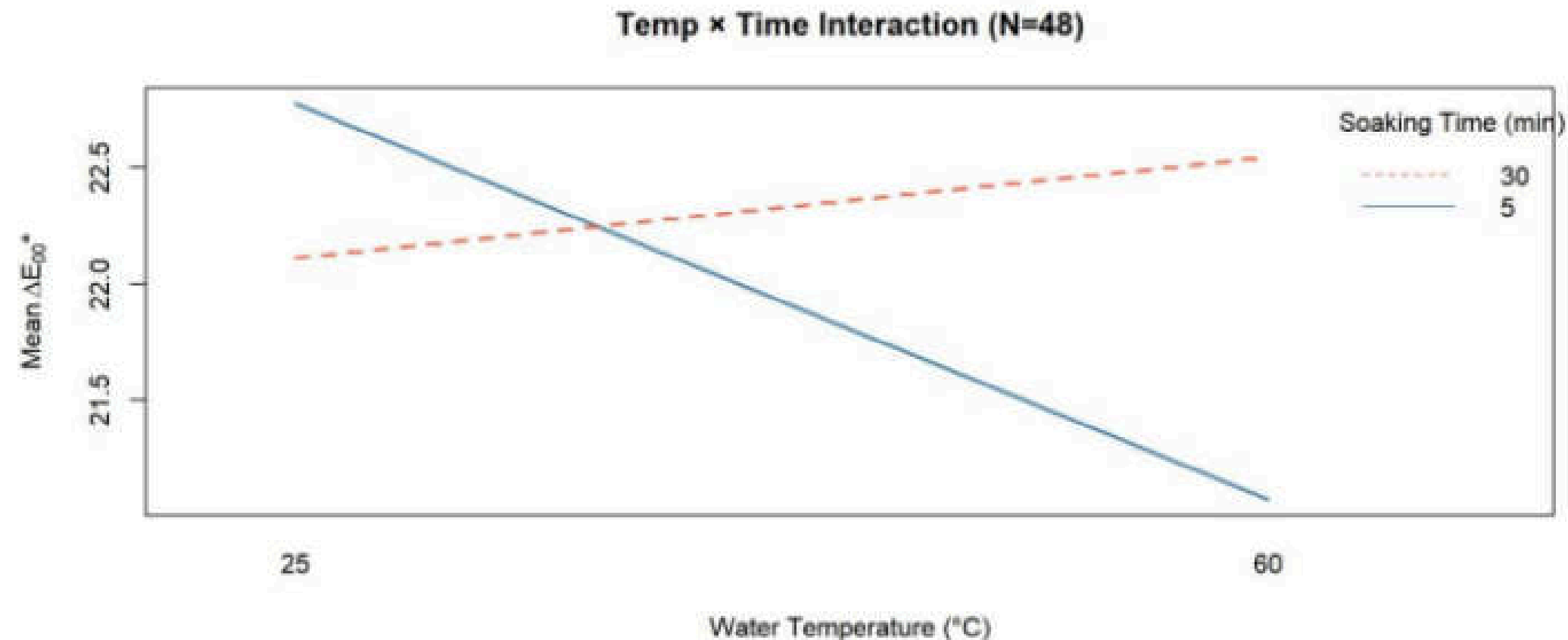
Statistical Model

Source	df	SS	MS	F	p-value
Day (Block)	1	12.520	12.520	4.409	0.042 *
Detergent Type (A)	1	6.303	6.303	2.220	0.144
Temperature (B)	1	4.818	4.818	1.697	0.200
Soaking Time (C)	1	1.981	1.981	0.698	0.409
A×B	1	0.597	0.597	0.210	0.649
A×C	1	2.448	2.448	0.862	0.359
B×C	1	13.738	13.738	4.838	0.034 *
A×B×C	1	0.165	0.165	0.058	0.811
Residuals	39	110.745	2.840		

Main effects &
3 interaction effects
-> not significant
($p > 0.14$)

Temp × Time
interaction effect
-> significant
($F(1,39) = 4.84$,
 $p = 0.034$)

