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Distribution of Practice Trials in the Learning and Retention of an Applied Sport Skill

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ABSTRACT
This study examined distributing practice trials for the initial acquisition and retention of an applied sport skill. One limitation of the distribution of practice literature has been the focus on motor learning lab based tasks, with few studies investigating the effect of different distribution schedules on the learning of more applied and sport specific skills. Participants (N = 77, M age = 19.52, SD = 1.90) practiced a continuous (dribbling) soccer skill in either a massed (1sec inter-trial interval) or distributed practice condition (inter-trial interval of 30secs). Participants completed 20 practice trials, 5 immediate retention trials (after 10mins), and 5 delayed retention trials (after 2 weeks). Distributed practice lead to better performance than massed practice during acquisition, however, both practice conditions were similar at immediate retention and delayed retention. The differences in the acquisition and retention phases highlight that practice distributions can have different effects on initial and later performance. This should be considered in an applied setting when considering how to space practice trials on a sport skill and whether improvements that can be seen within a season are important or whether retention of performance is important.

Keywords: Distribution of practice, Motor learning, Continuous skill, Inter-trial interval, Soccer

INTRODUCTION
The distribution or spacing of practice has been a key research topic throughout the history of motor learning (Magill, 1988). Research on the distribution of practice has commonly used the terms massed practice and distributed practice to contrast the differences between practice schedules, relating to the amount of rest provided. Because of differences in tasks, these tend to be relative terms, but in general, distributing practice refers to spacing periods of work with longer intervals of rest (Schmidt & Lee, 2005). When applied to the inter-trial interval, massed practice is a practice schedule where the amount of rest between trials is very short; and distributed practice is a schedule where the amount of rest between trials is relatively long (Magill, 2011). Most research was conducted in the 1940's and 1950's (Schmidt & Lee, 2005) and since then, research on this topic has been less apparent. Despite this, the influence of distributing practice trials on learning is still an area of some controversy (Magill, 2011). So that, while the effects of distributing practice have important implications for the design of training, the lack of theoretical development in this area appears to have slowed research progress (Schmidt & Lee, 2005). The most recent meta-analyses of the distribution of practice literature were conducted in the 1980's and 1990's by Lee and Genovese (1988) and Donovan and Radosevich (1999). These reviews supported that distributing practice, in general, resulted in better performance, but recommended further research. This general effect appeared to be moderated by suggestion that the long-term effects of massed versus distributed practice should be further investigated to compare the potential temporary performance effects with more permanent learning effects. Thus, controversy surrounding the distribution of practice seems to be related to the research not examining performance versus learning effects by using retention or transfer tests (Magill, 2011). Another issue in the distribution of practice literature may be the focus on simple lab based tasks, with few studies investigating the effect of different distribution schedules on the learning of more applied and sport specific skills. Lee and Genovese (1988) calculated 52 effect sizes from 47 articles and reported
that distributed practice produced larger initial effects on skill acquisition than massed practice ($d=0.96$) and also lead to better absolute retention ($d=0.53$). This retention conclusion, however, should be considered cautiously, given the ambiguous definitions of retention and transfer used in the meta-analysis (Christina & Shea, 1988; Donovan & Radosevich, 1999; Newell, Antoniou, & Carlton, 1988). For example, Lintern (1988) described that Lee and Genovese (1988) did not distinguish between short-term and long-term retention and argued that retention tests that are delayed by less than 20 mins probably do not separate performance and learning effects. Magill (1988) contended that one approach to overcome this is a longer term retention interval.

