Fast Food Marketing Campaign AB Test

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Background

A fast-food chain plans to add a new item to its menu. However, they are still undecided between three possible marketing campaigns for promoting the new product. In order to determine which promotion has the greatest effect on sales, the new item is introduced at locations in several randomly selected markets. A different promotion is used at each location, and the weekly sales of the new item are recorded for the first four weeks.

Goal

Evaluate A/B testing results and decide which marketing strategy works the best.

Question

Does the type of promotion and the week of implementation have an impact on the sales of the fast-food chain? Furthermore, is there any interaction between these factors that influences the sales outcome?

Data

```
## # A tibble: 6 x 7
##   MarketID MarketSize LocationID AgeOfStore Promotion  week SalesInThousands
##      <dbl> <chr>           <dbl>      <dbl>     <dbl> <dbl>             <dbl>
## 1        1 Medium              1          4         3     1              33.7
## 2        1 Medium              1          4         3     2              35.7
## 3        1 Medium              1          4         3     3              29.0
## 4        1 Medium              1          4         3     4              39.2
## 5        1 Medium              2          5         2     1              27.8
## 6        1 Medium              2          5         2     2              34.7
```

Methods

Our study focuses on two main factors of interest: Promotion Types (Promotion) and the choice of the week for implementing the promotion (Week). The experimental units, which are the stores in this case, belong to specific levels of MarketSize and were randomized within each treatment combination of Promotion and Week. The response variable in this experiment is SalesInThousands, which is measured on a continuous scale.

Although MarketSize is not the primary factor of interest in our experiment, we use it as a standalone blocking factor. The purpose of using blocks is to group the experimental units into homogeneous categories, which helps reduce the impact of nuisance factors such as Market Size on the experimental error.

To enhance visualization and understanding, I have converted the Promotion and Week columns into strings. The first promotion, implemented in the first week of the month, is designated as the baseline level or the control group for comparison.

```
## # A tibble: 548 x 4
##    MarketSize Promotion        week        SalesInThousands
##    <chr>      <fct>            <fct>                  <dbl>
```

```
##  1 Medium     Third_Promotion  First_week              33.7
##  2 Medium     Third_Promotion  Second_week             35.7
##  3 Medium     Third_Promotion  Third_week              29.0
##  4 Medium     Third_Promotion  Fourth_week             39.2
##  5 Medium     Second_Promotion First_week              27.8
##  6 Medium     Second_Promotion Second_week             34.7
##  7 Medium     Second_Promotion Third_week              28.0
##  8 Medium     Second_Promotion Fourth_week             27.7
##  9 Medium     First_Promotion  First_week              44.5
## 10 Medium     First_Promotion  Second_week             37.9
## # ... with 538 more rows
```

