One-Way ANOVA

일원분산분석 후 사후분석

**η²:** 종속변수의 전체 분산 중 독립변수에 의해 설명된 분산의 비율(R2랑 마찬가지 개념)

즉, payment method라는 변수 하나가 total charges라는 종속변수가 가지고 있는 분산의 12.3%정도 설명한다 (즉, 모형의 설명력)

Bonferroni correction: p(0.05)의 경우 0.05/n 으로 유의성 검정

종속: 연속형만 가능

독립: 이산형, 범주형만 가능

**Descriptives**

| Descriptives | | | | | |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
|  | | **PaymentMethod** | | **TotalCharges** | |
| N |  | Bank transfer (automatic) |  | 1542 |  |
|  |  | Credit card (automatic) |  | 1521 |  |
|  |  | Electronic check |  | 2365 |  |
|  |  | Mailed check |  | 1604 |  |
| Mean |  | Bank transfer (automatic) |  | 3079 |  |
|  |  | Credit card (automatic) |  | 3071 |  |
|  |  | Electronic check |  | 2091 |  |
|  |  | Mailed check |  | 1054 |  |
|  | | | | | |

# ANOVA

| ANOVA - TotalCharges | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | |
| PaymentMethod |  | 4.43e0+9 |  | 3 |  | 1.48e+9 |  | 328 |  | < .001 |  | 0.123 |  |
| Residuals |  | 3.17e+10 |  | 7028 |  | 4.51e+6 |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | |

## Post Hoc Tests

| Post Hoc Comparisons - PaymentMethod | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Comparison** | | | | | |  | | | | | | | | | | | |
| **PaymentMethod** | |  | | **PaymentMethod** | | **Mean Difference** | | **SE** | | **df** | | **t** | | **ptukey** | | **pbonferroni** | |
| Bank transfer (automatic) |  | - |  | Credit card (automatic) |  | 7.90 |  | 76.7 |  | 7028 |  | 0.103 |  | 1.000 |  | 1.000 |  |
|  |  | - |  | Electronic check |  | 988.43 |  | 69.5 |  | 7028 |  | 14.220 |  | < .001 |  | < .001 |  |
|  |  | - |  | Mailed check |  | 2024.82 |  | 75.7 |  | 7028 |  | 26.734 |  | < .001 |  | < .001 |  |
| Credit card (automatic) |  | - |  | Electronic check |  | 980.53 |  | 69.8 |  | 7028 |  | 14.048 |  | < .001 |  | < .001 |  |
|  |  | - |  | Mailed check |  | 2016.91 |  | 76.0 |  | 7028 |  | 26.537 |  | < .001 |  | < .001 |  |
| Electronic check |  | - |  | Mailed check |  | 1036.38 |  | 68.7 |  | 7028 |  | 15.087 |  | < .001 |  | < .001 |  |
| Note. Comparisons are based on estimated marginal means | | | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | |

Bank transfer하고 credit card는 아무 차이 없음

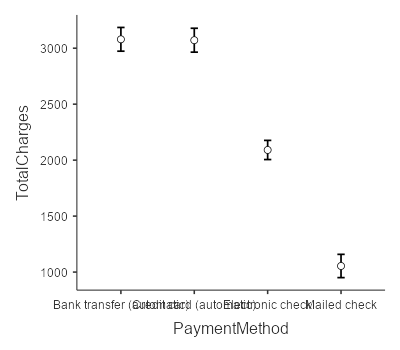
Bank transfer는 electroniccheck, mailedcheck에 대해서 분명히 다름(<0.001)

Creditcard는 electroniccheck이랑 mailedcheck에 대해 분명히 다름(<0.001)

