TEACHING THE UNKNOWABLE:
DOES ANALOGY LEAD TO IMPLICIT SKILL ACQUISITION
IN A DART-THROWING TASK?

by

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Abstract

This experiment was conducted to examine the hypothesis that learning by analogy will invoke characteristics of an implicit mode of learning. On Day 1, dart novices learned to throw darts as close as possible to the centre of a target under one of three scenarios: control (without instruction), implicit (while performing a distracting secondary task), and analogy (while imagining an analogous physical image). Each participant threw 6 blocks of 40 darts, receiving repeated instructions before each block. The next day (Day 2), participants were tested for retention and for transfer by the addition of a secondary distracting task. The results showed that significant learning took place in all groups over a period of six learning blocks on the first day. There was also significant response to retention and transfer testing on Day 2. Learning to throw darts without instruction was shown to be superior to learning under both of the other conditions – analogy and secondary task. The study demonstrated that dart throwing instruction using analogy was insufficient to induce the beneficial features of implicit learning. The chosen elastic analogy, in fact, led to a significant deterioration of performance when compared to controls during transfer on Day 2. Sex and skill differences are unlikely to have played a significant role in the main findings. The findings are discussed within the framework of current literature.
Dedication

To Rupa
Acknowledgments

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Table of Contents

Abstract ........................................................................................................................................ii

Dedication ....................................................................................................................................iii

Acknowledgments ......................................................................................................................iv

Table of Contents ........................................................................................................................v

List of Tables ................................................................................................................................viii

List of Figures and Illustrations .................................................................................................ix

CHAPTER ONE - Introduction ...................................................................................................... 1
  Rationale ...................................................................................................................................... 1
  Purpose ......................................................................................................................................... 4
  Definitions .................................................................................................................................... 5

CHAPTER TWO - Literature Review ............................................................................................ 7
  Introduction ................................................................................................................................. 7
  History ......................................................................................................................................... 7
  Implicit skills ............................................................................................................................... 9
  Benefits of Implicit learning ....................................................................................................... 10
  Implicit Learning in Physical Skills ............................................................................................ 11
  Implicit Golf .................................................................................................................................. 12
  Skilled Performance Under Stress ............................................................................................. 12
  Outcome Information, Errors, and Learning Skill ..................................................................... 13
  Verbal Overshadowing .............................................................................................................. 14
  Analogy and Implicit Learning .................................................................................................... 15
  Focus of Control and Learning .................................................................................................... 17
Skill, Focus of Attention, and Instruction ................................................................. 20
Summary ......................................................................................................................... 21

CHAPTER THREE: Method ......................................................................................... 23
Participants ..................................................................................................................... 23
Number of Groups ........................................................................................................ 23
Groups ............................................................................................................................. 24
Apparatus ....................................................................................................................... 25
Task ................................................................................................................................. 26
Design ............................................................................................................................. 26
Procedure ....................................................................................................................... 26
Analysis .......................................................................................................................... 28

CHAPTER FOUR: Results ............................................................................................ 30
Effect of Learning Group .............................................................................................. 30
Effect of Sex ................................................................................................................... 36
Effect of Experience ...................................................................................................... 38
Effect of Explicit Rules ................................................................................................. 40

CHAPTER FIVE: Summary and Conclusions ............................................................. 41
Introduction .................................................................................................................... 41
Discussion of Findings ................................................................................................. 41
  Evidence of Implicit learning ...................................................................................... 41
  Analogy and implicit learning ................................................................................... 44
  Focus of control ......................................................................................................... 45
  Verbal overshadowing ............................................................................................... 46
List of Tables

Table 1. Mean Scores and Standard Deviations Over 9 Experimental Blocks ............... 30

Table 2. Analysis of Variance with Repeated Measures for Learning and Performance Phases........................................................................................................................................ 33

Table 3. Analysis of Variance with Repeated Measures for Performance Phase Transitions........................................................................................................................................ 34

Table 4. Influence of Sex on Scores through Learning and Performance Blocks ........ 37

Table 5. Influence of Experience on Scores through Learning and Transfer Blocks ....... 39
List of Figures and Illustrations

Figure 1. Plots of Mean Scores of 3 Groups Over 9 Experimental Blocks....................... 31
Figure 2. Plots of Mean Scores of 3 Groups With SD Bars.............................................. 33
Figure 3. Plots of Mean Scores for Males (n=7) and Females (n=32).............................. 36
Figure 4. Plots of Mean Scores for 5 Levels of Dart-Throwing Experience .................... 38
Figure 5. Bar Chart of Mean Number of Rules per Group ............................................... 40
CHAPTER ONE

Introduction

Rationale

Vic Braden has coached many of the greatest tennis players in the history of the game. In Malcolm Gladwell’s book, Blink (2005), he is quoted, “Almost every pro in the world says that he uses his wrist to roll the racket over the ball when he hits a forehand.” Then Braden describes a video of tennis champion Andre Agassi. “We can tell with digitized imaging whether a wrist turns an eighth of a degree. But players almost never move their wrist at all. Look how fixed it is. He thinks he’s moving it at impact, but he’s not moving it until long after impact” (p. 68). Andre Agassi is fundamentally mistaken about how he hits a forehand. How can this be? One possible explanation is that Agassi has only implicit knowledge of his forehand stroke.

Implicit knowledge was defined by Schacter (1992) as that which is “revealed in task performance without any corresponding phenomenal awareness” (p. 11113). They are the skills that people have that cannot be put into words. For example, consider explaining to someone precisely how to walk, or how to recognize a face. Implicit learners have been studied in a variety of domains. They have been shown to get better with practice, without being able to verbally report the underlying structure of the task (Liao & Masters, 2001).

Consider that human senses process about 11,000,000 pieces of information per second, but individuals can only be consciously aware of about 40 (Wilson, 2002). The overwhelming majority of what we perceive and learn, then, from the moment we are born, is unconscious. As years go by, and as teaching becomes more formal, we come to
rely almost exclusively on conscious methods. Is there a way to tap into the vast resource of unconscious learning? Are there benefits?

The advantages of implicit learning were noted nearly 40 years ago by Corkin, who observed that these skills are “extremely difficult to eradicate through disuse and show little relationship to the level of general intellectual function” (Corkin, 1968, p. 255). Another implicit learning pioneer, Reber, found that implicit processes show robust performance under psychological stress (1993). The idea of tapping an unconscious resource has no doubt led to the increase in implicit learning research in the last 20 years (Farrow, 2004; Mathews, Buss, Stanley, & Blanchard-Fields, 1989). Not only have motor skills been shown to exist implicitly, but so have a host of cognitive skills, from face recognition to rules of grammar (Schooler, 1990).

Researchers studying physical skill acquisition have shown particular interest in implicit learning (e.g., Liao & Masters, 2001; Maxwell, Masters, Kerr, & Weedon, 2001). The idea of a physical skill being robust, especially in the face of stress, has obvious appeal to athletes who want to perform in competition without the deteriorating level of skill, otherwise known as *choking* (Beilock & Carr, 2001). Researchers have also shown interest in implicit learning as an alternative to direct instruction. A growing body of experimental evidence suggests that the use of instructions in the teaching of physical skills may be unnecessary, and in some instances, lead to performance degradation (Farrow, 2004; McNevin, Wulf, & Carlson, 2000).

Unfortunately, implicit skill acquisition, by virtue of being accessible only indirectly, has been difficult to model. Researchers have succeeded in doing so, however, by overloading conscious working memory during learning (Maxwell et al, 2001, Liao &
Masters, 2001). It seems that engaging in tasks that keep one’s working memory otherwise occupied encourages implicit skill acquisition. But the secondary tasks used in these studies, such as tone counting, would be awkward in real-life learning situations.

Analogy has been proposed as a means to encourage implicit motor learning. The use of an abstract concept to guide physical motion has the benefit of employing conscious resources without referring to specific body movements. In 2000, in the only experiment of its kind to date, Liao and Masters successfully used the image of a right angle triangle to teach the forehand topspin in table tennis. So far, there have been no studies confirming Liao and Masters’ findings. In addition, there is no research examining the features of an effective implicit teaching analogy.

Along the same lines, but in a separate area of physical movement research, an approach to training called focus of attention has been showing promise. Studies have demonstrated learning advantages of instructions based on an external, rather than internal, focus of attention (e.g., Marchant, Clough, & Greig, 2005; Perkins-Ceccato, Passmore, & Lee, 2003; Wulf, Hob, & Prinz, 1998; Wulf, Lauterbach, & Toole, 1999). For instance, in learning a golf swing, performance benefits more by concentrating on the result of the swing, (where the ball lands) rather than the action that produces it (how your elbow is bending).