Exploratory data analysis

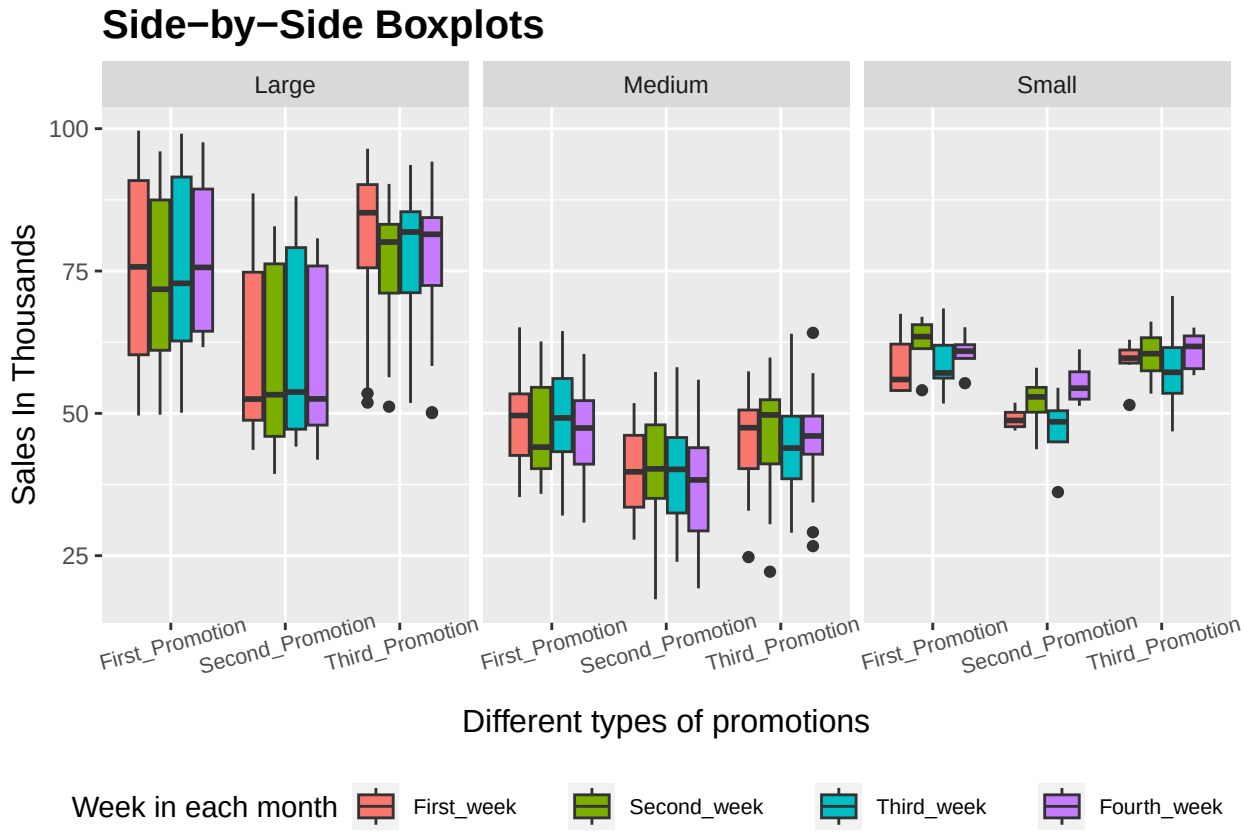

Figure 1: Investigating the impact of Promotion and Week on Sales across different market sizes

Regarding the facets, i.e. blocking factor levels, the overall sales of large market size is noticeably higher than medium and small market size which makes sense. However, it is interesting to see that the overall sales of medium market is lower than the small market and it might require further investigation. Across three different size of markets, we can also see a small u-shaped where the second promotion is generally

lower than the other two promotions.