Key Finding



	25°C (Ambient)	60°C (Heated)	Effect of temperature
5-min soak	22.78	21.07	-1.70 → heated water more effective
30-min soak	22.11	22.55	+0.44 → heated water slightly less effective
Effect of soaking time	-0.67 (longer → slightly better)	+1.48 (longer → worse)	

Disordinal Interaction

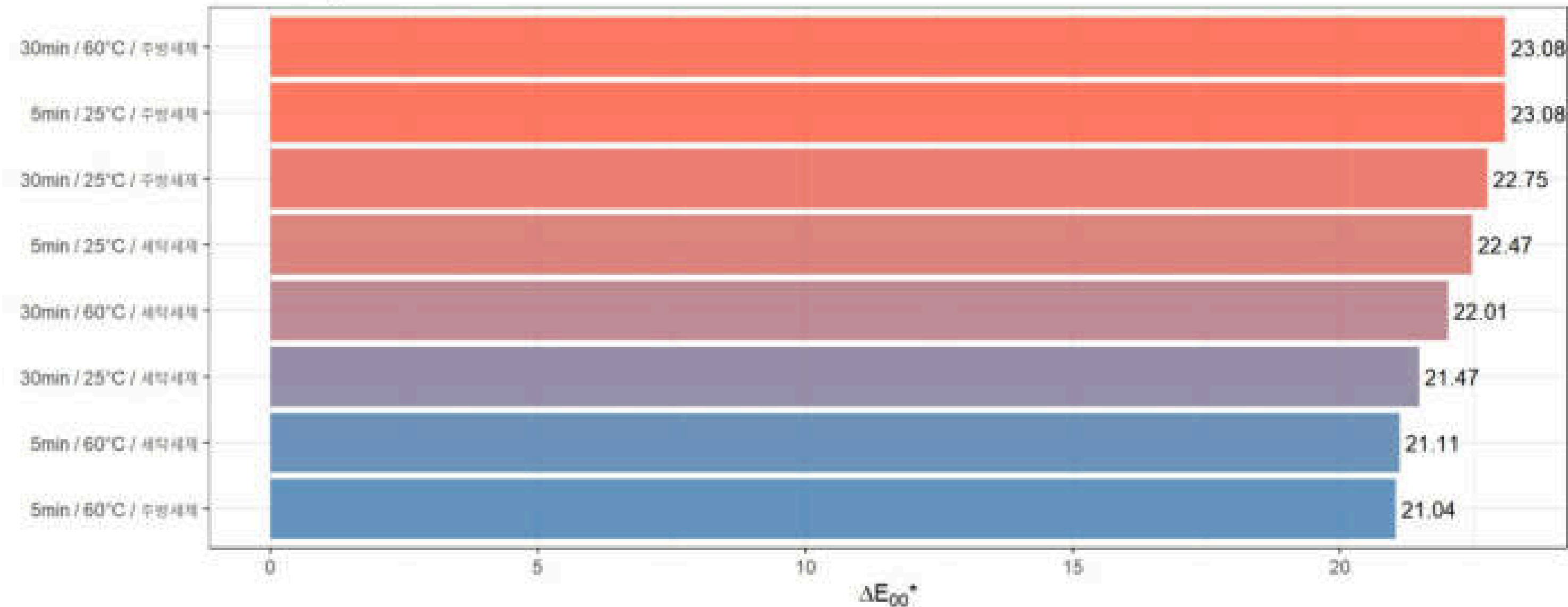
Heated water improves stain removal at 5-minute soaking **but** slightly negative effect at 30-minute soaking

Main effects cancel at the marginal level because their directions differ depending on the other factor's level.