Verbal interference is another new field of research in unconscious processes. Schooler (1990) demonstrated that requesting individuals to produce a verbal description of a previously seen face can hinder subsequent attempts at identification. One explanation for this so-called verbal overshadowing is that verbalization causes individuals to draw on verbal knowledge at the expense of non-verbal knowledge. There
is growing evidence that voicing or verbalizing one’s actions can impair implicit learning (Ericsson, 2002; Schooler, Ohlsson, & Brooks, 1993). And yet, none of the reviewed experiments of implicit learning of physical skills took precautions against this phenomenon.

Thus there is evidence that implicit learning has benefits, namely robustness over time and under stress. There is also some evidence that the use of analogy is effective in obtaining implicit learning. It also seems that focusing a learner’s attention externally rather than internally may be more effective in skill training. This study endeavored to confirm these findings, while avoiding verbal overshadowing.

**Purpose**

In 2001, Liao and Masters demonstrated the potential of a single analogy for teaching an implicit table tennis forehand topspin. The aim of the current study was to duplicate this previous work by testing an external analogy as a technique of implicit motor skill training in a dart throwing task. The experiment was designed to answer the following question:

Do analogy learners in a dart-throwing task demonstrate the beneficial features of implicit learning, namely retention and resistance to stress?

There are several reasons for the choice of dart-throwing as a skill. The extended arm motion lent itself to biomechanical analogies. The unusual nature of the sport (in Canada) provided the potential for greater naiveté in participants, and thus more opportunity to learn. The object of the activity was likely to lead to greater variance in the results (as opposed, say, to a putting experiment, where the result is bimodal: whether the
golf ball is holed or not). Finally, significant findings would better support generalization of the principles to other complex physical skills.

This study hoped to add to the literature on implicit learning by providing an additional example of implicit learning through analogy, this time with a more complex motor skill and a more externally-focused analogy. Strengthening the evidence for effectiveness of analogy learning would lead to more sophisticated questions about the characteristics of effective learning analogies.

Definitions

The terms explicit and implicit knowledge are similar in meaning to conscious and unconscious knowledge, but these latter terms have often been avoided because of their association with Freudian constructs (Greenwald, 1992).

Explicit knowledge refers to that expressed as conscious experience and that people are aware that they possess. Common use of terms “seeing” and “remembering” refer to explicit knowledge (Schacter, 1992). In this study, as in others (e.g. Liao & Masters, 2001, Maxwell, Masters, & Eves, 2000) the participant’s level of explicit knowledge was assessed as their ability to describe discrete physical rules used in the experimental task.

Implicit knowledge, by contrast, refers to knowledge that is not verbally reportable. Seger (1994) defined implicit learning as learned complex information without complete verballisable knowledge of what is learned. In this study, participants listing a smaller number of discrete physical rules used in the experimental task could be said to have less explicit knowledge and thus, more implicit knowledge of that task.
For the purposes of this thesis, the terms implicit and unconscious will be used interchangeably, as will conscious and explicit. The older terms are favoured by this researcher because they conjure up a more accessible, commonly understood concept that is no longer steeped in psychoanalysis.
CHAPTER TWO

Literature Review

Introduction

This chapter leads from the history of consciousness through the effects of outcome knowledge on a learned skill. Along the way, it reviews the discovery of implicit learning and its characteristics, implicit learning in physical skills, the issue of verbal interference, and the use of analogy and focus of control in instruction. This chapter also seeks to put forward some of the studies that have looked at the combined influence of factors in learning, such as skill and focus of attention, skill and choking under stress and learning with or without knowledge of outcome. This review of the literature examines relevant studies to date, and provides an awareness of the ubiquity of unconscious learning, its benefits, and the potential access to these provided by external analogy.

History

Imagine what it would be like to live in a completely different world, an alien place in which you couldn’t even know your own mind, a place where, bombarded by sensory stimuli, your mind could extract only the merest hint of the total, and yet you somehow believed—or were made to believe—that you were all-seeing and all-knowing…. Well, look no farther. This is exactly the world that you now inhabit. It is the world of the conscious mind, a world that is not at all what it seems. The science of consciousness has, in the last two decades, transformed our thinking about the brain and how it creates the world you experience (Ingram, 2005, p.12).
The popularity of recent books about consciousness (Gladwell, 2005; Ingram, 2005) illustrates why Ingram suggests that this area “has become, in the last few years, one of the most challenging and exciting areas of science” (p. 13). Given its recent popularity, it would be plausible to believe that the unconscious is a recent discovery. But in 1866, E. S. Dallas wrote “Outside consciousness there rolls a vast tide of life which is perhaps more important to us than the little isle of our thoughts which lies within our ken” (as cited in Wilson, 2002, p.17).

This 19th century metaphor was referring to the distinct separation between our “island” of conscious thoughts and the ocean “tide” of our unconscious. Today’s literature refers to knowledge that people are aware of as explicit. For example, you would be able to describe your key ring in words. Your knowledge of what you have seen, what you can remember and describe is explicit. Implicit knowledge refers to knowledge that we are unaware of, and that is often tapped indirectly. Imagine feeling for your keys at the bottom of a bag. Though you may have no trouble finding them, you would have difficulty describing how you did (beyond saying “I felt for them”). Your knowledge of how to feel for your keys is implicit. Now imagine teaching someone who has never seen or held keys to do the same! Since both kinds of knowledge can be acquired, we speak of learning explicitly (with awareness) or implicitly (without awareness).

In spite of early recognition of the importance of unconsciousness, it has proved to be an awkward area of research. Firstly, there is the issue of defining something which is not available to consciousness. To this day, there is controversy about what constitutes an adequate measure of conscious perceptual experience (Schacter, 1992). Secondly,
Sigmund Freud introduced a psychoanalytic definition of unconscious in his 1923 publication *The Ego and the Id*, which was very narrow and very different from the unconsciousness considered previously or since. His concept was so distracting that research was stymied until much later, when the new term “implicit” was substituted.

*Implicit skills*

Perhaps the recent excitement about the unconscious has to do with overcoming some of the difficulties inherent in its study. It took some ingenious experiments to prove the existence of implicit knowledge. For example, Milner, Corkin, and Teuber’s work in the 1960’s with a famous amnesiac showed definitively that it was possible to acquire new physical skills without being aware (Milner, Corkin & Teuber, 1968). H. M. acquired dense anterograde amnesia as a result of neurosurgery to cure his epilepsy. He could not remember anything new for more than a few seconds – the duration of his short term working memory. In one of the many motor skills he was tested on, H. M. was shown how to perform a physical tracing task called mirror drawing. In this exercise, he was asked to trace the outline of a figure while watching his hand in a mirror. The conflict between visual input and biophysical feedback is what makes this task challenging, but repeated practice leads to predictable improvements in all participants. H. M. improved at the usual rate, despite having absolutely no expressible memory of the task, or of the investigators (Corkin, 1968).

It is difficult to overemphasize the importance of H. M.’s case. It would henceforth be acknowledged that a person could learn something new without any idea that they had done so. And what is more, researchers subsequently started to look for, and find examples of implicit learning in non memory-impaired people.
A number of skills have been shown to be acquired implicitly. For instance, Reber (1989) has shown that artificial rules of grammar can be learned unconsciously. After exposure to a list of nonsense consonant strings that are ordered according to the complex rules of an artificial grammar, participants can distinguish novel strings that follow the rules from ones that don’t. Imagine sorting between two nonsense strings of consonants, identifying kinds of “words” that fit a kind of “sentence,” and being unable to say how you do this. That is what Reber’s participants experienced. Lewicki (1992) has also shown that participants can learn complex patterns and contingencies despite poor conscious knowledge of them. Research participants were able to infer the personality traits of “people” represented by a series of dots on a screen, having no idea how they did so. Of course, these examples of learning without awareness would remain trivial curiosities if it were not for the tendency of researchers to seek benefits in more normal situations.

**Benefits of Implicit learning**

Imagine a child in the final of a regional math contest. Imagine their reasoning ability unaffected by anxiety as they race to finish the final problem. Imagine that child undergoing neurosurgery, with a pediatric surgeon whose skills are impervious to stress. If math or surgery skills were learned implicitly, these examples would not be so farfetched. Implicit processes have been shown to be more resistant to the effects of psychological stress (Reber, 1993; Shacter, 1992). What if there was a way to teach a classroom of children an important skill – and you could be sure that the intellectually challenged children had the same chance at mastery? Reber (1993) found evidence of independence from intelligence on an implicit grammar-learning task. What if high
school calculus teachers found a way to teach integrals so that students would remember the concept when it came time for them to teach their own children? Allen and Reber (1980) found the effects of implicit learning to be more durable than explicit learning. What of people who are required to make vital decisions with the clock ticking? Turner and Fischler (1993) found that knowledge learned implicitly is more robust when a fast response is required.

It has been suggested that the majority of human knowledge and learning is implicit (Wilson, 2002). And yet the educational applications for learning this way are largely untapped. There are a few possible reasons for this, including its relative novelty, continuing theoretical controversy around its existence, and the inherent difficulty working in an area of knowledge that is not directly accessible. While the above examples of tapping implicit learning may seem beyond possibility, current research in physical skill development has potential for immediate application.

