The purpose of this study was to examine the contextual interference effect modulated by skill level in the throwing of different ball types by pitchers. College and high school baseball pitchers were asked to throw straight balls and breaking balls to the outside half and lower half of the home plate. Twenty pitchers were divided into 4 groups, determined by a combination of practice order (random or blocked) and skill level (high or low). A pretest comprised 10 trials (5 straight balls and 5 breaking balls in random order); 40 trials in a practice session were divided into 4 blocks, 10 trials each; and a posttest and retention test (after one day) involved 10 trials, similar to the pretest. The main finding of interest was an interaction effect of skill level with practice order in the retention test. For the low level pitchers there was no difference of practice order groups. However, for the high level pitchers, those in the random practice order group showed better control than the blocked practice order group. The result suggests that the contextual interference effect is modulated by skill level of pitchers.

**Keywords:** motor learning, variable practice, throwing ball type, practice schedule

1. Introduction

Shea and Morgan (1979) took an explanation of cognitive memory by Battig (1972) to use in the field of motor learning research. In their experiment, Shea and Morgan employed three patterns of barrier-knock down tasks, in which learners were asked to knock down wooden barriers as quickly and accurately as possible, and compared the effects of two learning schedules. One was a blocked practice schedule, in which learners performed all trials of the first pattern in succession, then performed all trials of the second pattern, then, finally, all trials of the third pattern. The other was a random practice schedule, in which learners randomly performed all trials of every pattern with the constraints that the number of trials for each pattern was the same and that the same pattern was never repeated more than twice in succession. During acquisition trials the blocked practice group performed faster than the random practice group. However, in the retention tests, performed both ten minutes later and ten days later, the random practice group performed faster than the blocked practice group. These findings have occupied the interest of many researchers since their publication because of the paradox that high performance in acquisition trials was shown to cause low retention, and vice versa (Shea and Morgan; for a review, see Magill and Hall, 1990). Since the publication of the Shea and Morgan study it has been common for researchers examining the contextual interference effect to compare the two contrasting schedules.

However, such research regarding the contextual interference effect has not always been consistent. Then the differential effects of the contextual interference effect on simple and complex tasks was obtained from meta-analytic study, which found that an effect size of .57 for basic research was significantly greater than an effect size of .19 for applied research (Brady, 2004). Therefore Brady (2008) described that the contextual interference effect is relatively robust in basic research but considerably weaker in an applied setting.

In the applied setting there were some researches regarding the contextual interference effect using sport tasks. Wrisberg and Liu (1991) using the long and short badminton serves task clarified that a ran-
Random practice schedules would yield better performance than a blocked one in the retention test. Further, Hall, Domingues and Cavazos (1994) using the baseball batting task for three kind of ball types clarified the same result. On the other hand French, Rink, and Werner (1990) and Jones and French (2007) using the volleyball skills test failed to find the effect in the retention test. These results regarding to the contextual interference effect using the sport task has not always been consistent.

Albaret and Thon (1998) explained that the reason of this inconsistency was the task difficulty. A random practice schedule would be better for simple tasks but a blocked one would be better for difficult task. Further, Guadagnoli and Lee (2004) revised the interpretation that two kinds of difficulty should be considered, namely nominal task difficulty and functional task difficulty. The nominal task difficulty reflects a fixed amount of difficulty, irrespective of who is performing the task. On the other hand the functional task difficulty is relative to the skill of the performer. According to Guadagnoli and Lee, learning is a function of the skill of the individual and the difficulty of the task to be learned. Therefore even if the nominal difficulty is same the functional difficulty is not same among learners. The functional difficulty depends on skill level of learners. Even if a random practice schedule is effective for experts in a task, the same schedule may be not effective for non-experts in the task. The task may be too difficult for non-experts even if it is not difficult for experts. Then non-experts may learn better in the blocked practice schedule rather than in the random practice schedule.