Lee and Genovese (1988) reported that the literature had focused on continuous motor tasks as opposed to discrete motor tasks. Continuous motor tasks are skills with an arbitrary beginning and end, which usually involves repetitive movements, whereas, discrete tasks are skills with a clearly defined beginning and end (Magill, 2011). They concluded that distributed practice was better for acquisition and retention on the continuous task in line with the previous literature, however, massed practice was better for acquisition and retention on the discrete task. The tasks in the Lee and Genovese meta-analysis were overwhelmingly lab based motor learning tasks as opposed to sport specific tasks, with the most common tasks being tracking tasks, inverted alphabet printing tasks, and mirror tracing tasks. Only one study utilised a sport related task, which was a novel basketball shooting task (discrete skill) used by Singer (1965). For example, Singer (1965) compared massed and distributed practice schedules for learning a novel skill involving bouncing a basketball off the floor and into the basket. Results suggested that distributed practice was superior to massed practice for immediate acquisition, measured at the end of practice; however, massed practice was superior to distributed practice at retention, measured one month after practice. Singer concluded that this suggested a benefit for massed practice for long-term retention of the skill. Dail and Christina (2004) compared massed and distributed practice for learning a golf-putting task and measured retention performance after 1, 7, and 28 days. Their findings, however, indicated that distributed practice of the discrete skill resulted in better acquisition and retention than massed practice, in line with research on continuous skills. This was also a discrete sport specific motor task and the emphasis of this study was to explore distribution of practice across sessions rather than distribution of trials within a session, that is, the inter-trial interval was not manipulated (which is the focus of the current study). Participants in both the massed and distributed practice conditions completed 240 practice trials and putts were "consecutive within a practice session" (Dail & Christina, 2004, p. 150). The massed condition practiced all putts in one session, whereas the distributed condition practiced 60 putts per session on 4 consecutive days. Thus, this provides little information about the inter-trial interval, and effects of spacing trials for the acquisition and retention of a sport-specific skill. In addition, both the basketball shooting and golf putting tasks, although being more applied than most tasks, are discrete sport skills, rather than continuous sport skills. In their meta-analysis, Donovan and Radosevich (1999) included 63 studies with 112 effect sizes and reported that distributed practice produced better performance than massed practice ($d=0.46$). They also calculated separate effect sizes for acquisition performance, defined as task performance immediately after practice, and retention performance, defined as task performance that was separated from practice by at least one day (24 hours). The effect size for acquisition was 0.45 and the effect size for retention was 0.51. It should be noted that only 16 effect sizes contributed to the overall effect size for retention, as few studies utilised a retention test, and of these studies, 13 used a retention interval of 24 hours and only 3 were for an interval greater than 24 hours. Donovan and Radosevich (1999) also explored complexity of the task, including overall complexity as well as mental and physical requirements of the task. The effect size for simple tasks was strongest ($d=0.96$), indicating a strong distribution of practice effect for these tasks. Interestingly, this effect size is very similar to that reported by Lee and Genovese (1988) and, as discussed previously, the tasks in the Lee and Genovese meta-analysis tended to represent simple lab based motor learning tasks. For more complex skills the effect sizes were smaller, with tasks high in overall complexity and high in physical requirements, but low in mental requirements (such as gymnastics skills, and balancing skills) having an effect size of 0.11; and tasks high in overall complexity and high in both mental and physical requirements (such as airplane control simulation and hand movement memorisation) having an effect size of 0.07. More research on sport specific skills is required to understand the effect of practice distribution in applied sport settings.
As stated earlier, the lack of theoretical development explaining the benefits of distributed practice for most activities appears to have slowed research progress (Schmidt & Lee, 2005). Explanations put forward include fatigue, cognitive effort, and memory consolidation (Magill, 2011). The fatigue explanation is that massed practice schedules, because of their short rest intervals, can induce fatigue, which could negatively influence learning. Massing practice may also reduce the amount of cognitive effort the learner uses on each practice trial, because the task becomes very repetitive. Memory consolidation suggests that to store information effectively in memory some rest is necessary for biochemical changes to occur. Providing additional rest may assist this to happen, however, this explanation appears to be more applicable to the distribution of practice sessions across days, than the spacing of trials within a session, since the biochemical changes are unlikely to occur in the time between trials, even if trials are distributed.

The distribution of practice trials has important application in the learning of skills. Research has focused on continuous motor skills, indicating that distributed practice leads to better performance and learning than massed practice. The majority of this research, however, has used laboratory based activities, and neglected to use an appropriate retention test to examine learning. By examining the factors of retention, and sport specific skills, we hope to provide some information that is of practical use in designing practice sessions and training programs for skill acquisition. The use of sport specific skills gives a much more practical focus than previous studies, which have tended to focus on simple lab based tasks with little real world application in sport. Therefore, this study aimed to compare massed and distributed practice on the acquisition of learning and retention of learning of a continuous applied sport skill.

MATERIALS AND METHODS

Participants

Participants were 77 university undergraduate students (52 male, 25 female) ranging in age from 18 to 26 years (M age = 19.52, SD = 1.59). Participants reported 18 different sports as a main sport, with most frequent sports reported being: Australian Rules football (n = 24), netball (n = 8), cricket (n = 7), basketball (n = 7), athletics (n = 7), and fitness/gym (n = 5). Most participants reported that they competed at either local (n = 40) or state (n = 22) level in their main sport, and few competed at either the international (n = 3), national (n = 6) or recreational (n = 6) level. In terms of previous soccer experience, 18 participants reported playing soccer competitively and 39 reported never having played soccer competitively. Of the 18 who had played, some had played only 1 season (n = 7), most playing between 2 and 5 years (n = 10), and fewer playing more than 5 years (n = 1). These participants reported that they had played at a state (n = 3), local (n = 14), and recreational (n = 1) level. Participants were assigned based on class allocation to one of two practice groups: distributed practice continuous skill (n = 42), and massed practice continuous skill (n = 35). The study was approved by a University Human Research Ethics Committee and all participants signed an informed consent form before beginning the study.