Implicit Learning in Physical Skills

The field of physical skill development has produced the most experimental work in the area of implicit learning (Maxwell, et al., 2001). There are obvious gains to be made with the advantages of robustness, durability, and resistance to psychological stress. Sport’s focus on optimizing skill acquisition and performance has further fueled ongoing research. Some physical skills have advantages for research. In effect, favoured sports for research (golf, soccer, and table tennis) seem to share some traits. They all involve complex motor activity but have familiar, measurable goals and results. They are simple to observe and evaluate and there is the possibility of easily quantifiable skill acquisition. Though darts would seem to be an ideal activity for this research area, and has been used
for other learning studies (e.g., Marchant, Clough, & Greig, 2005; Weir & Leavitt, 1990), no implicit learning studies so far have used this activity.

**Implicit Golf**

Maxwell, Masters, and Eves (2000) studied the effect of an extended period of practice on the performance of implicit versus explicit learners. In response to the consistently poorer performance of implicit learners in their own studies, the researchers sought to find out if performance in a golf putting task converged over an extended period of learning. Three groups of nine volunteers were randomized to either the implicit condition (a secondary tone-counting task except on the retention block), implicit control (same secondary tone-counting task throughout) and explicit (no instruction). Each participant putted 12 blocks of 50 times daily, on five consecutive days, (for a total of 3000 putts) and returned 72 hours later for a retention test consisting of a single block of 50 putts. Although the performance of the implicit learning groups remained below that of the explicit group throughout the learning phase, no statistically reliable differences were found during the retention test. The explicit group reported significantly more rules pertaining to the task than did the implicit learners. Maxwell, Masters, and Eves used these results to support their argument against excessive use of verbal instruction during skill acquisition, since this might ultimately hamper performance under stress.

**Skilled Performance Under Stress**

Using a series of golf putting experiments, Beilock and Carr (2001) were able to support the popular belief that attending to procedural skills hurts performance. This notion was formalized in an *explicit monitoring theory* of choking by Baumeister in 1984. By examining the generic knowledge and recollection of specific putts among experts
and novices, Beilock and Carr showed that skilled putting was learned in a way that supported performance without the need for step-by-step attentional control.

*Errors, Outcome Information, and Learning Skill*

Maxwell, et al. (2001) studied errors in participants learning to putt. Participants were randomized to learn with or without errors through a learning phase of eight blocks of 50 putts. The errorless putters started close to the hole and gradually increased the putting distance whereas the errorful learners started from the furthest distance. A test phase of 3 blocks of 50 putts each checked the learners for retention and transfer to a novel distance. Reducing the errors during learning in this study was associated with significantly better performance on both retention and transfer tasks. The authors concluded that skills acquired with frequent errors during learning place a greater demand on explicit resources and that errorless learning seems to confer an implicit quality to learner performance, namely retention and robustness under distraction. Surprisingly, the authors found no difference in the number of rules accrued by the groups. They hypothesized that rules in the errorless group were added late in the learning phase, thereby giving this group an early advantage that carried over to retention and transfer.

Does knowing the outcome of a task as it is being learned, be it an error or not, have an effect on acquisition of a specific movement? Hayes, Horn, Hodges, Scott, and Williams (2005) sought to answer that question using 14 non-skilled female participants and a soccer chip-shot that required them to land a ball on a target while clearing a height barrier. All participants received a video demonstration of a skilled player executing the skill. Then two groups of seven were formed, with one group having their vision occluded by liquid-crystal glasses at the moment of ball contact, thereby preventing
feedback on outcome. Outcome measures included distance from the target and analysis of videotaped movement kinematics. The participants who saw their ball land performed significantly better at getting closer to the target centre. Interestingly, participants blinded to their result showed physical technique more like that of the model. The authors concluded that demonstrations are downgraded or ignored when outcome feedback is provided.

*Verbal Overshadowing*

Physical skill development has the potential to more easily avoid words in a training situation. Coaches have the option to wordlessly model or demonstrate a skill. They may even choose to have their learners discover the skill on their own, using only the desired results as direction. By avoiding the use of words, participants avoid conflicts between explicit and implicit learning, also known as verbal overshadowing.

Jonathon Schooler (1990) coined the phrase “verbal overshadowing” and has studied its disrupting effects in facial recognition, memory, and other difficult-to-report stimuli. Schooler, Ohlsson, and Brooks (1993) also confronted the issue of verbal interference in problems involving implicit knowledge. They wanted to know if talking *through* would impair solving implicit insight problems. They designed a set of experiments. In experiment 1, undergraduate student participants went through 6 trials of one insight problem each. Half the participants were interrupted 2 minutes into their task and asked to write down how they had been trying to solve the problem. The other half was interrupted and asked to work on an unrelated crossword puzzle. The researchers looked at the total number of problems solved in the allotted time of 7.5 minutes per problem. Analysis of data using ANOVA showed that participants who attempted to
verbalize how they had been trying to solve insight problems solved significantly fewer problems than control participants. This result provided support for the hypothesis that verbalization interfered with the processes associated with insight.

Modeling implicit learning has, so far, required not only the avoidance of verbalization, but also the occupying of working memory so that the target skill is practiced without any potential for verbal awareness. This has usually required distracting secondary tasks, such as subtraction or random letter generation. Analogy has more recently been proposed as a practical alternative to these secondary tasks.

**Analogy and Implicit Learning**

Most attempts at teaching implicitly have used tasks to distract consciousness that would be impractical in real life (Maxwell, et al, 2001, Maxwell, Masters, & Eves, 2000). Teaching by analogy has therefore been proposed as a more practical means of gaining access to the advantages of implicit learning (Liao & Masters, 2001). Liao and Masters (2001) conducted experiments in table tennis to examine whether learning a forehand topspin by analogy would invoke characteristics of an implicit mode of learning. They assigned 30 university students to one of three conditions: analogy learning, implicit learning, and explicit learning. All participants were shown how to hold a ping-pong paddle, and shown a diagram illustrating the ball in topspin. The analogy learners were trained to use the hypotenuse of a right angle triangle as the model for a forehand topspin. Implicit learners were not given additional instructions, but were asked to perform a distracting task (calling out random letters every second) during the trials. The distracting task has been well established as a means of decreasing explicit rule formation – thus increasing chances of implicit learning. The explicit learners were given a list of 12 rules
to follow in making their shots. Accuracy was measured by remote video and awarded in points that increased as the ball struck set zones closer to the outside corner of the opposite side of the table. In the first experiment, participants hit 6 sets of 50 balls, followed by a rest period where they wrote down any rules they were using. This was followed by a transfer set – that had all participants counting backwards while they hit, and finally, by a retention set without any distracting activity. The second experiment had the same procedure but introduced an anxiety-provoking event before set 6 (participants were told that they were not meeting expectations) and a rule-reinforcing event (they were told not to think of rules!) before set 8. These new conditions were matched with corresponding control groups. The results showed no difference in performance for all groups through the training trials. All participants got better at about the same rate. As expected, backwards counting negatively affected the performance of explicit learners in experiment 1, as did the anxiety-provoking and rule-reinforcing event in experiment 2. Analogy learners, however, matched the improvements of implicit learners throughout, and continued to improve, unaffected by distractions.

This study, though simple in design, effectively showed the impact of a well-chosen analogy on the acquisition of a robust motor skill. The study’s failure to achieve separation of the analogy and implicit learning groups leaves some questions, however. Perhaps the implicit group was not sufficiently distracted by the letter-generation task. Or perhaps the analogy and distraction groups were in effect, equivalent, the chosen analogy acting simply as a distraction.

Note that the interruption and verbalization in the Schooler et al (1993) experiments are analogous to the procedure Liao and Masters (2001) used to ascertain
level of verbalization: during the rest period after the training phase and before the transfer phase, participants were asked to write down any physical rules they had used. Schooler et al (1993) suggested that any cognitive activity that relies primarily on non-reportable processes and information, including automated motor skills and implicit memory, may be vulnerable to verbalization. Researchers requesting verbalized thoughts, such as the written rules requested by Liao and Masters (2001), should seriously consider using control groups to determine whether verbalization is influencing performance. Deterioration in implicit performance, especially after written rules are required, could be explained on the basis of verbal interference, and may have led to an underestimate of implicit learners’ skills.

Analogy is not the only technique which has been proposed to indirectly assist in the teaching of physical skills. Another area of research has examined the effect of the location of a participant’s concentrated attention while executing a skill. This focus of attention or focus of control research shares some features of the analogy research in implicit learning.