Electroniccheck은 mailedcheck에 대해 분명히 다름

## Estimated Marginal Means

### PaymentMethod



그림을 보면 Bank transfer하고 credit card는 아무 차이 없음이 분명히 보임

근데 그 둘이 electronic check이나 mailed check하고는 분명히 다름이 보임

즉, 표와 그래프를 동시에 보면 굉장히 빠르게 이해할 수 있음

Two Way ANOVA

# ANOVA

| ANOVA - TotalCharges | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  | | **Sum of Squares** | | **df** | | **Mean Square** | | **F** | | **p** | | **η²** | |
| PaymentMethod |  | 3.74e0+9 |  | 3 |  | 1.25e+9 |  | 354.5 |  | < .001 |  | 0.106 |  |
| Contract |  | 6.17e0+9 |  | 2 |  | 3.09e+9 |  | 877.7 |  | < .001 |  | 0.175 |  |
| PaymentMethod ✻ Contract |  | 7.74e0+8 |  | 6 |  | 1.29e+8 |  | 36.7 |  | < .001 |  | 0.022 |  |
| Residuals |  | 2.47e+10 |  | 7020 |  | 3.52e+6 |  |  |  |  |  |  |  |
|  | | | | | | | | | | | | | |

* Main Effect 두개에 대한 post hoc test 결과

## Post Hoc Tests

| Post Hoc Comparisons - PaymentMethod | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Comparison** | | | | | |  | | | | | | | | | |
| **PaymentMethod** | |  | | **PaymentMethod** | | **Mean Difference** | | **SE** | | **df** | | **t** | | **ptukey** | |
| Bank transfer (automatic) |  | - |  | Credit card (automatic) |  | 47.7 |  | 68.8 |  | 7020 |  | 0.694 |  | 0.900 |  |
|  |  | - |  | Electronic check |  | -410.4 |  | 77.6 |  | 7020 |  | -5.290 |  | < .001 |  |
|  |  | - |  | Mailed check |  | 1820.7 |  | 70.7 |  | 7020 |  | 25.752 |  | < .001 |  |
| Credit card (automatic) |  | - |  | Electronic check |  | -458.1 |  | 77.7 |  | 7020 |  | -5.897 |  | < .001 |  |
|  |  | - |  | Mailed check |  | 1773.0 |  | 70.8 |  | 7020 |  | 25.035 |  | < .001 |  |
| Electronic check |  | - |  | Mailed check |  | 2231.1 |  | 79.4 |  | 7020 |  | 28.102 |  | < .001 |  |
| Note. Comparisons are based on estimated marginal means | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | |

| Post Hoc Comparisons - Contract | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Comparison** | | | | | |  | | | | | | | | | |
| **Contract** | |  | | **Contract** | | **Mean Difference** | | **SE** | | **df** | | **t** | | **ptukey** | |
| Month-to-month |  | - |  | One year |  | -1573 |  | 59.5 |  | 7020 |  | -26.4 |  | < .001 |  |
|  |  | - |  | Two year |  | -2414 |  | 61.7 |  | 7020 |  | -39.1 |  | < .001 |  |
| One year |  | - |  | Two year |  | -841 |  | 71.2 |  | 7020 |  | -11.8 |  | < .001 |  |
| Note. Comparisons are based on estimated marginal means | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | |

* Interaction Effect에 대한 Posthoc 결과:

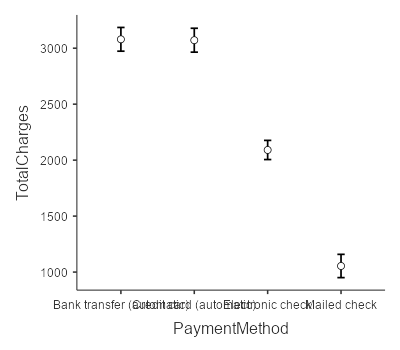
| Post Hoc Comparisons - PaymentMethod ✻ Contract | | | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Comparison** | | | | | | | | | |  | | | | | | | | | |
| **PaymentMethod** | | **Contract** | |  | | **PaymentMethod** | | **Contract** | | **Mean Difference** | | **SE** | | **df** | | **t** | | **ptukey** | |
| Bank transfer (automatic) |  | Month-to-month |  | - |  | Bank transfer (automatic) |  | One year |  | -1425.6 |  | 122.3 |  | 7020 |  | -11.656 |  | < .001 |  |
|  |  |  |  | - |  | Bank transfer (automatic) |  | Two year |  | -2278.4 |  | 110.6 |  | 7020 |  | -20.607 |  | < .001 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | Month-to-month |  | 81.6 |  | 111.5 |  | 7020 |  | 0.731 |  | 1.000 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | One year |  | -1469.8 |  | 121.7 |  | 7020 |  | -12.081 |  | < .001 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | Two year |  | -2172.6 |  | 109.7 |  | 7020 |  | -19.808 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | Month-to-month |  | 416.1 |  | 88.7 |  | 7020 |  | 4.691 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | One year |  | -1965.8 |  | 126.9 |  | 7020 |  | -15.493 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | Two year |  | -3385.5 |  | 164.0 |  | 7020 |  | -20.644 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 1336.9 |  | 99.5 |  | 7020 |  | 13.433 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 404.1 |  | 128.2 |  | 7020 |  | 3.153 |  | 0.071 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | 17.1 |  | 123.9 |  | 7020 |  | 0.138 |  | 1.000 |  |
|  |  | One year |  | - |  | Bank transfer (automatic) |  | Two year |  | -852.8 |  | 123.5 |  | 7020 |  | -6.907 |  | < .001 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | Month-to-month |  | 1507.1 |  | 124.4 |  | 7020 |  | 12.119 |  | < .001 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | One year |  | -44.3 |  | 133.5 |  | 7020 |  | -0.331 |  | 1.000 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | Two year |  | -747.0 |  | 122.7 |  | 7020 |  | -6.089 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | Month-to-month |  | 1841.7 |  | 104.4 |  | 7020 |  | 17.647 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | One year |  | -540.3 |  | 138.3 |  | 7020 |  | -3.907 |  | 0.005 |  |
|  |  |  |  | - |  | Electronic check |  | Two year |  | -1960.0 |  | 173.0 |  | 7020 |  | -11.332 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 2762.5 |  | 113.7 |  | 7020 |  | 24.297 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 1829.7 |  | 139.5 |  | 7020 |  | 13.118 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | 1442.6 |  | 135.5 |  | 7020 |  | 10.645 |  | < .001 |  |
|  |  | Two year |  | - |  | Credit card (automatic) |  | Month-to-month |  | 2359.9 |  | 112.8 |  | 7020 |  | 20.917 |  | < .001 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | One year |  | 808.6 |  | 122.8 |  | 7020 |  | 6.583 |  | < .001 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | Two year |  | 105.8 |  | 111.0 |  | 7020 |  | 0.953 |  | 0.999 |  |
|  |  |  |  | - |  | Electronic check |  | Month-to-month |  | 2694.5 |  | 90.3 |  | 7020 |  | 29.837 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | One year |  | 312.5 |  | 128.0 |  | 7020 |  | 2.442 |  | 0.378 |  |
|  |  |  |  | - |  | Electronic check |  | Two year |  | -1107.2 |  | 164.9 |  | 7020 |  | -6.716 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 3615.3 |  | 101.0 |  | 7020 |  | 35.811 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 2682.5 |  | 129.3 |  | 7020 |  | 20.747 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | 2295.4 |  | 125.0 |  | 7020 |  | 18.361 |  | < .001 |  |
| Credit card (automatic) |  | Month-to-month |  | - |  | Credit card (automatic) |  | One year |  | -1551.4 |  | 123.7 |  | 7020 |  | -12.539 |  | < .001 |  |
|  |  |  |  | - |  | Credit card (automatic) |  | Two year |  | -2254.1 |  | 112.0 |  | 7020 |  | -20.133 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | Month-to-month |  | 334.6 |  | 91.5 |  | 7020 |  | 3.656 |  | 0.014 |  |
