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Skill Acquisition and Transfer in a Simple Algebraic Task

Charan J. Singh
Edith Cowan University

SKILL ACQUISITION AND TRANSFER IN A SIMPLE ALGEBRAIC TASK

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Charan J. Singh

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USE OF THESIS

Abstract

Speelman's (1999) finding that performance of a skill is based to some extent on the context in which it is performed, rather than simply on the acquired skill itself, is not accounted for by the basic skill acquisition theories like ACT-R Theory or Instance Theory. The purpose of the current experiment was to examine whether the degree of change in context influences the degree of reduction in transfer. Forty participants were trained on an algebraic task and then tested in two different transfer conditions. Condition one included one new item and condition two included two new items in the transfer phase. Reaction time, the dependent variable, was measured to find out whether the performance of a learned skill was influenced by the number of new items incorporated into the transfer phase. The results showed that, with an increased number of items changed in the task, the transfer of the previously acquired skill decreased. The findings, along with those of Speelman's (1999), challenge some of the basic underlying assumptions of current theories of skill acquisition and transfer.

Author: Charan J. Singh

Supervisor: Dr. Craig Speelman

(Edith Cowan University)

Co-Supervisor: Dr. Murray Maybery

(University of Western Australia)

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Declaration

I hereby certify that this thesis to the best of my knowledge and belief does not,

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Date: 31/09/04

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Introduction

The area of skill acquisition and transfer has ignited enormous research over the years in the field of cognitive psychology, giving birth to many different theories. The basic underlying assumption of many prominent theories of skill acquisition is that once a skill has been learned, performance will continue at the same level in different environment conditions (Speelman & Kirsner, 2001). However, research conducted by Speelman and Kirsner challenges some of the current theories of skill acquisition and transfer as their findings revealed that skill acquisition and transfer is highly *context-specific*. Speelman and Kirsner found that the performance of old skills in the context of a new task was adversely affected and was not predictable on the basis of performance during acquisition. Speelman and Kirsner argued that any change in the task construction may influence performance of the task and cause disruption, an effect which may increase with task complexity. Examining the degree of disruption in the transfer of skill as a function of change in task context was the main focus of the current study.

The purpose of the present study was to determine the effect of skill acquisition and transfer in a simple algebraic task. In particular, this research examined whether skill acquisition and transfer are context-specific. In order to illustrate that a change in the context in which a skill is acquired may affect its performance and transfer, firstly some of the basic phenomena of skill learning are discussed, followed by the introduction of some prominent theories of skill acquisition and transfer. Secondly, challenges posed to the current theories of skill acquisition, and finally, the rationale behind the current study is presented.

The Three Phases of Skill Acquisition

The basic phenomena of skill learning are governed by three developmental stages (Fitts, 1964; Fitts & Posner, 1967). In the first stage, known as the *cognitive stage*, the declarative encoding of skill occurs. For example the laborious process of first learning how to drive a car and coming to realise the aim of the task and how to do it. The learner sets up goals and encodes them into memory. All instructions to perform a skill are declarative in nature in this stage. The process is often slow, full of errors and taxing on resources as this is the first step in learning any new skill. *Declarative knowledge* is explicit knowledge described as *knowing that* about an event and is processed consciously (Anderson, 2000; Cohen, 2003; Squire, 1986). On the other hand *procedural knowledge* is implicit knowledge regarding how to do things which is described as *knowing how* about an event, and is generally processed unconsciously (Anderson, 2000; Schacter, 1996).

The second stage, known as the *associative stage*, is mainly dominated by two major achievements (Fitts, 1964; Fitts & Posner, 1967). The first achievement involves detection of errors, and their elimination by the learner with practice. Secondly, skill performance becomes reliable and faster, due to the *strengthening* and refinement of skill procedures. Due to progression in the performance of the skill, the *declarative knowledge* is taken over by the *procedural knowledge* (Anderson, 1982, 1989).

In the third stage, known as the *autonomous stage*, the performance of a skill becomes much faster with practice over time and less taxing on the available attentional resources (Fitts, 1964; Fitts & Posner, 1967). The task performance is rapid and automatic in this last stage. Previously acquired *procedural knowledge* can be deployed with high speed and accuracy in the performance of the skill. According to Dennis and Schmidt (2003), at this level a learner is able to reach a stage called *priming,* where a sudden gain in speed of processing a stimulus is the function of its prior exposure. Development of rapid and automatic task performance without conscious control and attention is referred to as *automaticity*.