Key Finding

Mean Stain Removal by Treatment Combination

Smaller ΔE_{00}^* = Better Removal



Best

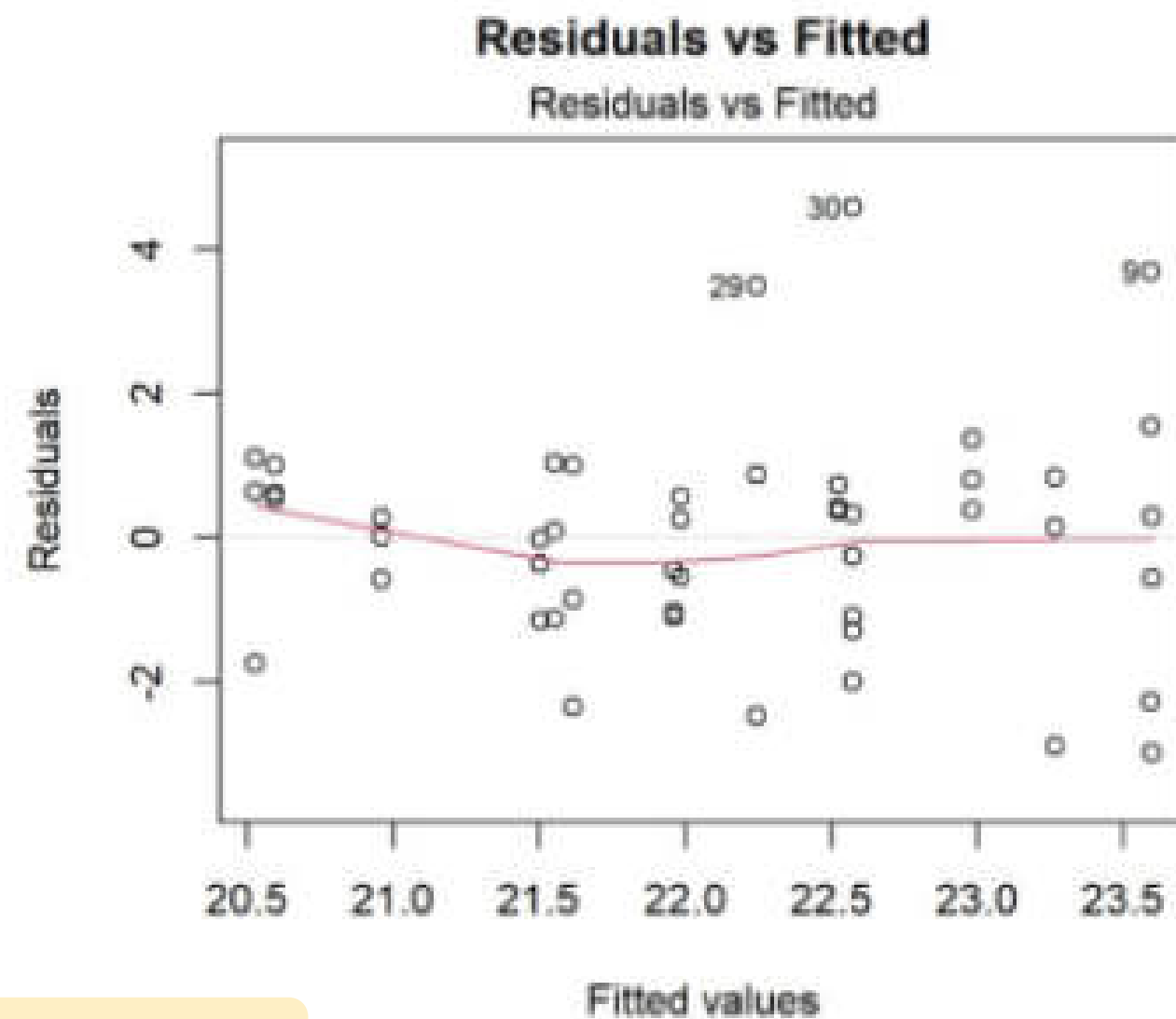
5-min / 60°C

Worst

30-min / 60°C

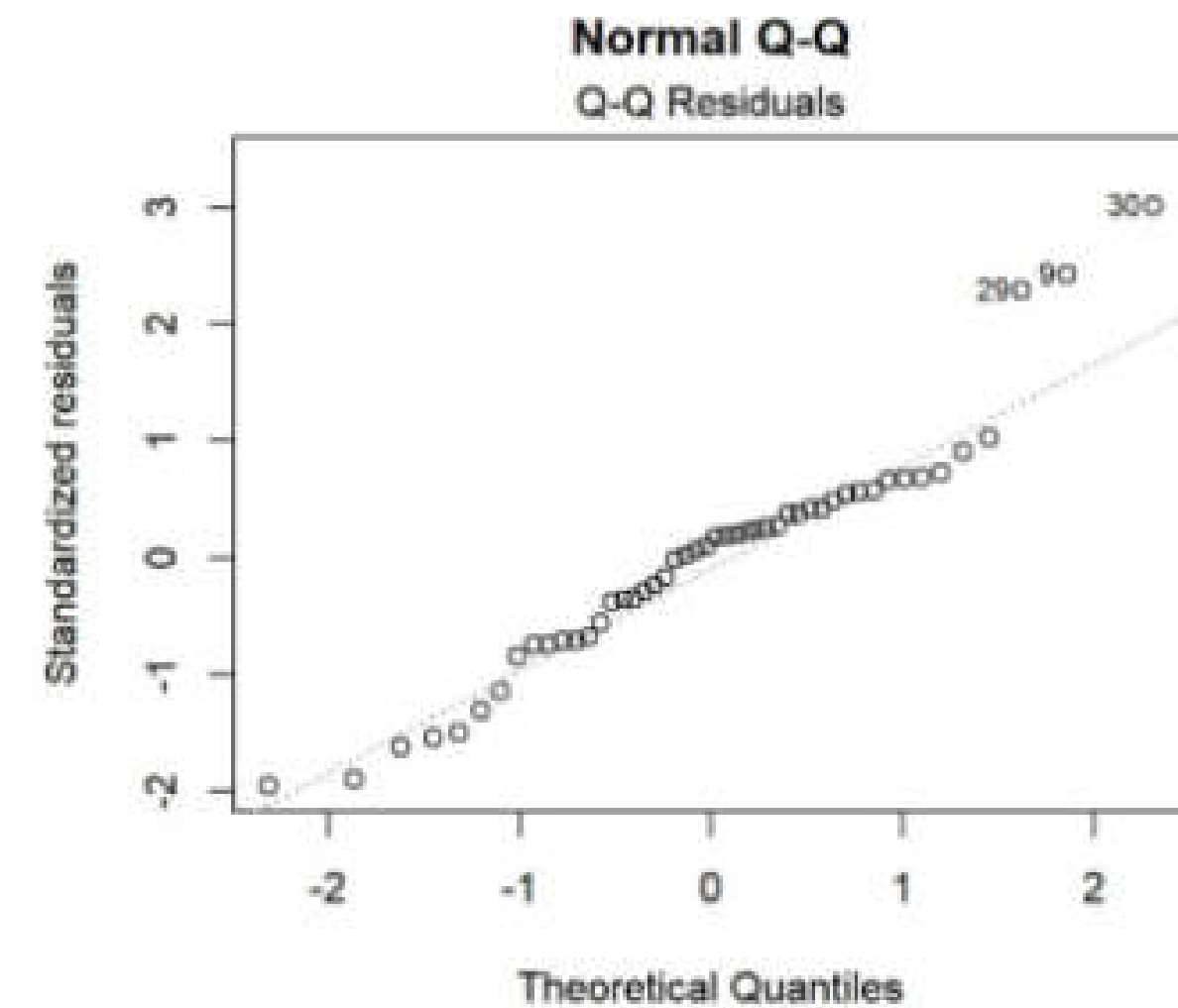
5-min / 25°C

Residuals & Q-Q plot



residuals

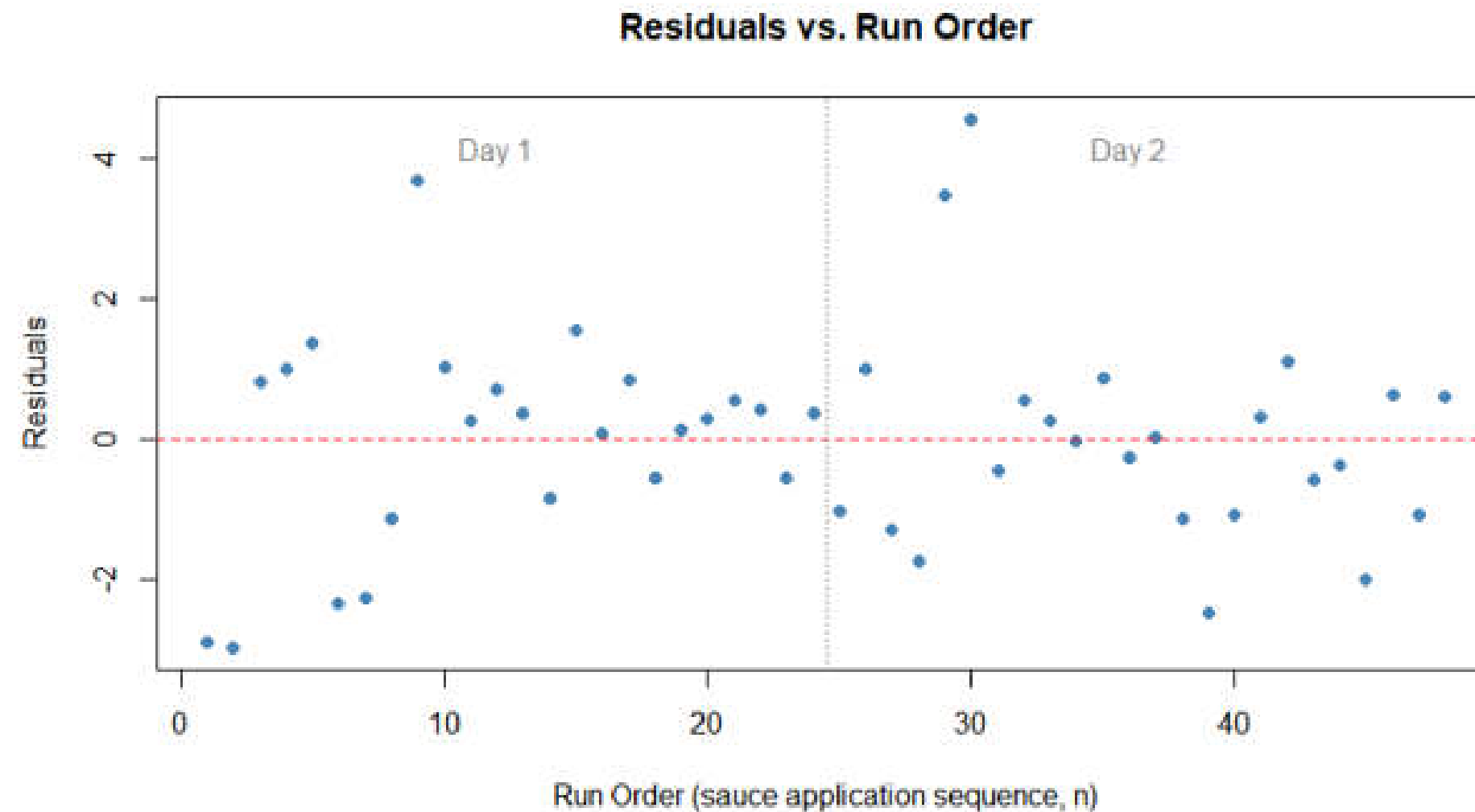
- no strong systematic pattern
- no evidence of a megaphone
- constant variance



Q-Q Plot

- most residuals lie close to the reference line
- normality reasonably satisfied
- +) Outlier Test: No externally studentized residual exceeded the Bonferroni-adjusted critical value

Residuals vs. Run Order plot



Independency

- no strong continuous patterns of same-signed positive (+) or negative (-) errors

DW Test

- Durbin-Watson statistic : 1.532 ($p=0.052$)
- This falls very close to the lower boundary of the conventional acceptable range (1.5–2.5)

Conclusions & Limitation

Only Temp * Time Interaction is Significant

Temp * Time interaction effect
 $F(1,39) = 4.84, p = 0.034$

Heated water + 5 mins soaking
-> best stain removal

Restricted generalization

Unidentified optimal intermediate settings due to two-level evaluation of factors

Inability to generalize to machine-washing



Thank you
