

表 1 主体间效应检验结果

| | SS | df | MS | F | Sig. | η_p^2 |
|-----------|---------|----|---------|----------|--------|------------|
| Intercept | 497.964 | 1 | 497.964 | 2024.544 | <0.001 | 0.991 |
| Group | 0.295 | 1 | 0.295 | 1.435 | 0.244 | 0.061 |
| Err. | 4.526 | 22 | 0.206 | | | |

根据研究设计首先进行主体间效应检验，结果如表 1 所示，组间变量 Group 的主效应不显著， $F(1,22)=1.435$, $p=0.244$, $\eta_p^2=0.061$, 表明在不考虑时间因素的情况下，实验组与对照组在因变量的总体平均水平上不存在显著差异。

表 2 主体内效应检验结果

| | Fauchly's Test | | | Greenhouse-Geisser | | | η_p^2 |
|------------|----------------|-------|---------|--------------------|----------------------|-----|------------|
| | W | Sig | Epsilon | SS | F | Sig | |
| Time | 0.591 | 0.004 | 0.710 | 0.252 | $F(1.419,44)=28.484$ | *** | 0.564 |
| Group*Time | | | | 0.244 | $F(1.419,44)=27.521$ | *** | 0.556 |

Note: *:p<0.05; **:p<0.01; ***:p<0.001

经对主体内因素 Time 及 Group × Time 交互效应进行检验，结果如表 2 所示，Mauchly 球形性检验结果显著， $W=0.591$, $p=0.004$, 表明数据不满球形性假设。后续分析采用 Greenhouse – Geisser 校正自由度 ($\epsilon =0.710$)。在校正后结果中，Time 的主效应显著， $F(1.419,44)=28.484$, $p<0.001$, $\eta_p^2=0.564$, 表明不同测量时间点之间的因变量均值存在显著差异。

另，Group × Time 交互效应亦达到显著水平， $F(1.419,44)=27.521$, $p<0.001$, $\eta_p^2=0.556$, 表明不同组别在时间维度上的变化模式存在显著差异。鉴于交互效应显著，需进一步对组内时间效应及同一时间点的组间差异进行简单效应分析。

表3 简单效应分析结果

| | 平均值 | 标准差 | 平均值对比 | | Sig. |
|-------------------------|-------|------|----------------|--------|--------|
| | | | 水平 | 差值 | |
| group= Treatment | | | | | |
| time1 | 2.704 | 0.25 | time1 - time 2 | 0.128 | <0.001 |
| time2 | 2.576 | 0.31 | time1 - time3 | 0.287 | <0.001 |
| time3 | 2.418 | 0.32 | time2 - time3 | 0.158 | <0.001 |
| group= Control | | | | | |
| Time1 | 2.691 | 0.23 | time1 - time 2 | -0.011 | 1.000 |
| time2 | 2.702 | 0.22 | time1 - time3 | 0.002 | 1.000 |
| time3 | 2.689 | 0.25 | time2 - time3 | 0.013 | 1.000 |
| time= 1 | | | | | |
| Treatment | 2.704 | 0.25 | Tre - Con | 0.013 | 0.893 |
| Control | 2.691 | 0.23 | | | |
| time= 2 | | | | | |
| Treatment | 2.576 | 0.31 | Tre - Con | -0.126 | 0.266 |
| Control | 2.702 | 0.22 | | | |
| time= 3 | | | | | |
| Treatment | 2.418 | 0.32 | Tre - Con | -0.272 | 0.032 |
| Control | 2.689 | 0.25 | | | |