**Focus of Control and Learning**

Wulf, Hob, and Prinz (1998) demonstrated the learning advantages of instructions based on an external focus of attention instead of an internal focus. Using a ski-simulator task, they found that instructing participants to focus on the force they exerted on the wheels of the platform was more effective than focusing their attention on their feet exerting the force. They showed that physical skills are best acquired with an external focus of control, that is, with attention directed at an external object, rather than a body part. The goal of Wulf, Lauterbach, and Toole’s (1999) study was to determine the
robustness and generalizability of the external focus advantage. That is, the benefit of attending to the result of an action rather than attending to what a body is doing to produce that action. This time, the skill taught to novices was a golf pitch shot. One group focused on the arm swing (internal focus), the other focused on the club swing (external focus).

Twenty-two undergraduate students from Munich with no prior experience hitting golf balls volunteered for the study. They were randomly split into the two groups and given 10 minutes of basic instruction on the pitch shot with a 9 iron, around grip, stance, and posture. The internal focus group was then asked to perform about 20 practice swings while focusing their attention on correct arm movements (left arm straight, right arm bent during backswing, both arms straight during forward swing, left arm bent, right arm straight during follow through). The external focus group also performed 20 practice swings. Their instructions, in contrast, were to let the club swing freely and focus on the weight of the club head, the straight-line direction of the club head path, and the acceleration of the club head moving toward the bottom of the arc. All participants were given feedback about their performance as necessary. The learner’s task was to hit golf balls into a circular target with a radius of 45 cm, located 15 m from where they were standing, outdoors, on a lawn surface. All participants hit 8 sets of ten balls. Between each set, they were reminded of their internal or external cues. The next day, another 3 sets of 10 balls were hit as a retention test.

Performances were scored in points decreasing with distance from the central target, from 5 to 0. The data were subjected to ANOVA. Though both groups became increasingly accurate in their shots across the first 8 sets, the external-focus group
achieved significantly higher scores (average 21.0) than the internal-focus group (average 10.8). The benefits were also seen a day later in the retention test, with the external focus achieving significantly greater accuracy.

Wulf, et al (1999) concluded that directing the learner’s attention to the club might generally be more effective than directing their attention to their arm movements. They suggested, “that the correct arm movements just seem to emerge as a natural consequence of the club movement” (p. 124). Their conclusions were supported by McNevin, Shea and Wulf (2003), who used a balancing task to demonstrate that increasing the distance of an external focus of attention enhanced learning. Note, once again, that the cue reminders that Wulf, et al’s participants received between sets may constitute another type of verbal interference. Any attempts by the participants to verbally understand accumulated unconsciously-learned behaviours may have led to a degradation of performance.

Marchant, Clough, and Greig (2005) used novice dart throwers to test the influence of attentional focusing strategies. Fifty-eight participants were randomly assigned to either internal, external or control strategy groups. The external instructions (not specified) directed attention towards the intended outcome, the internal instructions (not specified) directed attention to the actual movements, and the control instructions ('just do it') were non-specific. After 10 practice throws, each participant threw 10 blocks of 4 darts at a concentrically scored target. ANOVA with repeated measures showed that external and control group performance were not significantly different from each other but were both significantly different from the internal group performance. The authors concluded that an "internal instruction strategy constrains the motor system by interfering
with natural control processes, whereas an external focus allows automatic control processes to regulate movements” (Marchant, et al., 2005, p. 172).

**Skill, Focus of Attention, and Instruction**

Perkins-Ceccato, Passmore, and Lee (2003) studied how a golfer’s skill changed the effects of focus of attention. Twenty golfers, of which ten were highly skilled and ten were novices, were directed to pitch a ball with a 9-iron as close as possible to a pylon located at 4 increasing distances. Both groups were instructed to perform the task under two conditions: internal focus of attention and external focus of attention. For the internal focus, participants were told to concentrate on the form and force of the golf swing. The external focus of attention instructions asked the participants simply to concentrate on hitting the ball as close to the pylon as possible. The results provided some interesting associations between skill and the effect of focus of attention. The order in which instructions were given affected the low-skill and high skill golfers differently. Low skill golfers performed better overall when given internal focus instruction first. High skill golfers, on the other hand, performed better when presented with the external focus of attention instructions first. The authors interpreted these findings as supporting the view that, once the fundamentals of the golf swing have been learned well, performance benefits more by concentrating on the result of the swing, rather than the action that produces it.

Hodges and Franks (2002), in their review of the literature, also reported different effects of instruction depending on skill level. In reviewing the effect of demonstrations, they found that when the movement is not part of the learner's repertoire, demonstrations and instructions have little learning benefit. These authors reverse that finding at a higher
skill level, stating "If the necessary components to perform the action have already been acquired, then demonstrations, which facilitate the stringing together of these components, are likely to be useful learning aids" (Hodges & Franks, 2002, p. 807).

**Summary**

The preceding review has endeavored to lead the reader through a sequence of premises. Knowledge acquired implicitly is available for use without conscious or verbal awareness. There are advantages to learning implicitly, notably retention and resistance to deterioration under stress (Maxwell, Masters, Kerr, & Weedon, 2001). These advantages may be especially sought-after in physical training (Liao & Masters, 2001). There is support for the theory of choking that suggests that attending to procedural skills hurts performance (Beilock & Carr, 2001). Learning with errors may make also hurt performance under pressure, by making participants more susceptible to rule acquisition (Maxwell, et al., 2001). There is evidence that seeing the results of a skill newly learned makes novices likely to ignore demonstrations. Most attempts at teaching implicitly have used tasks to distract consciousness that would be impractical in real life (Maxwell et al., 2001, Maxwell, et al., 2000). Teaching by analogy has therefore been proposed as a more practical means of gaining access to the advantages of implicit learning (Liao & Masters, 2001). Verbal overshadowing is a potential threat to validity that needs to be taken into account in the design of implicit learning experiments. Using an external focus of control (Wulf, Hob, & Prinz, 1998) in skill instruction seems akin to analogy, and may, in fact, be a feature of the most effective analogies. Focus of attention strategies in instruction, however, may have different effects on novices and experts (e.g., Perkins-Ceccato, et al., 2003; Hodges & Franks, 2002).
Imagine if it was known, not only that analogy worked to teach implicit physical skills, but also how it worked and how that might differ depending on level of skill. It might be possible to design the ideal analogy for a training situation and take full advantage of the robustness of implicit learning. And we may no longer be surprised to find that Andre Agassi can’t explain his forehand. After all, that conscious ignorance is the hallmark of an implicit skill which is protecting the tennis star's forehand from the effects of time away from the sport and choking in competition.
CHAPTER THREE

Method

The primary purpose of this study was to test an external analogy as a technique of implicit motor skill training in a dart throwing task. The experiment was designed to answer the following question: do analogy learners in a dart-throwing task demonstrate the beneficial features of implicit learning, namely retention and resistance to stress?

Participants

Once ethical approval was granted, 47 university students were recruited. Throughout the study period, the researcher appeared in person at a lecture (with prior approval of the professor) and gave a short description of the study. Participants were offered an incentive in the form of a draw for a portable electronic music-playing device. There were 13 students per group for a total of 39 participants, 32 male and 7 female, from a variety of faculties including nursing, occupational therapy, physiotherapy, and philosophy. Eight students who had been assigned to deleted analogy groups, (see below) were not used in the analysis. Only one student failed to return for Day 2 of the experiment. Only his Day 1 data was used in the analysis.

Number of Groups

This study had originally been designed with 5 learning groups in mind. The intention was to compare (1) control and (2) implicit groups to 3 different analogy groups: (3) external analogy (elastic band), (4) internal analogy (catapult) and (5) nonsense analogy (toy boat). However, recruitment proved more difficult than anticipated. A preliminary review of the data was conducted after recruiting 21 participants randomized to 5 groups. There were few discernable trends, suggesting that small
samples in multiple groups might lead to a lack of power. It was therefore decided that
the number of learning groups should be reduced to three. This would increase sample
size in the remaining groups thus increasing power. Recruitment proceeded, with random
assignment to a control, an implicit (secondary task) and an analogy (elastic band) group.
The elastic band analogy was chosen over the others for its external focus.

Learning Groups

Students were randomly assigned to one of three learning groups.

1. The control learning group: These participants received no instruction in dart-
throwing. Before each learning block, they would be told only the goal of the task.
This group, therefore, learned by discovery, which has been shown to result in
explicit learning (Masters, 1992).

2. The unconscious learning group: Not only did these students receive no
instruction, but they were required in addition to perform a secondary task while
learning to throw darts. The letter generation task required them to recite random
letters of the alphabet at a rate of one per second in time with the beat of a
metronome. In previous studies, this method has been shown to lead to implicit
learning of complex motor skills (Masters, 1992; Liao & Masters, 2001).

3. The external analogy learning group: These participants were asked repeatedly
through the learning phase to imagine a biomechanical metaphor involving the tip
of the dart being connected to the target by elastic band. The use of analogy was
shown by Liao and Masters (2001) to lead to implicit learning.
The groups maintained their separate conditions through the learning blocks of the study’s first day, but were all three instructed in the same way during the performance blocks of Day 2.