Since Guadagnoli and Lee’s paper was published, there has been no study examining this idea in the motor task. But before then two studies (Del Rey, Wughalter, and Whitehurst., 1982; Guadagnoli, Holcomb, and Weber., 1999) examined the contextual interference effect for two kinds of skill level of learners. Del Rey, Wughalter, and Whitehurst (1982) demonstrated that novices who had practiced under a blocked protocol were more close to a target than novices who had practiced under a random protocol by using a golf putting task. In contrast, experienced participants who had practiced in a random protocol performed more close than the experienced participants who had practiced in a blocked protocol.

However, there are still two points to be considered in order to apply to the sport skill situation, namely tasks and participants. At first Del Rey, Wughalter, and Whitehurst (1982) used a relatively simple task compared to sport skills. Although Guadagnoli, Holcomb, and Weber (1999) used a kind of sport task, the task was still simple compared to some sport skills in the field because learners were only required to adjust the force parameter without consideration of many factors such as wind and inclination. In some sport skills learners are usually required to coordinate multi parameters at the same time in the field. Secondly experts were compared to novices in both studies. But in a sport situation novices were seldom involved. Most participants have practiced for a long time before athletic meets. Then not novices but low skill level players should be compared to high skill level players.

Therefore a throwing ball task from an elevated mound in a baseball bullpen was used in this study. Trained baseball pitchers of different skill levels were required to coordinate three parameters (release velocity, release angle, and release position) at the same time on the outdoors. The purpose of this study is to examine the interaction between skill level (high and low) and practice schedule (the random schedule and blocked schedule) in the throwing ball types task (straight and breaking balls) for baseball pitchers.

2. Method and Procedure

2.1. Participants

The participants were 20 male baseball pitchers (17 right-handed and three left-handed pitchers) from 15 to 22 years of age. All participants gave informed consent before participating in this study. They were randomly assigned to one of two groups (random schedule or blocked schedule) with the res-
striction of equal group sample size (n = 10). The participants in both the random schedule group and blocked schedule group respectively were divided into five high level pitchers or five low level pitchers on the basis of pretest scores. Three left-handed pitchers were assigned to high level random, high level blocked and low level random groups each.

2.2. Task

The task used in this study was to throw straight and breaking balls to the outside half and low half of the home plate of a right batter box for right-handed pitchers, (or left batter box for left-handed pitchers). Participants threw balls to a catcher from an elevated mound in a baseball bullpen. The target was set 60 cm behind the end of home base. The target was a 40 cm wide and 40 cm high quadrangle. The center of the target was set at a 45 cm height from the ground and to the side of the home plate (See Figure 1).

2.3. Procedure

The experimental schedule is shown at Figure 2. A pretest, consisting of five straight and five breaking balls in random order, was administered to examine the initial performance level of each participant after a warm-up period. After the pretest, participants in the blocked practice group threw either twenty straight after twenty breaking balls or twenty breaking after twenty straight balls (counterbalanced across subjects). Participants in the random practice group threw ball types in a predetermined random order, with the constraints that each ball type had to be thrown 5 times in each the four blocks and that no more than three balls of any ball type would be thrown consecutively. Then participants in both groups threw twenty straight and twenty breaking balls in total.

A 10-trial posttest consisting of five straight and five breaking balls in random order was administered five minutes after the acquisition trial sessions. And a 10-trial retention test consisting of five straight and five breaking balls in random order was administered one day later.

Coaches with more than five years’ baseball coaching career assessed a ball as successful when the specified type’s ball passed through or touched an area, which was defined and divided by strings (See Figure 1).
2.4. Statistics

At first, the Cochran’s and the Wilks’s methods were conducted to reveal whether distribution of successful trial number of pitching in acquisition blocks differed between groups in each block and the distribution differed between blocks in each group respectively. Then separate 3-way analyses of variance (ANOVA) was conducted to reveal whether the successful trial number of pitching in acquisition blocks differed between training schedule by testing interaction between training schedule, skill level, and practice block with repeated measure on the last factor.