Automaticity

As a learner approaches the third stage of skill acquisition, the development of *automaticity* in the performance of the skill is achieved. Task performance at this stage is without any conscious control, and becomes effortless and automatic (Anderson, 1993a, 1996, 2000; Logan, 1988, 1990, 1992a, 1998, 2002; Newell & Rosenbloom, 1981; Schneider & Fisk, 1984). Examples of *automaticity* in task performances have been supported by Anderson (2000) with *stroop effect,* where the tendency in naming a printed word interfered with the ability to say the colour of the ink in which the word is printed, and by Shiffrin and Schneider (1977) in their visual search experiments. Shiffrin and Schneider divided the performance of a task into two qualitatively different forms, namely *controlled processing* and *automatic processing.* Shiffrin and Schneider found that *controlled processing* demands resources and conscious control, is slow and full of errors. On the other hand *automatic processing* requires less resources, is fast and accurate. Through practice, *controlled processing* of a novice changes to more efficient *automatic processing* (Anderson, 1993a, 2000; Logan, 1998). In contrast to *automatic processing,* it can be argued that even automatic processes do need resources for processing and they are not totally accessed unconsciously (Besner & Care, 2003; Cheng, 1985; Gopher, Armony & Greensphan, 2000). The three stages of skill development described by Fitts and Posner (1967) contribute to a specific pattern of performance, which is known as the *power law of learning* (Newell & Rosenbloom, 1981).

The Power Law of Learning

With practice, people get faster and more accurate on the task they are performing (Anderson, 2000; Landin, Hebert & Fairweather, 1993; Maring, 1990; Mumford, Costanza, Baughman, Threlfall & Fleishman, 1994; Pirolli & Anderson, 1985; Shute & Gawlick, 1995). That is, whenever a task is practiced, the performance level improves over time (Anderson, 2000; Anderson, Fincham & Douglass, 1999; Newell & Rosenbloom, 1981). The pattern of task improvement of skill acquisition is referred to as the *power law of learning* (see Figure 1). The level of improvement made with additional practice diminishes over time and the pattern follows a mathematical power function. This is represented as $T = X + aP^{-b}$. In this formula T represents time, X represents the asymptotic latency, a represents initial performance time, P represents practice, and b represents rate of learning (generally $0 < b < 1$).

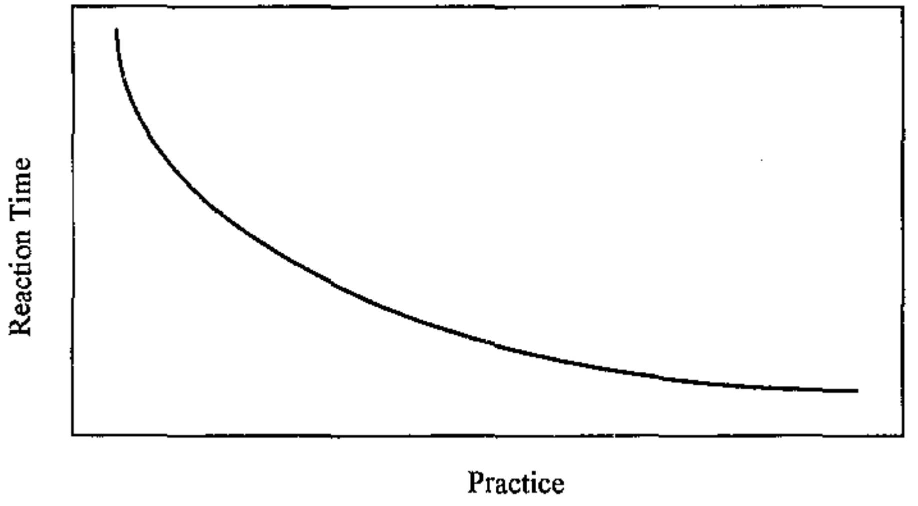

Figure 1. Reaction time in milliseconds for each practice block of the learning curve.