*Apparatus*

The dart-throwing task took place in a large, well-lit classroom that allowed one participant at a time to perform unwatched by other participants. A series of four dart boards were suspended from above the chalkboard at the front of the room (see Appendix A). Each board was centered on a 1.22 m by 1.22 m plywood backing that prevented any damage to the chalkboard underneath. Regulation 46 cm diameter bristle dart boards were positioned with the center at a height of 1.52 m from the floor and with masking tape toe-lines at 2.13 m perpendicular distance from the boards (see Appendix B). Darts were contained in a series of 4 clear plastic bowls; each containing 10 darts and placed on tables at each station, within easy reach of the participant. The participants used sets of 10 standard 24 gram darts. Broken darts were quickly replaced with spares. The boards were affixed with paper covers divided into 11 concentric rings of equal radial width, marked with scores of 0 for the outermost ring to 10 for the center circle (see Appendix A). The paper target covers were changed with each new group of participants. A laptop computer was programmed with a software metronome to produce tones for the secondary (working memory) task. Small external computer speakers were used to amplify both the recorded instructions and the metronome beats. A digital camera was used to capture an image of each of the 4 targets after each block, for each participant. The digital images were later viewed on a computer screen and scores were tallied visually. At the same time, scores were entered into a spreadsheet software program.
**Task**

The task for the participants was to throw the darts to strike as close to the center of the target as possible. Each throw was scored according to its position on the board (0 to 10). A dart that missed the board, or that bounced off, was given a score of 0. The participants threw 4 sets of ten darts in one block. They started at the left-most target before moving to the next one on their right, until they had thrown 40 darts, constituting one block. Participants were not given any time limit.

**Design**

There were two phases of the experiment on two consecutive days: a learning phase on Day 1 followed by a performance phase on Day 2. In the learning phase, participants threw a total of 240 darts in 6 blocks of 40 trials. Two minutes rest was allotted between blocks of trials, during which time digital pictures of the dart boards were taken (for subsequent scoring) and the thrown darts were collected. The performance phase consisted of three blocks of 40 throws: a retention test without instruction, followed by a transfer test (letter generation task) followed by a second retention test without instruction. There was similarly a two minute rest between the performance blocks. The first retention test was designed to show how well the skill was remembered. The transfer test was meant to show how well the learned skill was retained with a distracted working consciousness. And the second retention test was to show the cumulative effect of all learning and performance blocks.

**Procedure**

Once the participants were greeted in the study area, they were asked to read a letter of information (see Appendix C) and they signed a consent form (see Appendix D).
Each student was then randomized to a learning group. The participants were then introduced to the study set-up. At the beginning of the learning phase, all participants were verbally told that their goal was to “come as close to the centre of the target as you can.”

The control learning group listened to that same instruction in pre-recorded form (“Throw the dart as close to the centre of the target as you can”) before each block. The implicit learning group had the secondary task of random letter generation. A computer-based digital metronome was programmed to beat at one second intervals. Participants in this group were instructed to say aloud a random letter of the alphabet for each beat while concurrently throwing darts. Participants were asked to avoid saying letters in sequence and to be as accurate as possible on both tasks. The external analogy learning group heard a pre-recorded instructional message before each block of 40 throws: “Imagine the tip of the dart is fixed to the center of the target by a strong elastic band.”

Before they left, students were asked how often (if ever) they had played darts. Responses were noted and grouped in one of five categories (never, 1-5x, 6-10x, 10-15x, >15x). Participants were not given a time limit (but completed the six learning blocks in an average of 20 minutes, and spent no more than 30 minutes in the study room on Day 1).

On Day 2, each participant was greeted and asked to throw 40 darts (10 darts at 4 targets = one block) with no instructions except a verbal reminder to aim for the centre. This constituted the first retention block. Each participant was then asked to throw a second block of darts, the transfer block, while performing the random letter generation
task. Each participant concluded their performance phase with a second retention block without instruction.

Finally, participants were asked to complete an Episodic Questionnaire (as employed by Beilock & Carr, 2001) at the end of their participation (see Appendix E). In this protocol, participants were given the following written instructions: “Pretend that your friend just walked in the room. Describe the last throw you took, in enough detail so that your friend could duplicate that last throw you made in detail, just like you did.” Since there is evidence that writing or verbalizing physical movements may interfere with subsequent skill (verbal overshadowing, as in Ericsson, 2002), verbal protocols were requested only at the end of the experiment. The participants were asked not to discuss their group approach or their scores outside of the study, in order to limit treatment diffusion and rivalry. These verbal protocols were tallied by a researcher who was blinded to the participant’s group. They counted the number of discrete physical rules described by each participant and tabled them in a spreadsheet.

**Analysis**

SPSS 14.0 was used for statistical analysis. Data were recorded in the form of scores (minimum 0, maximum 400) for each block of 40 throws (10 darts per target, 4 targets per Block). Scores were arranged in an SPSS data sheet, with variables: name, group learning set (6) performance set (3), sex, and experience. For each of the 3 groups of 13 participants, there were 6 learning scores from the first day and 3 scores for the second day. Day 2 scores were in the form of: retention (R1), transfer (T), and retention (R2). (One student from group 5 did not attend the second day. His performance scores were excluded from analysis.) The mean scores and standard deviations for each group
and set were tabulated and graphed. ANOVA with repeated measures was selected for analysis of within-subject and between-subject effects. This procedure effectively uses each participant as their own control thereby limiting the effect of inter-participant variability and increasing the power of the analysis. The within-subject factors were the blocks, six for the learning phase and three for the performance phase. The between-subject factors were group (1=control learning, 3=external analogy learning, and 5=implicit learning); sex (male, female) and experience (never, 1-5x, 6-10x, 11-15x, >15x). To establish the relationship between groups and scores, a two-way ANOVA with repeated measures on the block factor was used as follows: a 3 X 6 (group x block) for the learning phase and the 3 X 3 (group x block) analysis for the performance phase. In addition, ANOVA with repeated measures was used to analyze the effect of group on each of three blocks of performance, namely from the end of Day 1 to the start of Day 2 (L6 – R1); from the first retention block to the transfer block (R1 – T); and from the transfer block to the second retention block (T – R2). Sex and experience factors were analyzed in a similar fashion. The number of verbal rules for each group was compared using a one way ANOVA.
CHAPTER FOUR

Results

The study results are divided into four sections: Effect of Learning Group, Effect of Sex, Effect of Experience, and Effect of Explicit Rules. The first and most important is the effect of learning group, which provides the answers to the central question. In the figures, tables, and text below, the designation ‘L’ refers to the learning blocks, ‘R’ refers to the retention blocks, and ‘T’ to the test block. Taken together, L1 through L6 form the ‘learning phase’, and R1, T, R2 form the ‘performance phase’.

Effect of Learning Group

Individual scores are tabled in Appendix F. Means and standard deviations for each group over the 9 experimental blocks are listed in Table 1.

Table 1

Mean Scores and Standard Deviations Over 9 Experimental Blocks

<table>
<thead>
<tr>
<th>Group</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
<th>R1</th>
<th>T</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>M</td>
<td>219</td>
<td>229</td>
<td>234</td>
<td>235</td>
<td>232</td>
<td>232</td>
<td>224</td>
<td>226</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>33</td>
<td>21</td>
<td>31</td>
<td>27</td>
<td>25</td>
<td>18</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>Implicit</td>
<td>M</td>
<td>204</td>
<td>210</td>
<td>208</td>
<td>208</td>
<td>218</td>
<td>216</td>
<td>214</td>
<td>217</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>44</td>
<td>39</td>
<td>37</td>
<td>37</td>
<td>28</td>
<td>28</td>
<td>50</td>
<td>31</td>
</tr>
<tr>
<td>Elastic Analogy</td>
<td>M</td>
<td>194</td>
<td>193</td>
<td>201</td>
<td>206</td>
<td>207</td>
<td>213</td>
<td>191</td>
<td>191</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>41</td>
<td>36</td>
<td>37</td>
<td>41</td>
<td>35</td>
<td>35</td>
<td>37</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>M</td>
<td>206</td>
<td>210</td>
<td>214</td>
<td>216</td>
<td>219</td>
<td>220</td>
<td>209</td>
<td>211</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>39</td>
<td>32</td>
<td>35</td>
<td>35</td>
<td>29</td>
<td>32</td>
<td>38</td>
<td>29</td>
</tr>
</tbody>
</table>

\[a \text{n} = 13 \text{ for each learning group.} \quad \text{bNo Instructions.} \quad \text{cRandom Letters.} \quad \text{dLearning Blocks (1-6).} \quad \text{eRetention Blocks (1, 2).} \quad \text{fTest.}\]
Figure 1 shows line plots of mean scores for the three experimental groups over the learning and performance phases. This figure gives an accessible visual summary of the experimental results and as such will be referred to repeatedly in the text below. Though each group’s line looks significantly different in this graph, large standard deviations create an overlap at most of the data points in Figure 1. Figure 2 illustrates this effect.