Task

The sport skill was a soccer dribbling task, where participants were required to dribble a soccer ball around a diamond shaped course as quickly as possible. Score was the time taken to complete the course in seconds. The task was completed indoors in a gymnasium with a flat concrete floor. The course was marked using cones as displayed in Figure 1. The total distance to dribble was 25.4 metres. The soccer ball was an official size 5 match regulation soccer ball.

Inter-Trial Interval and Conditions

The inter-trial interval was timed using a handheld stopwatch. For the sport skill (dribbling) the inter-trial interval was recorded from the time the participant returned to the start cone until the participant was instructed by the researcher to start the next trial with the instruction “go”. The massed practice condition completed all practice trials with an inter-trial interval of 1 second. The distributed practice condition completed all practice trials with an inter-trial interval of 30 seconds.

Design and Procedure

The study involved each participant for 2 sessions, which were conducted two weeks apart. In the first session the researchers explained the study protocol and participants completed procedures for informed consent. Participants were randomly assigned to a training condition and task. Participants then practiced the continuous (dribbling)
soccer skill in either the massed (1sec inter-trial interval) or distributed practice condition (30sec inter-trial interval). Participants completed 20 practice trials and then after 10 minutes, completed 5 immediate retention trials (20 sec inter-trial interval). In the second session, conducted 2 weeks later, participants completed a further 5 delayed retention trials (20 sec inter-trial interval). A score for performance was provided to participants as verbal feedback on completion of each trial during practice and retention.

**Analysis**

The analysis of this study consisted of repeated-measures ANOVAs for the continuous sport skill investigating change in performance across Time and Time X Condition. Repeated-measures ANOVAs with effect sizes were also conducted for the continuous sport skill in the distributed and massed practice schedules. The repeated-measures ANOVAs comprised: the initial acquisition trial with the last 5 acquisition trials, the initial acquisition trial with the immediate retention trials, the initial acquisition trial with the delayed retention trials, the last 5 acquisition trials with the immediate retention trials, the last 5 acquisition trials with the delayed retention trials, and the immediate retention trials with the delayed retention trials.

**RESULTS**

Performance scores for the massed and distributed practice conditions for the sport skill are presented in Figure 2. The score is reported in terms of time (in seconds) taken to complete the trial, where a low score represents better performance. The first 20 trials represent the acquisition phase, then the next 5 trials are immediate retention, and then the final 5 trials are the delayed retention trials as indicated. The analysis indicated that there was a significant difference in performance between the first acquisition trial and the last 5 acquisition trials (Time – F(1, 82) = 28.687, p = .000; Time X Condition – F(1, 82) = 20.614, p = .000); between the initial acquisition trial and the immediate retention trials for Time (F(1, 82) = 69.774, p = .000) but not for the Time X Condition interaction (F(1, 82) = 1.806, p = .183); and between the initial acquisition trial and the delayed retention trials for Time (F(1, 82) = 55.203, p = .000), but not for the Time X Condition interaction (F(1, 82) = .319, p = .574). The analysis examining changes in performance from the last 5 acquisition trials to the immediate retention trials indicated a significant difference for Time (F(1, 82) = 76.113, p = .000) but not for the Time X Condition interaction (F(1, 82) = .000, p = .996). There were also significant differences in performance between the last 5 acquisition trials and the delayed retention trials (Time – F(1, 82) = 21.108, p = .000; Time X Condition – F(1, 82)
There was a significant difference in performance between the immediate retention trials and the delayed retention trials for Time (F(1, 82) = 50.611, p = .000), but this interaction was not significant for the Time X Condition interaction (F(1, 82) = 2.895, p = .093).