Power function learning has been observed in many skilled behaviours learned over time, for example cigar rolling, sentence repetition, visual search and evaluation of circuits. Therefore, it has been viewed as one of the few fundamental laws in psychology (Anderson, 1993a, 1996, 2000; Anderson, Fincham & Douglass, 1997, 1999; Newell & Rosenbloom, 1981; Speelman & Kirsner, 1997). Recently though, Heathcote, Brown and Mewhort (2000) have suggested that *the power law of learning* is an artefact of the method used to analyse group averaged data to reduce noise in measurement and thus help to reveal general trends.

Skill Acquisition and Transfer

Extrapolations of learning function are used to determine the extent of transfer by comparing the observed and predicted performance for testing hypothesis in the research of skill acquisition and transfer (Logan, 1992b). Transfer of a skill is defined as the performance level of a skill in a new or different situation other than that in which it was acquired (Greig & Speelman, 1999). Hence, skill transfer is assessed on the prediction of improvement of a skill from its initial learning to its performance in a different task. In the current experiment, the pattern of skill acquisition and transfer in the same algebraic task but using different values were compared with a power function to determine the rate of transfer between two phases.

Theories of Skill Acquisition

There are several theories of skill acquisition and transfer (Anderson, 1982, 1983, 1987, 1989, 1993a, 1993b, 1996, 2000; Logan, 1985, 1988, 1990, 1992a, 1992b, 1995, 1998, 2002, 2004; Palmeri, 1997a, 1997b; Rickard, 1997, 1999; Ritter, 1998; Young & Lewis, 1999) that may be utilized to describe the phenomenon of skill development (Anderson, 2000; Anderson & Fincham, 1994; Blessing & Anderson, 1996; Wenger, 1999), whereas there is no single theory which adequately explains the phenomenon of skill acquisition and transfer as a whole. Two prominent theories of skill acquisition and transfer have dominated the literature, firstly a *rule based theory* that argues that performance of a skilled behaviour is governed by item-general knowledge as proposed by Anderson (1982, 1983, 1987, 1989, 1993a, 1993b, 1996, 2000), and secondly an *exemplar based theory* that argues that performance of a skilled behaviour is governed by item-specific knowledge as proposed by Logan (1985, 1988, 1990, 1992a, 1992b, 1995, 1998, 2002, 2004). The prime emphasis of this research was on the abovementioned two theories.

Item-general skills are those that can be applied beyond the specific domain in which they were acquired (Anderson, 1982, 1983, 1987, 1989, 1993a, 1993b, 1996, 2000). To verify whether skills are general or specific, the level of transfer is measured by its performance on a given task (Greig & Speelman, 1999). General skills have been demonstrated in computer programming (Corbett & Anderson, 1992), in human-computer interaction skills (Speelman & Kirsner, 1993), in computer language learning (Lehrer & Littlefield, 1993), in the lexical decision task (Kirsner & Speelman, 1993, 1996), in a task involving syllogistic reasoning (Speelman & Kirsner, 1997), and playing video games (Day, Arthur & Gettman, 2001). Similarly, Williams, Ward, Knowles and Smeeton (2002) reported an example of general skills transfer in their experiment. Their study focused on the measurement, training and transfer of skill in the game of tennis. The study concluded that players who were trained using video simulation and feedback performed better in both laboratory and field tests compared to players who did not receive any video training and feedback. Hence, this study concluded that useful training in general skills could have immense positives in the performance of everyday tasks such as driving and sports.

Item-specific skills are those that can only be applied to the specific task in which they were acquired (Greig & Speelman, 1999). Specific skills have been found by Johnstone, Ashbaugh and Warfield (2002) in superior writing skills within a specific task domain, by Logan and Klapp (1991) in an alphabet arithmetic task, in display tasks by Jenkins and Hoyer (2000), by Doane, Alderton, Sohn and Pellegrino (1996), in visual discrimination skills, and in a word identification task by Masson (1986). An example of specific skills has been illustrated by Rickard and Bourne (1996), who designed two experiments to test the unique combination of operands and the required operation of basic arithmetic skills like multiplication and division. Participants in their experiments were trained on operations of multiplication and division and then were tested by using different values for the same arithmetic tasks. The results of experiment one confirmed that there was no *positive transfer* when the test tasks did not exactly match the practice task. Results of experiment two confirmed that there was complete transfer when the test task matched exactly the practice tasks.