Figure 1. Plots of Mean Scores of 3 Groups Over 9 Experimental Blocks.

Figure 2 represents the same data shown in Figure 1, but in this case, vertical bars are added to represent the range of one standard error of the mean below and above each point, and the groups are separated into 3 plots for clarity.
Figure 2. Plots of Mean Scores of 3 Groups with SE Bars

While the clear lines of Figure 1 illustrate the trends in the data, Table 2 contains the results of the analysis of these trends. In Table 2, the within-subject effects are listed in the first horizontal panel while the between-subject effects are provided on the second horizontal panel. The table is also divided between the learning blocks (L1 to L6), and the performance blocks (R1, T, R2). The degrees of freedom (df) are displayed along with the corresponding $F$ value and $p$-value. The Block x Group sections show the $F$ value for interactions of the two factors. Within-subject results for the learning phase were tested for sphericity with Mauchly’s W, and the performance phase results were
tested for equal covariance with Box’s M. Both of these statistics are noted with corresponding results in the text.

Table 2
Analysis of Variance with Repeated Measures for Learning and Performance Phases

<table>
<thead>
<tr>
<th>Phase</th>
<th>df</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning</td>
<td>5</td>
<td>3.24**</td>
<td>0.01</td>
</tr>
<tr>
<td>Block X Group</td>
<td>10</td>
<td>0.60</td>
<td>0.81</td>
</tr>
<tr>
<td>Performance</td>
<td>2</td>
<td>5.34**</td>
<td>0.01</td>
</tr>
<tr>
<td>Block X Group</td>
<td>4</td>
<td>0.49</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Between Subjects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning</td>
<td>2</td>
<td>2.96</td>
<td>0.06</td>
</tr>
<tr>
<td>Performance</td>
<td>2</td>
<td>4.87**</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**$p < .01$**

Note in Figure 1 the general learning trend as all 3 groups appear to increase their scores over blocks 1 through 6. There is indeed a significant within-subject main effect of learning block for all three groups as seen in Table 2, $F(5,39) = 3.24, p = 0.01$; Mauchly’s $W = 0.52, p = 0.07$. This suggests that all three groups learned over the 6 blocks. There was no significant between-subject effect of group in the learning phase, $F(2,39) = 2.96, p = 0.06$, suggesting that the groups did not learn at significantly different levels.

The performance phase in Figure 1 has a similar shape for all three groups. Table 2 shows the significant within-subject effect of block, $F(2,39) = 5.34, p = 0.01$; Box’s M $= 11.02, p = 0.65$. This suggests that scores for all three groups changed significantly in this phase. The significant between-subject effect in the performance phase, $F(2,39) =$
4.87, \( p = 0.01 \), suggests that here, the groups differed significantly from one another. Post hoc testing for Group using the Bonferroni procedure showed that only the control and analogy groups were significantly different (\( p = 0.01 \)). This suggests that there is a significant difference in how much better the control group performed than did the analogy group, but no such difference between analogy and implicit groups (as might be anticipated by looking at Figure 1).

Table 3 allows a closer look at the individual components of the performance phase. The within-subject effects are listed in the first horizontal panel while the between-subject effects are provided on the second horizontal panel. The table is also divided in three performance blocks, L6 to R1, R1 to T, and T to R2. The degrees of freedom (\( df \)) are displayed along with the corresponding \( F \) value and \( p \)-value. The performance phase results were tested for equal covariance with Box’s M, and this statistic is noted with corresponding results in the text.

Table 3

Analysis of Variance with Repeated Measures for Performance Phase Transitions

<table>
<thead>
<tr>
<th>Transition Blocks</th>
<th>( df )</th>
<th>( F )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L6, R1</td>
<td>1</td>
<td>3.07</td>
<td>0.09</td>
</tr>
<tr>
<td>R1, T</td>
<td>1</td>
<td>0.19</td>
<td>0.67</td>
</tr>
<tr>
<td>T, R2</td>
<td>1</td>
<td>6.53*</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Between Subjects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L6, R1</td>
<td>2</td>
<td>2.17</td>
<td>0.13</td>
</tr>
<tr>
<td>R1, T</td>
<td>2</td>
<td>4.01*</td>
<td>0.03</td>
</tr>
<tr>
<td>T, R2</td>
<td>2</td>
<td>6.13**</td>
<td>0.01</td>
</tr>
</tbody>
</table>

\* \( p < .05 \). \** \( p < .01 \)
Table 3 shows that there is only one significant within-subject difference between Day 1 and Day 2 (L6 to R1). It is between the test block (T) and second retention block (R2), $F(1, 38) = 6.53, p = 0.02$ (Box’s M = 1.73, $p = 0.95$). This suggests that only during this final performance stage was there a significant block effect. One might have anticipated this finding given the relative flatness of the first two steps graphed in Figure 1 contrasting with the upward slope for all three groups in the final step.

There are two significant between-subject effects reported in the lower panel of Table 3. From first retention (R1) to test (T), $F(2, 38) = 4.01, p = 0.03$. Post hoc Bonferroni shows significance only between the control and analogy groups ($p = 0.03$). From test (T) to second retention (R2), $F(2, 38) = 6.13, p = 0.005$. Once again, the control and analogy groups account for the only post-hoc significance (Bonferroni, $p = 0.006$). Although looking at Figure 1 might suggest that the implicit and elastic groups are quite distinct as well, post hoc Bonferroni did not confirm a significant difference ($p = 0.051$).

This dissection of the performance phase suggests (see also Figure 1) that while all participants appeared to respond to retention and testing, only the analogy group showed a significant (negative) difference in performance as compared to the control group.
Effect of Sex

Figure 3 shows the mean scores for male and female participants over the learning and performance blocks.

![Figure 3. Plots of Mean Scores for Males (n=7) and Females (n=32)](image)

Table 4 provides the repeated measures results for males and females through the learning and performance phases. The within-subject effects are listed in the first horizontal panel while the between-subject effects are provided on the second horizontal panel. The degrees of freedom (df) are displayed along with the corresponding F value and p-value. The Block x Group sections show the F value for interactions of the two
factors. Within-subject results for the learning phase were tested for sphericity with Mauchly’s W, and this statistic is noted with corresponding results in the text.

Table 4

Influence of Sex on Scores through Learning and Performance Blocks.

<table>
<thead>
<tr>
<th>Phase</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>5</td>
<td>1.22</td>
<td>0.30</td>
</tr>
<tr>
<td>Block X Sex</td>
<td>5</td>
<td>0.69</td>
<td>0.63</td>
</tr>
<tr>
<td>Performance</td>
<td>2</td>
<td>2.98</td>
<td>0.06</td>
</tr>
<tr>
<td>Block X Sex</td>
<td>2</td>
<td>1.16</td>
<td>0.32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>1</td>
<td>16.56**</td>
<td>0.00</td>
</tr>
<tr>
<td>Performance</td>
<td>1</td>
<td>4.09**</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*p < .05.  **p < .01

Both plotted lines in Figure 3 seem to depict a similar pattern of increasing score over the learning blocks. There is no significant within-subject effect of block, however, over the learning phase (See Table 4, F(5, 39) = 1.22; p = 0.30; Mauchly’s W = 0.54, p = 0.09). The male learning curve is significantly higher than the female curve, as revealed by the between-subject effect in Table 4 (F(1, 39) = 16.56, p < .01).

Figure 3 seems to show males and females reacting to the performance blocks, with males’ scores, for instance, appearing to drop during testing. This within-subject effect is not significant, however (F(2, 38) = 2.98, p = 0.06). Male scores do remain significantly higher than female scores through the performance phase, with between-subject F = 4.09, (p < 0.05). There is no significant interaction between block and sex. In summary, the small group of male students significantly outscored their female
counterparts throughout the study blocks. But when grouped by sex, participants showed no significant changes through the learning or the performance phases.

**Effect of Experience**

Figure 4 shows the plots of mean scores for 5 levels of dart-throwing experience over the learning and performance phases. For this figure, the participants were divided according to self-reported lifetime number of dart-throwing episodes, ranging from ‘never’, through ‘1 to 5 times’, ‘6 to 10 times’, ’11 to 15 times,’ or ‘more than 15 times’.

![Figure 4](image)

Figure 4. Plots of Mean Scores for 5 Levels of Dart-Throwing Experience

Table 5 provides the repeated measures statistics for grouped level of experience over the learning and performance phases. The within-subject effects are listed in the first
horizontal panel while the between-subject effects are provided on the second horizontal panel. The degrees of freedom (df) are displayed along with the corresponding F value and p-value. The Block x Group sections show the F value for interactions of the two factors.

Table 5
Influence of Level of Experience on Scores through Learning and Transfer Blocks.

