

## **Multiple Comparison Procedures - a Note and a Bibliography**

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### **Abstract**

This paper represents an attempt to offer a comprehensive bibliography of references on multiple comparison procedures (MCPs). MCPs have applications in several areas such as Pharmaceutical Companies, Clinical Research, Genomics, Education, Physiology, Data Mining in Market Research.

### **Keywords**

Pairwise comparisons, Comparisons with the best, Comparisons with a control, Comparisons with the mean

### **1. Introduction**

The term “Multiple Comparisons” refers to making several tests for statistical significance of differences between means (or proportions or variances, etc.) within a group. Statistical procedures that are designed to take into account and properly control for the multiplicity effect through some combined or joint measure of erroneous inferences are called multiple comparison procedures (MCPs). It is a fundamental problem of practical importance. They can be conducted in different ways. The following four types of multiple comparison procedures are seen in the literature based on the objective of the researcher:

- (i) MCA (all-pairwise multiple comparisons) considers  $\mu_i - \mu_j$  for all  $i \neq j$  to be of primary interest.
- (ii) MCB (multiple comparisons with the best) considers  $\mu_i - \max_{j \neq i} \mu_j$  for  $i =$

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- 1,...,  $k$  to be of primary interest.
- (iii) MCC (multiple comparisons with a control) considers  $\mu_i - \mu_k$  for  $i = 1, \dots, k-1$  to be of primary interest.
  - (iv) MCM (multiple comparisons with the mean) considers  $\mu_i - \bar{\mu}$  or  $\mu_i - \bar{\bar{\mu}}$  for all  $i = 1, \dots, k$  to be of primary interest, where  $\bar{\mu}$  and  $\bar{\bar{\mu}}$  are the unweighted and the weighted means of the  $\mu_i$ 's.

Except the MCA all other three types (MCB, MCC, and MCM) of multiple comparisons comes under the category many-to-one comparisons. Tukey (1993) recommends MCM over MCA for large  $k$ , because the result of  $k$  comparisons in MCM would be easier to comprehend than the result of  $k(k-1)/2$  comparisons in MCA. This advantage is shared by MCB and MCC, which make  $k$  and  $k-1$  comparisons, respectively. In the quality control setting, MCM is usually known as analysis of means (ANOM).

The foundation of the subject of multiple comparisons was laid in the late 1940s and early 1950s, principally by David Duncan, S.N.Roy, R. C. Bose, Henry Scheffe and John W.Tukey, although some of the ideas appeared much earlier in the works of Fisher, Student, and others.

The MCPs have applications in Pharmaceutical Companies, Clinical Research, Genomics, Education, Physiology, Data Mining in Market Research. The following are some practical situations where MCPs are used:

- (i) A medical research team conducts a clinical study comparing the success rates of different drug regimens for a particular disease.
- (ii) Comparison of system designs via computer simulation.
- (iii) In experiments of gain in animal weight effected by different feeding rations.
- (iv) A polling service wishes to determine the most popular candidate before a certain election.
- (v) A manufacturer would like to know which of three potential plant layouts will maximize expected revenues.
- (vi) In a clinical trial a control group consists of patients treated with a standard existing therapy, and the treatment groups consist of patients treated with new therapies.

By scanning the references of available papers it is observed that a good number of papers with applications of MCPs appeared in the journals of different disciplines. e.g., Psychology, Education, Agriculture, Health Maintenance Industry and Epidemiology. Undoubtedly, some references pertaining to the area of MCPs might have been overlooked in compiling this bibliography. The authors would appreciate information about those which have escaped their attention.