Item-General Theory

The Adaptive Control of Thought (ACT*) Theory, recently modified to the ACT-Rational Theory (Anderson, 1982, 1983, 1987, 1989, 1993a, 1993b, 1996, 2000) is one of the most widely accepted theories of general skill acquisition. Anderson designed his theory around the three stages of skill acquisition proposed by Fitts (1964). The first stage of skill acquisition in the ACT-R Theory is known as the *declarative stage,* which is equivalent to Fitts' (1964) *cognitive stage*, where basic factual information regarding the learning of a new skill by a novice is encoded in a declarative form.

Gradual transition from the first learning stage to the second stage is known as the *knowledge compilation stage,* which is equivalent to Fitts' (1964) *associative stage.* This stage involves gradual conversion of *declarative knowledge* into *procedural knowledge* through practice. *Procedural knowledge* is stored as productions and organized as hierarchical structures in the human memory system

(Anderson, 1982). The ACT-R Theory of skill acquisition proposes that performance of a skill is based on the execution of productions. Productions are defined as *"if-then"* statements, such that when the *"if"* condition is matched with the correct information, a particular *"then"* action is performed (Anderson, 1982, 1989). With continuing practice of a task, the related productions used to perform that task becomes strong, thus improving performance.

The third stage of the ACT-R Theory is called the *procedural stage*, which is equivalent to Fitts' (1964) *autonomous stage* where further learning occurs after the knowledge achieves its procedural form (Anderson, 1982, 1983, 1987). In the ACT-R Theory *automaticity* for a skilled behaviour is achieved through the methods of *compilation* and *strengthening*. *Compilation* of *declarative knowledge* into *procedural knowledge* is further composed of two main processes, *proceduralisation* and *composition*. Gradual conversion of *declarative knowledge* into productions is called *proceduralisation*. At this stage, *proceduralisation* of a skill is not dependent on memory retrieval from its initial *declarative knowledge*.

A learner at this stage maps the solution of the current problem into a past solution taken from successful experiences through a process called *analogy* (Anderson, 1982, 2000). Previous experience can be superseded by a more recent performance into a more refined production, by a process of combining two or more productions into one. The process is known as *composition*. With practice the load imposed by skill performance on the available attentional resources is reduced, because no *declarative knowledge* is retained in working memory and the task is performed automatically. All intermediate steps to reach the end goal are collapsed and the same task is achieved in less steps by the new production (Anderson, 1989, 1996; Speelman & Maybery, 1998). The speed of retrieval of a memory representation is determined by its strength. Anderson (1993b) argued that ACT-R Theory is a basic framework used for the acquisition of problem solving strategies in both novice and familiar situations.

The second method for achieving *automaticity* in the ACT-R Theory is referred to as the *strengthening* process. Anderson (1982, 1983, 1987) argued that *strengthening* is a process of faster application of an appropriate production. Improvement in a skill that follows a *power law of learning* is achieved due to the *strengthening* of individual productions with extensive practice of a task. The speed-up in the performance is related to the level of activation of the memory for a particular production, which affects its retrieval time. Thus, *procedural knowledge* is further gradually refined with continuous practice, which involves *strengthening* of the production rules, leading to faster and more efficient performance.
Anderson argued that each production rule is governed by its unique processing method, which triggers its own specific response from the declarative database for each cognitive behaviour to take place (Anderson, 1982, 1987, 1996). Learning of a skilled behaviour is based on the successful acquisition of the production rule and its application in a specific condition. Anderson argued that human cognition is a sum of the total knowledge stored as *chunks*. For every situation the best-fit chunk is retrieved through the activation process. Thus, Anderson emphasized that performance depends upon the amount of knowledge encoded and the right use of the encoded knowledge.

At times more than one production is applicable to a specific situation. In such an event, competition between productions takes place and the most specific production is applied (Greig & Speelman, 1999). Therefore, ACT-R Theory postulates that practice on a task can result in the development of both item-general and item-specific knowledge (Anderson, 1982, 1983, 2000; Anderson & Reder, 1999a, 1999b). Skill transfer would be specific in situations where the same event is previously encountered but would be general enough in situations where new tasks share some similarities with previously encountered events. Carlson, Sullivan and Schneider (1989) argued that with practice the serial processing of the memory retrieval remains constant, while it is only the individual component processing which speeds up. *Automaticity* in ACT-R Theory leads to qualitative changes in the characteristics of skill acquisition and transfer (Anderson, 1982, 2000).

