MEMORANDUM

To: Dr. Duha Ali **From:** Matthew Huang **Date:** June 8, 2025

Intro and Data

The study examined how distraction, screw turning direction, and hand dominance affect the time to unscrew a bolt in a restricted wrist posture. Fifty-seven Cal Poly students each unscrewed four bolts (one with each combination of hand and direction) under **either** a distraction condition (doing mental math problems in parallel) or a no-distraction condition (normal background noise). Each participant used **both** their dominant and nondominant hand in separate trials, as well as **both** inward (flexion) and outward (extension) screw directions. The time to fully unscrew each bolt was recorded (in seconds) with a stopwatch, yielding 228 total observations (4 trials x 57 participants). The design is a mixed incomplete-block 2×2×2 factorial:

- **Distraction** was a **between-subjects** factor (each participant experienced only one level),
- **Hand** and **Direction** were **within-subject** factors (each participant experienced all combinations).

Methodology

To analyze how distraction, screw direction, and hand dominance affected bolt removal time, we used a **mixed-effects ANOVA model** on the log-transformed completion times. The log transformation on unscrewing times was applied to better meet the assumptions of normality required for linear modeling. *(See Figure 1)*

ANOVA is a statistical method used to determine whether different experimental conditions lead to significantly different average outcomes. In this case, we used it to assess whether our factors (Distraction, Hand, and Direction) had significant effects on unscrewing times.

Because each participant completed multiple trials (one for each hand and direction), the data includes "repeated measures". This means the observations from the same participant are **not independent**. To account for this, we used a **mixed-effects model**, which includes:

- **Fixed effects**: These are variables whose levels we specifically want to compare (Distraction, Direction, Handedness, Direction and Handedness).
- **Random effects**: These represent random sources of variability we want to account for, but not directly test. Participant was treated as a random effect in our model.

Initially, the model included all main effects (Distraction, Hand, Direction) as well as all possible **interactions** between them. However, only the interaction between Hand and Direction showed potential importance and was retained in the final model. The other interaction terms (involving Distraction) were removed to simplify the model, as they were not statistically significant and did not improve model fit.

Key Findings

1. **Direction** has an **extremely significant** effect on unscrewing time. ($p<0.0001$) flexion unscrewing took on average 10.4s, where extension took 15.2s (4.8s longer on average). Around 45% slower for extension.
2. **Handedness** has a **significant** effect on unscrewing time. ($p=0.001$) the dominant hand trials averaged 12.2 s, whereas nondominant hand trials averaged 13.3 s (1.1s longer on average). Around 9% slower for the nondominant hand.
3. The **interaction** between **Direction and Handedness** has a **potentially significant** effect. ($p=0.06$) Perhaps surprisingly, the performance penalty from using the nondominant hand is less severe during extension compared to flexion. For dominant hand, extension takes 5.14s longer

(53% slower than flexion), while for non-dominant hand, extension takes 4.3s longer (39% slower than flexion). *(See Figure 2 below)*

4. Surprisingly, **Distraction** shows **no** significant effect on time. (p=0.927) Fixing other variables. The average time for distracted participants was 12.7s, compared to 12.9s with no distraction (negligible difference). Additionally, there were no significant interactions involving distraction. Meaning that the performance disadvantage of using one's nondominant hand, and the slower times for extension, were consistent whether or not the participant was distracted.

Power analysis and Future Design Recommendations

Statistical power is the chance that a test will detect a real effect if one exists. A common goal is 80% power, meaning you're likely to catch meaningful effects 4 out of 5 times. Power increases with larger effects, more consistent data, and more participants. **Replications** mean the number of independent participants per condition. This study had 28 replications (8 combinations x 28 replications = 228 total observations)

The study had strong power to detect large effects (like the ~5-second difference from wrist direction), and likely moderate ones too. But it was **not powered to detect small effects**, like the ~1-second difference from hand use or distraction. So, the lack of significance for distraction doesn't mean it had no effect — just that the study may have been too small to tell.

Power and Sample Size:

Maximum DIfference	Power	Replications Needed for 0.8 Power
1	0.3195	99
2	0.8460	25
3	0.9937	12

Given that the number of participants is fixed (i.e. limited by class size), a recommendation is to consider making **distraction a within-subjects factor** in future iterations. In other words, each participant would perform trials under both distraction and no-distraction conditions. Within-subject designs generally require fewer participants to detect effects, as well as allowing for higher order interactions to be detected.

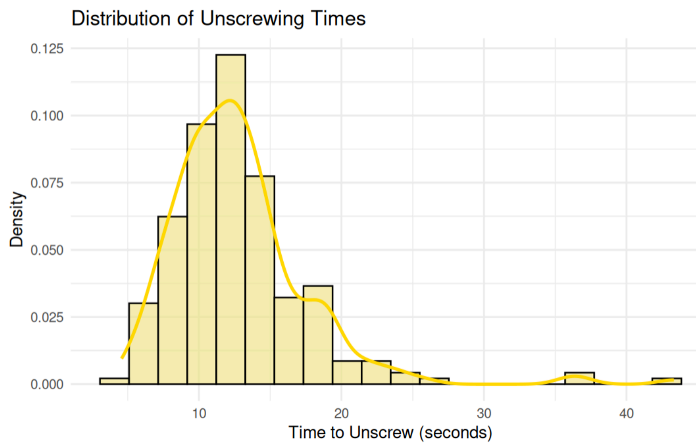

Figure 1.

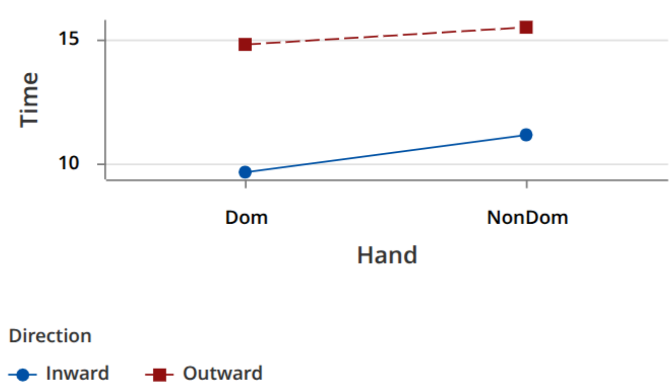

Figure 2.

Histogram displaying distribution of overall unscrewing times. There is a right skew, which is why we use a log-transform to achieve normality.

Interaction between Direction and Handedness is demonstrated by the difference in “slopes” of the lines, which represent the mean times to unscrew a bolt.