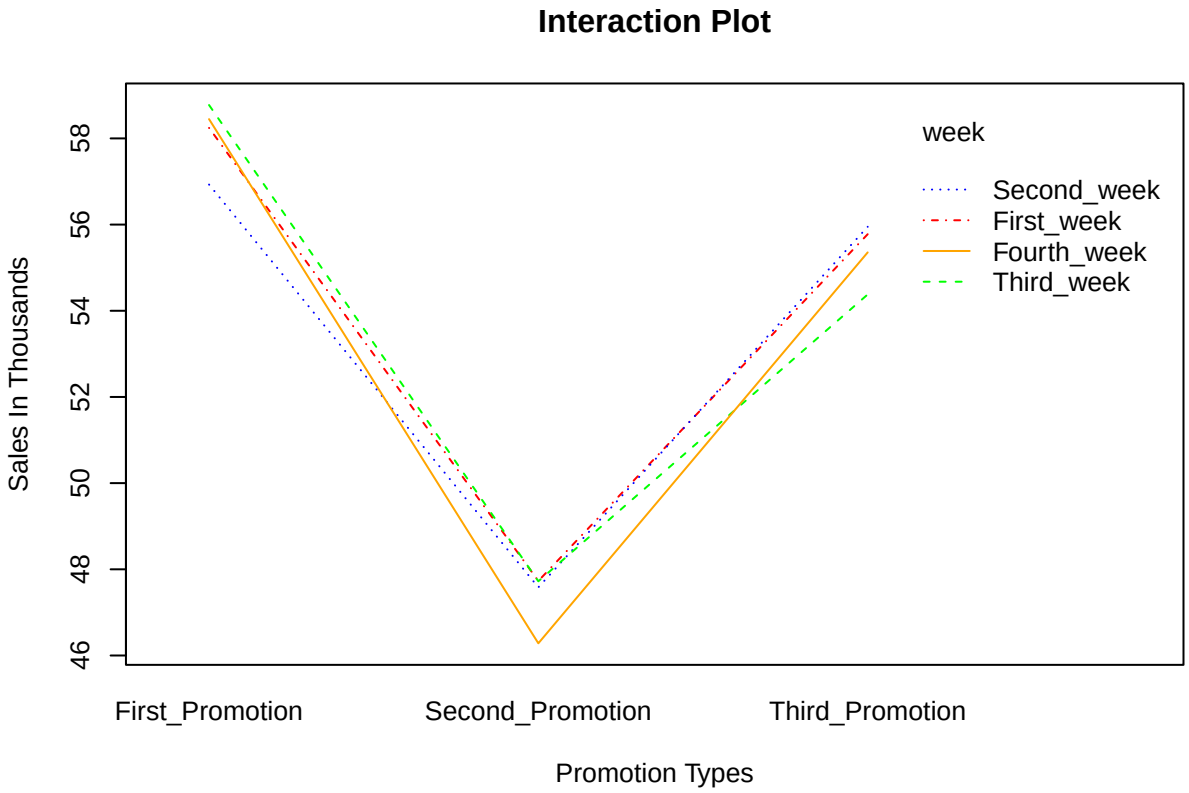

Figure 2: Graphical evidence of a two-factor interaction

It seems like The interaction plot shows some crossed behaviors among the treatments in Promotion and week even though their shapes are similar. This deserves further statistical investigation.

```
## # A tibble: 5 x 6
##   term              df   sumsq   meansq statistic p.value
##   <chr>          <dbl>   <dbl>    <dbl>     <dbl>   <dbl>
## 1 Promotion          2 11449.   5725.       47.7     0
## 2 week               3    24.1     8.02      0.07    0.98
## 3 MarketSize         2 77803.  38902.      324.      0
## 4 Promotion:week     6   200.     33.3       0.28    0.95
## 5 Residuals        534 64087.    120.       NA      NA
```

With alpha = 0.05, we have evidence to reject the null hypotheses for the main effects of Promotion but not for the main effects of week and the interaction effects despite the graphical evidence of a two-factor interaction that is shown in figure 2 above.

Post-Hoc Tests

After estimating the model, Tukey's honestly significant differences (HSD) test is conducted to reveal all possible pairwise comparisons among the levels of the main and interaction effects while appropriately controlling Type I errors.

```
## # A tibble: 78 x 7
##    term       contrast                   null.~1 estim~2 conf.~3 conf.~4 adj.p~5
##    <chr>      <chr>                        <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
##  1 Promotion  Second_Promotion-First_Pr~       0  -10.8   -13.5    -8.05    0
##  2 Promotion  Third_Promotion-First_Pro~       0   -2.73   -5.45   -0.02    0.05
##  3 Promotion  Third_Promotion-Second_Pr~       0    8.04    5.38   10.7     0
##  4 week       Second_week-First_week           0   -0.4    -3.82    3.01    0.99
##  5 week       Third_week-First_week            0   -0.32   -3.73    3.1     1
##  6 week       Fourth_week-First_week           0   -0.58   -3.99    2.83    0.97
##  7 week       Third_week-Second_week           0    0.09   -3.32    3.5     1
##  8 week       Fourth_week-Second_week          0   -0.17   -3.58    3.24    1
##  9 week       Fourth_week-Third_week           0   -0.26   -3.67    3.15    1
## 10 MarketSize Medium-Large                     0  -26.4   -28.8   -23.9     0
## # ... with 68 more rows, and abbreviated variable names 1: null.value,
## #   2: estimate, 3: conf.low, 4: conf.high, 5: adj.p.value
```