Distributed Practice Condition: The analysis for the distributed practice schedule for the continuous sport skill indicated significant changes in performance across all contrasts. There was a significant difference in performance between the initial acquisition trial and the last 5 acquisition trials (F(1, 41) = 42.964, p = .000, η = .512); between the initial acquisition trial and the immediate practice trials (F(1, 41) = 47.911, p = .000, η = .539); and between the initial acquisition trial and the delayed retention trials (F(1, 41) = 32.869, p = .000, η = .445). There was also a significant difference between performance in the last 5 acquisition trials and the immediate retention trials (F(1, 41) = 23.821, p = .000, η = .367) and between last 5 acquisition trials and the delayed retention trials (F(1, 41) = 9.558, p = .004, η = .189). There was a significant difference in performance between the immediate retention trial and delayed retention trial (F(1, 41) = 9.558, p = .004, η = .189), however, this represented a decrease in performance rather than an improvement.

Massed Practice Condition: The analysis for the massed practice schedule for the continuous sport skill indicated no significant differences in performance across the acquisition trials (from initial acquisition trial to the last 5 acquisition trials) (F(1, 41) = .387, p = .537, η = .009), but significant difference in performance across other contrasts. There was a significant difference in performance between the initial acquisition trial and the immediate retention trials (F(1, 41) = 24.314, p = .000, η = .370) and between the initial acquisition trial and the delayed retention trials (F(1, 41) = 22.929, p = .000, η = .359). There was also a significant difference in performance between the last 5 acquisition trials and the immediate retention trials (F(1, 41) = 98.642, p = .000, η = .706) and the last 5 acquisition trials and the delayed retention trials(F(1, 41) = 53.010, p = .000, η = .564). There was no significant difference between the immediate retention trials and the delayed retention trials (F(1, 41) = .10, p = .919, η = .000), suggesting that performance levels were maintained.

Fig. 2: Time in Seconds for Massed and Distributed Practice Conditions During the Acquisition Phase (Trials 1-20) and Immediate Retention (10 Mins) and Delayed Retention (2 Weeks) Trials on the Sport Skill (Soccer Dribbling)
SUMMARY OF RESULTS

There was a significant improvement in performance during acquisition. In addition, performance on immediate retention and delayed retention test was significantly better than the initial acquisition, indicating that performance improvements from acquisition were retained for both practice schedules. Performance did decrease from immediate to delayed retention. In comparing the practice conditions, across the acquisition phase, distributed practice lead to better performance than massed practice. The distributed condition improved significantly from the initial acquisition to the last 5 acquisition trials, and this was also reflected in better performance in immediate and delayed retention than for the initial acquisition. The massed condition did not produce significant improvements in performance across the acquisition phase, however, did improve from acquisition to immediate and delayed retention. Both conditions exhibited improvements in performance from the last 5 trials of acquisition to the immediate and delayed retention phases. It is interesting to note, however, that performance of the distributed condition became worse from immediate retention to delayed retention, whereas, there was no significant drop in performance for the massed condition. Thus, it appears that there was an initial acquisition performance benefit for distributed practice during acquisition, however, was not important for retention performance, with scores for both conditions (massed and distributed) being significantly better in immediate and delayed retention than for the initial acquisition, but not significantly different from one another. This indicates both groups performed similarly in retention, with the massed group displaying depressed performance in the acquisition phase, but similar amounts of performance improvement in retention.

DISCUSSION

Reviews have supported that distributing practice, in general, results in better performance of motor skills (Donovan & Radosevich, 1999; Lee & Genovese, 1988). This general effect, however, may be different for acquisition and retention performance. In addition, most studies have investigated using simple lab based motor tasks, rather than more applied and sport specific skills. In this study, in line with previous research, distributed practice was more advantageous for acquisition of the continuous sport skill than massed practice (Donovan & Radosevich, 1999; Lee & Genovese, 1988). Distributed practice, however, was no more beneficial for retention performance than massed practice, with both conditions displaying similar performance improvements from initial performance to immediate and delayed retention. Most previous research on motor skills has been conducted on continuous skills and has suggested an advantage for distributed practice over massed practice for acquisition and retention performance (Donovan & Radosevich, 1999; Lee & Genovese, 1988). This research, however, has predominantly been with simple motor tasks, rather than more sport specific skills, and there have also been issues with measuring retention performance. In the current study, distributed practice lead to better acquisition performance on the continuous sport skill than massed practice. However, both massed and distributed practice showed similar levels of improvement at immediate and delayed retention. This finding then indicates that distributed practice may be better for acquisition, but is no more effective than massed practice for retention of performance. Lee and Genovese (1988) reported a smaller effect size for retention performance than for acquisition performance for distributed practice over massed practice. Donovan and Radosevich (1999) reported similar effect sizes for acquisition and retention. Both these reports for retention performance, however, should be considered cautiously given that the number of studies using a retention test was small and because the retention intervals were generally less than 24 hours. The finding of differences in acquisition performance, but similar retention performance in the current study could indicate that massing of practice leads to a decrease in performance (acquisition phase) but this may not cause a decrease in learning (retention phase) (Adams & Reynolds, 1954). For example, Adams and Reynolds (1954) had participants practice a rotary pursuit task for 40 trials. One group of participants practiced under distributed practice conditions, the other groups all began under massed practice conditions and then switched to distributed practice after 5, 10, 15 or 20 trials of massed practice following a 10 minute rest. Results suggested that all the groups that switched showed increased performance immediately after the rest, to levels higher than the performance they were exhibiting during massed practice, even in the initial trial after switching. All the switching groups were at similar levels to the distributed group in the final trials, showing that the depressed performance effects of massed practice did not persist throughout learning. Adams and Reynolds
(1954) recommended that their findings needed to be verified on other types of tasks. Our findings for the continuous sport skill appeared to be similar to those of Adams and Reynolds (1954). The distributed group displayed a performance advantage during acquisition; however, this advantage disappeared at retention, with both conditions displaying similar levels of performance improvement. That is, massed practice seemed to act more as a performance variable than a learning variable, affecting acquisition performance, but not retention.