|  |  |  |  | - |  | Electronic check |  | One year |  | -2047.4 |  | 128.9 |  | 7020 |  | -15.889 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | Two year |  | -3467.1 |  | 165.5 |  | 7020 |  | -20.946 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 1255.4 |  | 102.0 |  | 7020 |  | 12.304 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 322.6 |  | 130.1 |  | 7020 |  | 2.479 |  | 0.354 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | -64.5 |  | 125.9 |  | 7020 |  | -0.512 |  | 1.000 |  |
|  |  | One year |  | - |  | Credit card (automatic) |  | Two year |  | -702.8 |  | 122.0 |  | 7020 |  | -5.758 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | Month-to-month |  | 1885.9 |  | 103.6 |  | 7020 |  | 18.204 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | One year |  | -496.0 |  | 137.7 |  | 7020 |  | -3.602 |  | 0.017 |  |
|  |  |  |  | - |  | Electronic check |  | Two year |  | -1915.7 |  | 172.5 |  | 7020 |  | -11.105 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 2806.8 |  | 113.0 |  | 7020 |  | 24.838 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 1873.9 |  | 138.9 |  | 7020 |  | 13.491 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | 1486.9 |  | 134.9 |  | 7020 |  | 11.019 |  | < .001 |  |
|  |  | Two year |  | - |  | Electronic check |  | Month-to-month |  | 2588.7 |  | 89.2 |  | 7020 |  | 29.013 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | One year |  | 206.7 |  | 127.2 |  | 7020 |  | 1.625 |  | 0.900 |  |
|  |  |  |  | - |  | Electronic check |  | Two year |  | -1213.0 |  | 164.3 |  | 7020 |  | -7.384 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 3509.5 |  | 100.0 |  | 7020 |  | 35.099 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 2576.7 |  | 128.5 |  | 7020 |  | 20.045 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | 2189.6 |  | 124.2 |  | 7020 |  | 17.624 |  | < .001 |  |
| Electronic check |  | Month-to-month |  | - |  | Electronic check |  | One year |  | -2381.9 |  | 109.7 |  | 7020 |  | -21.716 |  | < .001 |  |
|  |  |  |  | - |  | Electronic check |  | Two year |  | -3801.6 |  | 151.1 |  | 7020 |  | -25.163 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 920.8 |  | 76.4 |  | 7020 |  | 12.053 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | -12.0 |  | 111.2 |  | 7020 |  | -0.108 |  | 1.000 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | -399.1 |  | 106.2 |  | 7020 |  | -3.758 |  | 0.009 |  |
|  |  | One year |  | - |  | Electronic check |  | Two year |  | -1419.7 |  | 176.2 |  | 7020 |  | -8.056 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Month-to-month |  | 3302.8 |  | 118.6 |  | 7020 |  | 27.847 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 2370.0 |  | 143.5 |  | 7020 |  | 16.515 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | 1982.9 |  | 139.7 |  | 7020 |  | 14.198 |  | < .001 |  |
|  |  | Two year |  | - |  | Mailed check |  | Month-to-month |  | 4722.5 |  | 157.7 |  | 7020 |  | 29.951 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | One year |  | 3789.7 |  | 177.2 |  | 7020 |  | 21.391 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | 3402.6 |  | 174.1 |  | 7020 |  | 19.548 |  | < .001 |  |
| Mailed check |  | Month-to-month |  | - |  | Mailed check |  | One year |  | -932.8 |  | 120.0 |  | 7020 |  | -7.774 |  | < .001 |  |
|  |  |  |  | - |  | Mailed check |  | Two year |  | -1319.9 |  | 115.4 |  | 7020 |  | -11.440 |  | < .001 |  |
|  |  | One year |  | - |  | Mailed check |  | Two year |  | -387.1 |  | 140.8 |  | 7020 |  | -2.748 |  | 0.203 |  |
| Note. Comparisons are based on estimated marginal means | | | | | | | | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | | | |

## Estimated Marginal Means

### PaymentMethod ✻ Contract



그래프 인사이트:



One way anova에서 이 그래프랑 대조적으로, one-year two-year의 경우에는 electronic check가 올라감 (month to month만 떨어지고). Payment method만 놓고 봤을 때는 electronic check이 그다지 total charges가 높지 않은 것 같았는데 여기에 contract이라는 변수를 같이 감안해서 보니까 oneyear twoyear contract인 사람들은 payment method가 electronic check인 경우에 굉장히 높더라. 즉, interaction effect가 유의했다는 뜻