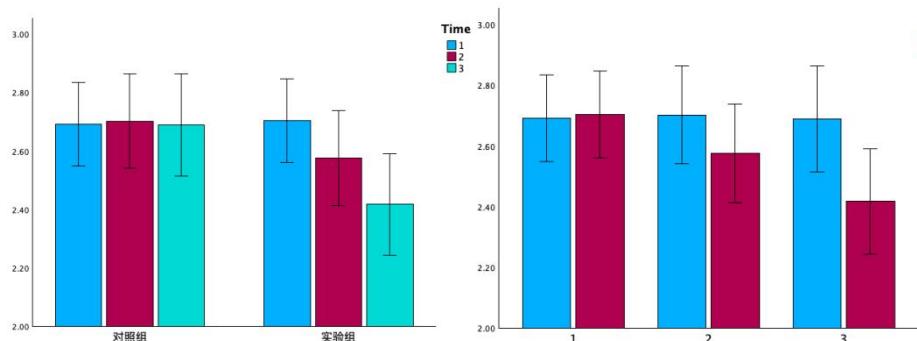


图1 简单效应分析结果图

经分别对组间变量和组内变量进行简单效应分析，结果如表3所示，实验组 (Treatment) 中，时间因素的简单效应显著。具体而言，time1 的均值显著高于 time2 ($p<0.001$) 和 time3 ($p<0.001$)，且 time2 的均值亦显著高于 time3 ($p<0.001$)，表明实验组因变量水平随测量时间呈显著递减趋势；对照组 (Control) 中，时间因素的简单效应不显著，各时间点之间的均值差异均未达到统计显著水平（均 $p=1.000$ ），说明对照组因变量在整个测量过程中保持相对稳定。

进一步的组间简单效应分析结果显示，在 time1 与 time2 时，实验组与对照组之间的均值差异均不显著 (time1: $p=0.893$; time2: $p=0.266$)；而在 time3 时，实验组的均值显著低于对照组，差异达到统计显著水平 ($p=0.032$)。该结果表明，组间差异主要出现在后期测

量阶段。图 1 同样显示实验组的因变量均值随时间逐渐下降，而对照组的均值在各时间点保持相对稳定；Time1、Time2 时间节点实验组与对照组无显著差，Time3 时间节点实验组与对照组差异显著。该图呈现内容与方差分析结果一致，进一步直观反映了 Group \times Time 的显著交互效应。

表3 简单效应分析结果

| | 平均值 | 标准差 | 平均值对比 | | Sig. | Effect Size ¹ | | |
|-------------------------|-------|------|----------------|--------|--------|--------------------------|-----------------|------------|
| | | | 水平 | 差值 | | Cohen's d | 95%CI | Magnitudes |
| group= Treatment | | | | | | | | |
| time1 | 2.704 | 0.25 | time1 - time 2 | 0.128 | <0.001 | 0.536 | [0.675, 1.782] | Medium |
| time2 | 2.576 | 0.31 | time1 - time3 | 0.287 | <0.001 | 1.062 | [1.085, 2.413] | Large |
| time3 | 2.418 | 0.32 | time2 - time3 | 0.158 | <0.001 | 0.545 | [0.876, 2.085] | Medium |
| group= Control | | | | | | | | |
| Time1 | 2.691 | 0.23 | time1 - time 2 | -0.011 | >0.999 | -0.045 | [-0.522, 0.316] | Negligible |
| time2 | 2.702 | 0.22 | time1 - time3 | 0.002 | >0.999 | 0.006 | [-0.408, 0.428] | Negligible |
| time3 | 2.689 | 0.25 | time2 - time3 | 0.012 | >0.999 | 0.043 | [-0.303, 0.535] | Negligible |
| time= 1 | | | | | | | | |
| Treatment | 2.704 | 0.25 | Con - Tre | -0.013 | 0.893 | -0.056 | [-0.893,0.778] | Negligible |
| Control | 2.691 | 0.23 | | | | | | |
| time= 2 | | | | | | | | |
| Treatment | 2.576 | 0.31 | Con - Tre | 0.126 | 0.266 | 0.466 | [-0.366,1.329] | Small |
| Control | 2.702 | 0.22 | | | | | | |
| time= 3 | | | | | | | | |
| Treatment | 2.418 | 0.32 | Con - Tre | 0.272 | 0.032 | 0.935 | [0.083,1.850] | Large |
| Control | 2.689 | 0.25 | | | | | | |

Note: ¹: R-Package: effectsize, Cohen's d derived from mixed-model ANOVA, Effect size magnitudes were interpreted using Cohen's conventions: negligible ($|d| < 0.2$), small ($0.2 \leq |d| < 0.5$), medium ($0.5 \leq |d| < 0.8$), and large ($|d| \geq 0.8$).