Also, Cochran’s and Wilks’s methods were conducted to reveal whether distribution of successful

Table 1  Mean (M) and standard deviation (SD) of successful trial number of pitching in a pretest, the acquisition blocks, a posttest, and a retention tests for 4 groups

<table>
<thead>
<tr>
<th></th>
<th>pretest</th>
<th>block 1</th>
<th>block 2</th>
<th>block 3</th>
<th>block 4</th>
<th>posttest</th>
<th>retention</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High level</td>
<td>M 3.20</td>
<td>3.20</td>
<td>3.80</td>
<td>3.80</td>
<td>3.60</td>
<td>3.40</td>
<td>2.20</td>
</tr>
<tr>
<td>N=5</td>
<td>SD 0.45</td>
<td>0.75</td>
<td>0.40</td>
<td>0.75</td>
<td>1.02</td>
<td>1.14</td>
<td>1.10</td>
</tr>
<tr>
<td>Low level</td>
<td>M 2.00</td>
<td>2.00</td>
<td>3.00</td>
<td>4.00</td>
<td>3.60</td>
<td>2.60</td>
<td>3.00</td>
</tr>
<tr>
<td>N=5</td>
<td>SD 0.71</td>
<td>0.89</td>
<td>1.26</td>
<td>0.63</td>
<td>1.02</td>
<td>1.52</td>
<td>0.71</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High level</td>
<td>M 3.40</td>
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<td>2.80</td>
<td>2.40</td>
<td>2.80</td>
<td>4.20</td>
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<tr>
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<td>1.17</td>
<td>1.20</td>
<td>0.84</td>
<td>0.84</td>
</tr>
<tr>
<td>Low level</td>
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<td>2.20</td>
<td>3.40</td>
<td>4.00</td>
<td>3.80</td>
<td>3.00</td>
<td>3.20</td>
</tr>
<tr>
<td>N=5</td>
<td>SD 1.00</td>
<td>0.75</td>
<td>0.80</td>
<td>1.26</td>
<td>2.40</td>
<td>1.22</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Figure 3  Mean successful trial number of pitching in a pretest, the acquisition blocks, a posttest five minutes later, and a retention test one day later from the acquisition blocks. The asterisk1 (+1) indicates the significant difference between Low level and High level groups in the pretest (p<.01). The asterisk2 (+2) indicates the significant difference between Block 1 and Block 2 (p<.05). The asterisk3 (+3) indicates the significant difference between Block 1 and Block 3 (p<.05). The asterisk4 (+4) indicates the significant difference between Random and Blocked groups in the retention test (p<.05). The asterisk5 (+5) indicates the significant difference between High level random and High level blocked groups in the retention test (p<.05). Mean successful trial number of pitching in acquisition blocks and tests for 4 groups.
trial number of pitching in the pretest, the posttest, and the retention test differed between groups in each test and the distribution differed between tests for each group respectively. Then separate 3-way ANOVA was conducted to reveal whether successful trial numbers of pitching in the pretest, the posttest, and the retention test differed between training schedule by testing interaction between training schedule, skill level, and test time with repeated measure on the last factor. The Mauchly’s method revealed that the sphericity assumption of successful trial on the last factor. The Mauchly’s method revealed that the sphericity assumption of successful trial number of pitching in acquisition blocks between groups in each block and between four blocks in each group were not significantly different. The Tukey HSD method was used for post hoc comparisons of means. The level adopted for statistical significance was \( p < .05 \) for all tests. The SPSS software for Macintosh (Version 18.0) in IBM was used for statistics.

3. Results

The mean successful trial numbers of pitching in a pretest, the acquisition blocks, a posttest five minutes later, and a retention test one day later from the acquisition phase are shown in Table 1 and Figure 3.

3.1. Successful trial numbers in the acquisition blocks

The Cochran’s method revealed that distribution of successful trial numbers of pitching in acquisition blocks between groups in each block were not heterogeneous, \( G \) for block1 \((4,4) = 0.32, p < .05\), \( G \) for block2 \((4,4) = 0.53, p < .05\), \( G \) for block3 \((4,4) = 0.41, p < .05\), \( G \) for block4 \((4,4) = 0.62, p < .05\).