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All the above papers and books are further categorized in the following five types by giving their serial numbers:

- (i) MCA:** 1, 3, 6, 7, 15, 22, 28, 31, 36, 38, 40, 50, 58, 59, 60, 61, 63, 68, 69, 70, 72, 75, 76, 78, 80, 81, 82, 85, 91, 92, 104, 106, 107, 112, 118, 119, 120, 121, 122, 124, 127, 131, 137, 143, 148, 149, 154, 155, 161, 165, 166, 167, 168, 171, 172, 173, 177, 179, 185, 186, 188, 193, 198, 199, 200, 201, 203, 204, 205, 206, 207, 208, 215, 217, 218, 220, 222, 229, 231, 232, 236, 237, 241, 242, 254, 260, 262, 263, 264, 265, 266, 271, 283, 284, 291, 293, 301, 312, 314, 348, 362, 380, 381,

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382, 395, 400, 403, 411, 412, 419, 423, 426, 427, 434, 435, 436, 437, 438, 439, 440, 445, 452, 455, 460, 461, 472, 473, 476, 480, 488, 501, 502, 508, 509, 511, 518, 527, 528, 541, 543, 565, 567, 573.

(ii) **MCB:** 129, 157, 181, 192, 243, 245, 246, 247, 248, 249, 255, 282, 310, 316, 494, 571.

(iii) **MCC:** 13, 14, 16, 17, 18, 20, 21, 44, 45, 52, 56, 73, 74, 87, 89, 96, 98, 99, 116, 117, 125, 126, 130, 157, 160, 212, 213, 233, 238, 302, 315, 329, 356, 374, 399, 409, 449, 456, 457, 458, 459, 474, 475, 477, 478, 479, 503, 513, 552, 553.

(iv) **MCM:** 8, 9, 35, 64, 97, 134, 135, 142, 162, 187, 326, 334, 335, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 352, 357, 358, 359, 361, 372, 373, 378, 384, 385, 386, 387, 388, 389, 390, 391, 392, 428, 429, 430, 431, 446, 447, 497, 512, 526, 557, 558, 559, 560, 561, 562, 563, 564.

(v) **Miscellaneous:** 2, 4, 5, 10, 11, 12, 19, 23, 24, 25, 26, 27, 29, 30, 32, 33, 34, 37, 39, 41, 42, 43, 46, 47, 48, 49, 51, 53, 54, 55, 57, 62, 65, 66, 67, 71, 77, 79, 83, 84, 86, 88, 90, 93, 94, 95, 100, 101, 102, 103, 105, 108, 109, 110, 111, 113, 114, 115, 123, 128, 132, 133, 136, 138, 139, 140, 141, 144, 145, 146, 147, 150, 151, 152, 153, 156, 158, 159, 163, 164, 169, 170, 174, 175, 176, 178, 180, 182, 183, 184, 189, 190, 191, 194, 195, 196, 197, 202, 209, 210, 211, 214, 216, 219, 221, 223, 224, 225, 227, 226, 228, 230, 234, 235, 239, 240, 244, 250, 251, 252, 253, 256, 257, 258, 259, 261, 267, 268, 269, 270, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 285, 286, 287, 288, 289, 290, 292, 294, 295, 296, 297, 298, 299, 300, 303, 304, 305, 306, 307, 308, 309, 311, 313, 317, 318, 319, 320, 321, 322, 323, 324, 325, 327, 328, 330, 331, 332, 333, 336, 347, 349, 350, 351, 352, 353, 354, 360, 363, 364, 365, 366, 367, 368, 369, 370, 371, 375, 376, 377, 379, 383, 393, 394, 396, 397, 398, 401, 402, 404, 405, 406, 407, 408, 410, 413, 414, 415, 416, 417, 418, 420, 421, 422, 424, 425, 432, 433, 441, 442, 443, 444, 448, 450, 451, 453, 454, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 481, 482, 483, 484, 485, 486, 487, 489, 490, 491, 492, 493, 495, 496, 498, 499, 500, 504, 505, 506, 507, 510, 514, 515, 516, 517, 518, 519, 520, 521, 522, 524, 525, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 542, 544, 545, 546, 547, 548, 549, 550, 551, 554, 555, 556, 566, 568, 569, 570, 572.