简单效应分析：基于模型的Cohen's d效应量

| 分析类型 | 组别 | 对比 | 均值差 | t值 | p值 | Cohen's d | 95%CI | 效应大小 |
|------|-----|---------------------|--------|--------|--------|-----------|-----------------|------|
| 组内比较 | 实验组 | T1 - T2 | 0.128 | 5.800 | < .001 | 0.536 | [0.675, 1.782] | 中等效应 |
| 组内比较 | 实验组 | T1 - T3 | 0.287 | 8.241 | < .001 | 1.062 | [1.085, 2.413] | 大效应 |
| 组内比较 | 实验组 | T2 - T3 | 0.158 | 6.981 | < .001 | 0.545 | [0.876, 2.085] | 中等效应 |
| 组内比较 | 对照组 | T1 - T2 | -0.011 | -0.490 | > .999 | -0.045 | [-0.522, 0.316] | 极小效应 |
| 组内比较 | 对照组 | T1 - T3 | 0.002 | 0.048 | > .999 | 0.006 | [-0.408, 0.428] | 极小效应 |
| 组内比较 | 对照组 | T2 - T3 | 0.012 | 0.551 | > .999 | 0.043 | [-0.303, 0.535] | 极小效应 |
| 组间比较 | T1 | Control - Treatment | -0.013 | -0.136 | 0.893 | -0.056 | [-0.893, 0.778] | 极小效应 |
| 组间比较 | T2 | Control - Treatment | 0.126 | 1.142 | 0.266 | 0.466 | [-0.366, 1.329] | 小效应 |
| 组间比较 | T3 | Control - Treatment | 0.272 | 2.290 | 0.032 | 0.935 | [0.083, 1.850] | 大效应 |

表3 简单效应分析结果

| | 平均值 | 标准差 | 平均值对比 | | Sig. | Effect Size ¹ | |
|-------------------------|-------|------|----------------|--------|--------|--------------------------|---------------|
| | | | 水平 | 差值 | | Partial-Eta Squared | 95%CI |
| group= Treatment | | | | | | | |
| time1 | 2.704 | 0.25 | time1 - time 2 | 0.128 | <0.001 | 0.605 | (0.295,0.744) |
| time2 | 2.576 | 0.31 | time1 - time3 | 0.287 | <0.001 | 0.755 | (0.519,0.842) |
| time3 | 2.418 | 0.32 | time2 - time3 | 0.158 | <0.001 | 0.689 | (0.413,0.799) |
| group= Control | | | | | | | |
| Time1 | 2.691 | 0.23 | time1 - time 2 | -0.011 | 1.000 | 0.011 | (0.000,0.196) |
| time2 | 2.702 | 0.22 | time1 - time3 | 0.002 | 1.000 | 0.000 | (0.000,0.033) |
| time3 | 2.689 | 0.25 | time2 - time3 | 0.013 | 1.000 | 0.014 | (0.000,0.205) |
| time= 1 | | | | | | | |
| Treatment | 2.704 | 0.25 | Tre - Con | 0.013 | 0.893 | 0.001 | (0.000,0.109) |
| Control | 2.691 | 0.23 | | | | | |
| time= 2 | | | | | | | |
| Treatment | 2.576 | 0.31 | Tre - Con | -0.126 | 0.266 | 0.056 | (0.000,0.288) |
| Control | 2.702 | 0.22 | | | | | |
| time= 3 | | | | | | | |
| Treatment | 2.418 | 0.32 | Tre - Con | -0.272 | 0.032 | 0.193 | (0.000,0.440) |
| Control | 2.689 | 0.25 | | | | | |

Note: ¹: R-Package: effectsize.