Also, the Wilks’s method revealed that the distribution between blocks in each group were not heterogeneous, \( \chi^2_{\text{mve}} \) for blocked-high \((11) = 14.28, p < .05\), \( \chi^2_{\text{mve}} \) for blocked-low \((11) = 19.12, p < .05\), \( \chi^2_{\text{mve}} \) for random-high \((11) = 6.58, p < .05\), \( \chi^2_{\text{mve}} \) for random-low \((11) = 18.71, p < .05\). Therefore the homogeneity of both distribution between the four groups in each block and between four blocks in each group were not significantly different.

Then separate 3-way ANOVA was conducted to reveal whether successful trial number of pitching in acquisition blocks differed between training schedule by testing interaction between training schedule, skill level, and practice block with repeated measure on the last factor. The Mauchly’s method revealed that the sphericity assumption of successful trial numbers of pitching in acquisition blocks between blocks was not kept, \( W(5) = .292, p < .05 \). Then the degrees of freedom were adjusted by the Greenhouse-Geisser’s method.

Only the main effect for block, \( F(1,16) = 3.67, p < .05 \), partial \( \eta^2 = .19 \) was significant. Post-hoc comparisons of the means showed that the mean successful trial number of pitching in block 1 was significantly lower than the scores of those in both blocks 2 and 3. Neither the training schedule x skill level interaction, \( F(1,16) = 2.11, p > .05 \), the training schedule x block interaction, \( F(1,16) < 1.0 \), the skill level x block interaction, \( F(1,16) = 2.62, p < .05 \), the training schedule x skill level x block interaction, \( F(1,16) < 1.0 \), nor the main effects for training schedule, \( F(1,16) < 1.0 \), or skill level, \( F(1,16) < 1.0 \) was significant.

3.2. Successful trial number of pitching in the pretest, the posttest, and the retention test

The Cochran’s method revealed that the distribution of the successful trial numbers of pitching in the pretest, the posttest, and the retention test between groups in each test were not heterogeneous, \( G \) for pretest \((4,4) = 0.50, p > .05\), \( G \) for posttest \((4,4) = 0.40, p < .05\), \( G \) for retention test \((4,4) = 0.33, p > .05\).

Also, the Wilks’s method revealed that the distribution between tests in each group were not heterogeneous, \( \chi^2_{\text{mve}} \) for blocked-high \((11) = 8.32, p > .05\), \( \chi^2_{\text{mve}} \) for blocked-low \((11) = 8.19, p > .05\), \( \chi^2_{\text{mve}} \) for random-high \((11) = 9.08, p > .05\), \( \chi^2_{\text{mve}} \) for random-low \((11) = 8.34, p > .05\). Therefore the homogeneity of both distribution between the four groups in each block and between four blocks in each group were not significantly different.

Then separate 3-way ANOVA was conducted to reveal whether the successful trial numbers of pitching in the pretest, the posttest, and the retention test differed between training schedule by testing interaction between training schedule, skill level, and test time with repeated measure on the last factor. The Mauchly’s method revealed that the sphericity assumption of successful trial number of pitching in the pretest, the posttest, and the retention test between tests was kept, \( W(2) = .996, p > .05 \).

Then interaction between training schedule, skill level, and test time was significant, \( F(2,48) = 3.66, p < .05 \), partial \( \eta^2 = .14 \). Then, separate 2-way ANOVAs were conducted to reveal whether success-
ful trial number of pitching in the pretest, the posttest, and the retention test differed between the training schedules by testing interaction between the training schedules and the skill levels respectively.

In the pretest the main effect for skill level was significant, \( F(1,16) = 16.90, p < .01, \) partial \( \eta^2 = .52. \) Post-hoc comparisons of the means showed that the mean successful trial number of pitching for the high skill level throwers was significantly higher than the score of low skill level. Neither the training schedule x skill level interaction, \( F(1,16) < 1.0 \) nor the main effect for training schedule \( F(1,16) < 1.0, \) was significant.

In the posttest neither the training schedule x skill level interaction, \( F(1,16) = 1.36, \) nor the main effects for training schedule, \( F(1,16) < 1.0, \) or skill level, \( F(1,16) < 1.0 \) was significant.