Conclusion

```
## # A tibble: 3 x 7
##   term       contrast     null.value estimate conf.low conf.high adj.p.value
##   <chr>      <chr>             <dbl>    <dbl>    <dbl>     <dbl>       <dbl>
## 1 MarketSize Medium-Large          0    -26.4   -28.8     -23.9            0
## 2 MarketSize Small-Large           0    -13.6   -17.5      -9.75           0
## 3 MarketSize Small-Medium          0     12.8     9.14     16.4            0
```

First of all, it is essential to highlight that the blocking factor MarketSize is statistically significant.

```
## # A tibble: 3 x 7
##   term      contrast                    null.~1 estim~2 conf.~3 conf.~4 adj.p~5
##   <chr>     <chr>                         <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
## 1 Promotion Second_Promotion-First_Prom~       0  -10.8   -13.5    -8.05    0
## 2 Promotion Third_Promotion-First_Promo~       0   -2.73   -5.45   -0.02    0.05
## 3 Promotion Third_Promotion-Second_Prom~       0    8.04    5.38   10.7     0
## # ... with abbreviated variable names 1: null.value, 2: estimate, 3: conf.low,
## #   4: conf.high, 5: adj.p.value
```

Based on the pairwise results, it is statistically significant that during the **second promotion**, the outcome is expected to decrease by 10.77 thousand dollars compared to the **first promotion**.

It is also statistically significant that during the **third promotion**, the outcome is expected to increase by 8.04 thousand dollars compared to the **second promotion**.

However, it is not statistically significant that the **third promotion** is different from **first promotion** because its adjusted p-value is slightly higher than 0.05 .

Therefore, we can conclude that both the first and third promotions are better than the second promotion. However, even though we can see from the estimate column in the above table that during the third promotion, the outcome is expected to decrease by 2.73 thousand dollars compared to the first promotion, we cannot assert that the first promotion is the best. This is because there is no statistical evidence to support that claim, as its adjusted p-value is slightly higher than 0.05.

```
## # A tibble: 4 x 7
##   term           contrast                null.~1 estim~2 conf.~3 conf.~4 adj.p~5
##   <chr>          <chr>                     <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
## 1 Promotion:week Second_Promotion:First~       0   -10.5   -18.1   -2.93       0
## 2 Promotion:week Second_Promotion:Secon~       0   -10.7   -18.2   -3.07       0
## 3 Promotion:week Second_Promotion:Third~       0   -10.5   -18.1   -2.93       0
## 4 Promotion:week Second_Promotion:Fourt~       0   -12.0   -19.6   -4.37       0
## # ... with abbreviated variable names 1: null.value, 2: estimate, 3: conf.low,
## #   4: conf.high, 5: adj.p.value
```

If we focus on the significant difference corresponding to the two-factor interaction, specifically with the control treatment "First Promotion" and "First week" (our CONTROL treatment), we observe that all four rows with statistically significant levels are associated with the "Second Promotion." This leads us to conclude that the "Second Promotion" performs worse than our control group (implementing the first type of promotion in the first week of the month) regardless of which week of the month the promotion is implemented.

Summary

Based on the statistical analysis, we have strong evidence to suggest that both the first and third promotions lead to better outcomes compared to the second promotion. However, we cannot confidently state that the first promotion is superior to the third promotion due to the lack of significant statistical support, as indicated by the adjusted p-values. We also find that the "Second Promotion" shows a significant decline compared to our control group, indicating that implementing the first type of promotion in the first week of the month is more effective than the "Second Promotion."