<table>
<thead>
<tr>
<th>Phase</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning</td>
<td>5</td>
<td>2.78*</td>
<td>0.02</td>
</tr>
<tr>
<td>Block X Experience</td>
<td>20</td>
<td>0.71</td>
<td>0.82</td>
</tr>
<tr>
<td>Performance</td>
<td>2</td>
<td>3.76*</td>
<td>0.03</td>
</tr>
<tr>
<td>Block X Experience</td>
<td>8</td>
<td>0.52</td>
<td>0.84</td>
</tr>
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<td><strong>Between Subjects</strong></td>
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<tr>
<td>Performance</td>
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*p < .05

The general upward trend of all the lines in Figure 4 shows significant within-subject effect of learning block for all levels of experience as shown in Table 5 (F(5, 39) = 2.78, p = 0.02). One can also note that the more experienced dart-throwers score significantly higher through the learning blocks, as evidenced visually by the separation of their lines in Figure 4, and by the between-subject F value of 3.25 (p = 0.02) noted in Table 5. The post-hoc Bonferroni test showed a significant difference (p = 0.026) only between the two largest groups: those who had thrown 0 to 5 times (n = 12) and those who had thrown over 15 times (n = 10). The groups show significant changes through the performance blocks (within-subject F(2, 38) = 3.76, p = 0.03), but these changes are not
significantly different from one another (between subject $F(4, 38) = 0.9, p = 0.47$). There is no significant block x experience effect. It would thus seem that, in this experiment, dart-throwing experience leads to higher scores and may affect the rate of learning, but does not affect the reaction to retention and testing.

*Effect of Explicit Rules*

Figure 5 displays in a bar chart the mean number of accumulated written physical rules (derived by questionnaire) for each experimental group.

![Bar Chart of Mean Number of Rules per Group with Standard Error Bars](image)

Figure 5. Bar Chart of Mean Number of Rules per Group with Standard Error Bars

This figure illustrates the nearly equivalent number of rules accumulated by all 3 groups over the experiment. Indeed, simple ANOVA showed there were no significant differences (ANOVA $F = 0.279, p = 0.76$). Further, repeated measures ANOVA (number of rules x block) revealed no within or between-subject effect of significance.
CHAPTER FIVE

Summary and Conclusions

Introduction

The experiment was designed to answer the following question: do analogy learners in a dart-throwing task demonstrate the beneficial features of implicit learning, namely retention and resistance to stress? The primary purpose of this study was to test analogy as a technique of implicit motor skill training. The current experiment attempted to duplicate the work of Liao and Masters (2001) and also to extend this work, by introducing a different motor task (dart throwing) and a specifically focused analogy (externally focused).

Before directly answering the central research question, however, it will be important to review some preliminary issues around the definition and measurement of implicit learning. As such, this chapter first reviews the lack of evidence of implicit learning and offers potential explanations.

Discussion of Findings

Evidence of implicit learning

Before discussing the group learning effects in this study, it is interesting to raise a question that is pivotal for much of the research in this field: did implicit learning take place? The research reviewed in Chapter 2 relied on one defining characteristic of implicit learning, namely the absence of complete verballisable knowledge of what is learned (Seger, 1994). This characteristic has been supported by the significantly fewer rules reported by implicit group participants. For instance, in their 2000 golf putting study, Maxwell, Masters, and Eves had an explicit group accumulate twice as many rules
as the implicit group. The dart study reported here, however, showed no significant differences in rule acquisition. This is not a new problem. The difference in accumulated rules was not useful, for example, in the golf putting experiment of Maxwell, Masters, Kerr, & Weedon (2001). The authors in this case, resorted to citing the similarity between control and implicit groups through learning and retention as evidence of implicit learning. Although the explicit learning group in Liao & Masters’ 2001 study reports fewer rules, this evidence is weakened by their procedure. All explicit group participants were given a set of 12 basic techniques on how to hit a topspin, whereas the implicit and control group were given none. It is interesting to note that this dart study and the study by Maxwell, Masters, Kerr, & Weedon (2001) share a similar design: several blocks of many trials. Perhaps rule-counting as a means of keeping track of verbalized knowledge becomes less valid with repeated trials of a task.

If implicit learning took place over the learning blocks of this experiment, there is no way to distinguish it from the control (discovery) group’s learning. Although the mean score plots in Figure 1 suggest differences, none of significance were found. This suggests that there are no differences, or that there is a lack of power to distinguish the control from the implicit group (Type II error), or the possibility (in spite of the support above) that the study procedure was inadequate to assure truly implicit learning, or that the implicit conditions were detrimental.

Resistance to stress is a key feature of implicit learning. Failure to separate the control group from the implicit group may have been caused by lack of sufficient stress during performance. The transfer task of random letter generation had a similar (neutral) effect on implicit and control groups and a significantly negative impact on the analogy
group. Although the implicit learning characteristic of resistance to stress has also been noted in resistance to secondary tasks, studies examining stress have usually added a psychological element to the task in order to ensure stress (e.g., Liao and Masters, 2001). The fact that the implicit group in this study had been performing the letter generation throughout learning also meant that transfer would require little new attention. Exposure to a novel stress during the transfer block of performance, such as backwards subtraction from 1100 by 3’s (Liao and Masters, 2001) may have significantly separated the control from the implicit group.

‘Errors’ (being unsuccessful at striking the centre of the target) and ‘observed outcomes’ (having knowledge of one’s better and worse throws) were both a feature of this study and may both have contributed to the lack of evidence of implicit learning in the analogy and implicit groups. As noted earlier, errors may lead to increased rule-forming and explicit learning characteristics (Maxwell et al., 2001). Having to observe all of their outcomes may, in addition, have encouraged participants to stray from their instruction set, as in Hayes, Horn, Hodges, Scott, and Williams (2005). Having the participants throw darts while blindfolded or shrouded would have eliminated this potential for explicit rule formation.

The existing literature and the current study seem both to suffer from the lack of a consistent, valid test for implicit learning. That being said, the random letter generation used in this study has been shown to successfully induce implicit learning of complex motor skills (e.g., Masters, 1992; Hardy et al., 1996), and the results of this experiment show some typical features of implicit learning. The pattern of learning, for instance, (increases similar to control but overall lower scores) is much like the patterns seen
elsewhere in the literature (e.g. Liao & Masters, 2001, Maxwell, 1999). Without a better test than self-reported rules, and for the sake of discussion, it is hypothesized that some form of implicit learning took place during this study.

*Analogy and implicit learning*

Contrary to the table tennis study by Liao and Masters (2001), the analogy group in this dart experiment showed no beneficial features of implicit learning. Instead, the analogy group fared significantly worse than the control group through retention and transfer.

There are two potential reasons for this discrepancy with the current literature. First, this study’s participants did not have general instructions, whereas Liao and Masters (2001) gave all participants instruction on a “shake hands grip” and a diagrammed explanation of the topspin they were trying to achieve. Perhaps some introductory knowledge of the flight of a dart would have leveled the starting point from which each group was to learn. Second, a poor analogy may have been chosen. The elastic analogy was chosen based on its external focus, in line with the theory noted in Chapter 2. It is possible that it proved inadequate in eliciting the desired learning effect. The visual quality of “imagine the tip of the dart is fixed to the centre of the target by a strong elastic band” is different from the more abstract, yet specific instruction used in Liao and Masters (2001). The table tennis participants were to pretend to draw a right-angle triangle with the paddle. They were then told that, to impart topspin to the ball, they should strike the ball while bringing the paddle up the hypotenuse of the triangle (Liao & Masters, 2001). In contrast to the table tennis analogy, which implies movement with direction, the elastic analogy implied no movement at all. It is possible that the
biomechanics required to imitate a dart fixed by an elastic band somehow countered a
more natural throwing movement that may have been more successful.

If this is true, this study showed that not every analogy will induce the features of
implicit learning. In fact, the chosen elastic analogy, though having a feature that would
theoretically support its success – namely its external focus – fared poorly. Analogy
learners in this study learned no better than those distracted by a secondary memory task.
What is more, they fared poorest of all when subjected to, and recovering from, this
secondary task themselves.