In the retention test the main effect for the training schedule was significant, \( F(1,16) = 9.93, p < .05, \) partial \( \eta^2 = .38. \) Post-hoc comparison of the means showed that the mean successful trial number of pitching in random practice was significantly higher than the score of blocked practice, although there was no significant main effect for skill level, \( F(1,16) < 1.0. \) The training schedule x skill level interaction, \( F(1,16) = 6.87, p < .05, \) partial \( \eta^2 = .30 \) was also significant. The simple main effect in the high skill level was significant and the mean successful trial number of pitching of the random practice group was significantly higher than the score of the blocked practice group, \( F(1,16) = 11.11, p < .01, r = .59 \) although the simple main effect in the low skill level was not significant, \( F(1,16) < 1.0. \)

4. Discussion

In the retention test the random practice groups were significantly higher than the blocked groups in the throwing ball type task in which pitchers were required to both throw straight and breaking balls. Thus, the contextual interference effect was confirmed not only for the simple basic tasks, but also the complex sport tasks in which learners were usually required to coordinate multi parameters at a same time in the field. This result is different from the results of both French, Rick, and Werner (1990) and Jones and French (2007), who did not show the contextual interference effect in a volleyball skills test task. Rather this result supports the results of both Wirnsberg and Liu (1991) using the badminton serves task and Hall, Domingues and Cavazos (1994) using the baseball batting task, who showed the contextual interference effect.

However, the most important contribution of the present study is that it shows that this contextual interference effect in retention held true only for high skill level throwers. Among the high skill level pitchers, the random practice group performed significantly more successful trials than the blocked group although there was no such difference between groups in the case of the low skill level pitchers. Therefore, in the task of this study the random practice schedule was effective only for high skill pitchers for whom the task was not functionally so difficult. On the other hand there was no difference between the random schedule and the blocked schedules in low skill pitchers for whom the task was functionally a little more difficult. The result in this study is almost the same with the result of Guadagnoli, Holcomb, and Weber (1999) using a golf putting task. Guadagnoli, Holcomb, and Weber (1999) demonstrated that novices who had practiced under a blocked protocol were nearer to target than novices who had practiced under a random protocol although the experienced participants who had practiced in random protocol performed more close than the experienced participants who had practiced in blocked protocol. However, there was no difference between schedule for low skill level pitchers in the result of this study although there was a difference between schedule for novices in the the result of Guadagnoli, Holcomb, and Weber (1999). This discrepancy seems to depend on the difference of functional difficulty between novices and low skill level pitchers. The random schedule was not so difficult for low skill level pitchers although it was too difficult for novices.

Previous researches regarding the contextual interference effect using sport task have not been consistent. A reason of this inconsistency was explained by Albaret and Thon (1998) and Guadagnoli and Lee (2004). Albaret and Thon (1998) explained that it was because of the task difficulty. On the other hand, Guadagnoli and Lee (2004) revised the idea by Albaret and Thon (1998), and proposed that it was because of the functional task difficulty, which is related with both the nominal task difficulty and the skill level of the performer. The result in this study was different between skill levels of participants even in the same nominal task difficulty. Therefore this

Although there was a significant difference between skill levels in the pretest and retention test, there was no difference between skill levels in both acquisition trials and posttest. This seems to be because learners can correct their performance from trials just before in the case of both the acquisition trials and posttest, while they need to perform from trials more than 24 hours before in the case of both the pretest and retention test.

The participants were not the trained but novices in some previous research of the contextual interference effect in sport skill task. But in a sport situation participants are not novices but have practiced for a long time before athletic meets. The contextual interference effect in this study was confirmed for high skill level pitchers who have practiced for a long time. Then this result should be particularly useful in the conditioning situation rather than in the skill learning situation.

The sample size in this study is small. Then a study using more participants should be examined about this theme. Further a study about the throwing ball type task needs to be examined using novices in order to confirm the discussion in this study.

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• North American Society for the Psychology of Sport and Physical Activity