The use of a sport specific continuous skill may explain why there was no retention advantage for distributing practice for the continuous sport skill. For example, the review by Donovan and Radosevich (1999) reported the largest effect for simple tasks ($d = 0.96$), and smaller effect sizes for tasks high in overall complexity and high in physical requirements, but low in mental requirements ($d = 0.11$) and tasks high in overall complexity and high in both mental and physical requirements ($d = 0.07$). Thus, the advantage of distributing practice may not apply as strongly to more complex skills or more sport specific skills.

Implications and Future Directions

Although the number of trials used in the current study (20 trials) was not large it was similar to that used in some other studies (e.g., Adams and Reynolds, 1954; Reynolds & Adams, 1953). Perhaps more trials are needed to evaluate the performance and learning effects. It is also possible that the sport skill was already reasonably well known by participants, given that dribbling a soccer ball is a reasonably common motor skill, and this may have been reflected in the lack of significant long-term improvement for that skill. A more novel, but still sport-specific skill, that participants are naive to may be worth investigating. However, this would also make the findings less practically relevant, given that in most applied sport setting players are practicing relatively well-known skills. Research with sport specific skills with performers who are already skilled at a sport may be useful to provide recommendations to teachers, coaches, and instructors on how best to schedule practice in applied settings. Given that there was a different effect for the continuous sport skill than that expected based on literature reviews, which are predominantly focused on non-sport specific tasks; more studies on sport tasks would be important to ascertain whether distributing practice is the optimal approach in applied settings. The different effects in this study may be due to the nature of a sport specific task and the effects of distributing practice on sport specific skills should be further investigated. In addition, the current study focused on the inter-trial interval for a sport specific skill, more research on the effects of distributing sessions would also seem justified. Dail and Christina (2004) did investigate the effects of distributing practice sessions for a discrete sport specific task (golf-putting) and reported that distributed practice resulted in better acquisition and retention than massed practice. More research on the distribution of practice in relation to sessions and trials and with different types of sport specific skills is recommended, especially since both sessions and trials can be manipulated in a practical setting.

It is important to utilise retention tests and consider retention in evaluating which practice conditions are best for skill learning. The differences in the acquisition and retention phases for the continuous sport skill highlight that practice distributions can have different effects on initial and later performance. This should also be considered in an applied setting when considering how to space practice trials on a sport skill and whether improvements that can be seen within a session are important or whether retention of performance is important. Since distributing practice lead to better acquisition performance on the continuous sport skill, this would be advised where short term performance change is needed, such as perhaps in preparation for a game or the warm-up before a game. There could also benefit in producing immediate acquisition in very early stages of learning, where players are getting a basic idea of the skill and may get some initial confidence from successful performance. Since both massed and distributed practice lead to similar retention performance, it may be more advantageous in an applied setting, where long term performance is important, to utilise massed practice, since this allows for more practice trials in the same amount of time. This would allow other drills and practice elements to be included in a practice session, since it would take less time to complete the same number of trials, or would allow for more total number of trials on the skill. These are important applied questions for coaches and teachers.

AUTHOR'S NOTE

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CONCLUSION

Distributed practice was more advantageous for acquisition performance on the continuous applied sport skill, but did not result in better learning (retention performance).

REFERENCES


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