Focus of control

As a result of this study, it appears that externality of attentional focus is, by itself,
inadequate in eliciting implicit learning. Unlike the experiments on focus of attention
reviewed in Chapter 2, this study did not contrast an internal focus with an external focus.
It is therefore impossible to assess whether the current study’s analogy group would have
performed better than a group focused on internal body movements. But since Marchant,
Clough, and Greig’s 2005 study of dart throwers found a control group indistinguishable
from an externally focused group, and superior to an internally focused group, and the
current study’s analogy group was inferior to control, it is unlikely that the analogy group
derived benefit from an external focus. In fact, it may be that the analogy, detached from
biomechanical association, became as deleterious as an internal focus of attention. Once
again, consider the contrast between Liao and Masters (2001) topspin analogy, rooted in
a basic arm motion and restricted to describing direction (“strike the ball while bringing
the paddle up the hypotenuse of the triangle”) and the current study’s analogy, with no
reference to movement: “imagine the tip of the dart is fixed to the centre of the target by a
strong elastic band.” An effective analogy may require biomechanical relevance, perhaps built on specific movement, such as the instructions given to the externally focused group in Wulf, Lauterbach and Toole’s 1999 golf chip shot study. After 10 minutes of instruction on basic grip, stance, and posture, participants were asked to let the club perform a pendulum-like motion, letting the club swing freely, focusing on the weight of the clubhead. Equivalent instructions in the current study might have included 10 minutes instruction on dart-throwing stance and grip, followed by directions to fix shoulder and elbow, loosen wrist, and allow the forearm to swing through an arc, like a catapult, with release of the dart at the apex of the arc.

*Verbal overshadowing*

This study was designed to avoid the possibility that verbalizing or writing any physical rules before the end of all trials might jeopardize the validity of any subsequent trials (as in Schooler, Ohlsson, & Brooks, 1993). There was no difference in reported rules, and thus no evidence of discrepant verbalization between the three experimental groups. Verbal overshadowing, therefore, likely played no role.

*Skill level and sex*

Males significantly outscored females through both the learning phase and the performance phase. The analogy group had fewer males (1) than the control group (2) and the implicit group (4), but the highest mean scores were in the control group and the males formed less than 20% of the whole sample. Thus the potential for sex to explain other findings is low.

There was a significant effect related to skill level through the learning phase. As has been shown, skill level can have an effect on response to focus of instruction.
(Perkins-Ceccato, Passmore et al., 2003; Hodges & Franks, 2002). Participants that are more skilled may have been more responsive to external focus conditions, such as in the analogy group. But since there was no evidence of the benefit to the analogy group, and since the levels of experience were fairly well distributed, the likelihood of an experience effect accounting for other findings is also low.

Limitations

Participants and Power

Calculation of power (and thus number of subjects required) for this experiment was not possible without knowing the effect size to expect. Group sizes in similar studies (e.g. 10 participants per group in Liao & Masters, 2001) were relied upon. Three groups of 13 in the current study proved sufficient to produce some significant results. Some observed differences that were not significant in this study, however, may have proved statistically significant with larger groups. Three groups of 13 came at the sacrifice of two additional analogy groups that were part of the study’s original design. Additional participants and another analogy group may have led to a separation of the control and implicit groups and to more interesting comparisons between types of analogy.

Dart Throwing Skill

A number of limitations could be suggested related to the chosen task and method. It is possible that participants were asked to throw too many darts. This may have led to fatigue, lack of concentration, or disinterest, though the significant within-subject learning trends suggest otherwise. The large number of trials may also have led to accumulation of explicit rules, as suggested in Maxwell, et al (2001). Participants might have also benefited from some fundamental instruction on gripping the darts. Studies
reviewed earlier (Liao & Masters, 2001; Wulf et al., 1999) both gave their participants basic instruction on proper grip of the club or bat. It is possible that this kind of instruction could have encouraged more consistency without adversely affecting the instruction conditions for throwing darts.

*Future Research*

The current experiment suggests that the effective characteristics of analogy in the invoking of implicit learning have yet to be established. In addition, this experiment highlights the absence of a consistent and valid measure of implicit learning. Researchers should next look to perform a study to test various analogy and focus of attention configurations in the induction of implicit learning. As suggested above, the analogies should be rooted in biomechanically correct physical movement, and endeavor to shape a limited part of the task. Universal basic instruction should be used to encourage a consistent starting point for the task. A valid test of implicit learning will be essential for ongoing research in this area. Perhaps objective physical measures, such as inconsistently tracked movements or minor hesitations should be evaluated as better markers for explicit versus implicitly learned skill.

*Conclusions*

This study demonstrated that dart throwing instruction using analogy was insufficient to induce the beneficial features of implicit learning. Though it showed that a difficult and complex motor skill could be learned over a short period of time, the current experiment failed to reproduce Liao and Masters’ 2001 conclusions that analogy learning may be an effective method for teaching skills implicitly in sport. The chosen analogy, in fact, led to a significant deterioration with respect to controls during the performance
phase. An external focus of attention was shown to be insufficient, on its own, as the characteristic of an effective analogy. Learning to throw darts without instruction (sometimes referred to as discovery learning) was shown to be superior to learning under two other conditions – analogy and implicit (secondary task) learning. Sex and skill differences were unlikely to have played a significant role in the main findings. This study also revealed that the induction of implicit learning could, at best, only be demonstrated indirectly, and that reporting physical rules by questionnaire was inadequate as a method of determining whether implicit learning takes place.
References


Appendix A

Pictures of Experimental Setup
Appendix B

Diagram of Experimental Setup

1.52 m

2.13 m

46 cm

Wall

Floor

Toe line

Toe line

Toe line
Appendix C

Letter of Information

Implicit Darts

Participant: ________________________________

INFORMATION SHEET FOR PARTICIPANTS

This study is being conducted by Michael Sylvester and is sponsored by the Queen’s Faculty of Education.

This study is being conducted to examine how well adults learn to throw darts using different kinds of instructions. You will stand in front of a dart board and then the experimenter will verbally describe the context of the experiment. During the session you will throw darts at a dart board, trying to come as close as possible to the center. There will be two phases of the experiment over two days: a learning phase followed by a test phase. In the learning phase, you will throw a total of 240 darts in 6 sets of 40 trials. You will have two minutes rest between sets of trials, during which time the thrown darts will be collected. On the second day, the test phase will consist of three test sets of 40 throws. During the middle set, you be asked to generate random letters while throwing. There will be 5 minutes rest between the test sets. At the end of both sessions, you will be asked to complete a brief, anonymous questionnaire on your learning.

The entire session should last approximately 45 minutes, 30 minutes on the first day and 15 minutes on the second day.

There are no known physical, psychological, economic, or social risks associated with this study. Your participation in this procedure is completely voluntary and you may
withdraw from this study at any time without any consequences on your academic standing at Queen’s University. You will be awarded a course credit for your participation in this study whether you complete it or not.

The only information we will be recording about you in addition to the questionnaire is how you perform during the study. The only individuals who will have access to this information are researchers with scholarly interests in cognition at Queen’s University. Your confidentiality is guaranteed and your performance will not be connected to your name in any publication.

If you would like further information about the study, or have additional questions or concerns, please feel free to contact Michael Sylvester email sylvestr@post.queensu.ca. You may also contact the Dean of the Faculty of Education at Queen’s University: Dr. Rosa Bruno-Jofre (613) 533-6210, or the Chair of the Queen's University General Research Ethics Board, Dr. Joan Stevenson, (613) 533-6081, email: stevensj@post.queensu.ca., or Michael Sylvester’s supervisor, Dr. Denise Stockley, Educational Developer and Assistant Professor of Education, (613) 533-6000 x 74304, email: stockley@post.queensu.ca.
Appendix D

Consent Form

I, _______________________, have volunteered to participate in the study titled, Implicit Darts.

I have read the Letter of Information and understand what is required for participation in the study. I understand that I will be standing in front of a dart board throwing darts during 2 sessions, lasting 30 and 15 minutes respectively, on two consecutive days. I understand that my participation in the study is completely voluntary and that I am free to withdraw at any time. I also understand that my confidentiality will be protected throughout the study, and that the information I provide will be available only to researchers with scholarly interests in cognition.

Should I have further questions I understand that I can contact any of the following individuals: Michael Sylvester, email sylvestr@post.queensu.ca, the Dean of Faculty of Education, Dr. Rosa Bruno-Jofre, 533-6210, Chair of the General Research Ethics Board, Dr. Joan Stevenson, (613) 533-6081, email stevensj@post.queensu.ca, or Michael Sylvester’s supervisor, Dr. Denise Stockley, Educational Developer and Assistant Professor of Education, (613) 533-6000 x 74304, email: stockley@post.queensu.ca.

Signature: ____________________________________________

Date: _______________________________________________
Appendix E

Questionnaire with Example Answer

Questionnaire

Pretend that your friend just walked in the room. Describe the last throw you took, in enough detail so that your friend could duplicate that last throw you made in detail, just like you did.

*Step up to the line with your right foot forward. Plant your feet shoulder width apart.*

*Hold the container of darts in your left hand. Pick up one dart with your right hand.*

*Look at the bull’s eye while you throw the dart. Keep your elbow in and extend your elbow in a straight line to the bull’s eye as you throw the dart. Visualize the dart being pulled towards the bull’s eye when you throw it. Don’t get annoyed if you miss terribly, just get the next dart and try the same thing again. Try to compensate if all darts go to the left/right by shifting your body to the opposite side.*
# Appendix F

## Scores of Grouped Subjects Over Learning Blocks

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