Transfer and the ACT-R Theory

Anderson (1982, 1993a, 1993b, 2000) found that transfer between two tasks is dependent on the common productions between them. Thus, skill transfer from one task to another is a function of the number of common productions between the two tasks. Transfer of general skills is in response to similar stimuli, whereas specific skills can only be performed in response to a particular stimuli. The extent of transfer of a skill is determined by the extent of *procedural knowledge* shared between the performance of an old task and a new task. If a new task requires a different set of productions from those developed to perform old tasks then the transfer will be limited.

Skill transfer between two tasks can be different depending on the situations. Transfer of a skill would be faster if there was a task similarity between the training and transfer tasks (Eyring, Johnson & Francis, 1993). *Positive transfer* can be defined as a gain in the performance of a second task due to experience in the first task (Anderson, 2000). An example of the *positive transfer* was illustrated by Anderson and Fincham (1994). They conducted three experiments on computers to determine the extent of the relationship between *declarative* and *procedural knowledge*. The experiment was divided into phases. Participants were presented with strings of characters on the computer screen and were asked to memorize them. Later the participants were asked to recall the digit strings as they occurred based on the original examples. In the initial recall stage Anderson and Fincham found that participants used precise examples, but with practice they recalled without any references to the examples. Participants followed the *power law of learning* in recalling the original examples but lacked the same processing method. The study concluded that there was *positive transfer* in the recall procedure, however with more practice the effect diminished over days.

Anderson (2000) described a reduction in the performance level of an acquired skill in a subsequent task as *negative transfer*. The best example of *negative transfer* described by Luchins (as cited in Anderson, 2000) in his research is that of the *einstellung effect* where participants repeat a solution to a given task based on previous successful experiences, even when a simpler solution to the given task is possible. Finally, if performance of a given task does not have any common overlapping productions with the performance of a preceding task, Anderson's (1982) ACT-R Theory states that there will be *zero transfer* between the two. Transfer of a skill can be influenced due to the difficulty of initial learning and the methods acquired during learning, which are applied at transfer regardless of their success for processing transfer conditions (Doane, Sohn & Schreiber, 1999; Woltz, Bell, Kyllonen & Gardner, 1996).

In summary, item-general theories of skill acquisition proposes that transfer between two tasks is the function of common features shared between the tasks. The significance of the task performance should be common to the degree that both tasks should share the same processing methods (Greig & Speelman, 1999). For the processing of item-specific information and the underlying assumptions of sharing the same processing methods for the same tasks, the performance level should be equal, regardless of the nature of the events themselves.

Item-Specific Theory

The second most popular theory of skill acquisition and transfer, which has also attracted considerable attention in the literature, is Gordon Logan's Instance Theory (Logan, 1985, 1988, 1990, 1992a, 1992b, 1995, 1998, 2002, 2004), recently modified to the Instance Theory of Attention and Memory (ITAM). Instance Theory has three underlying assumptions. The first assumption is the *obligatory encoding assumption*, that encoding of information is a result of unavoidable attention provided to each stimulus at the time of task performance. Each stimulus is encoded into memory along with the responses it evoked and the achieved results. The second assumption is the *obligatory retrieval assumption*, which assumes that recall of an encoded stimulus from the stored memory base is essential. The third assumption is the *instance representation assumption*, which is the assumption that each individual episode is encoded and stored separately as an instance in memory. Many instances are encoded and stored due to extensive practice of a task, and these are later recalled to influence further execution of the task.

Logan (1988, 1990, 1992, 2002, 2004) claimed skill transfer to be item-specific and mainly the result of increased episodic memory. Logan argued that performance of a skill could be automatic and fast only if an instance of the acquired skill can be retrieved. Instances are representations of specific responses to particular stimuli that are stored in episodic memory for later retrieval. According to Logan's (1988) Instance Theory, skilled behaviour is item-specific and no transfer of skill can occur if items are changed. If retrieval of the acquired skill is based on a specific response to a specific stimulus then the performance of the skill is considered item-specific in nature. Thus, Logan's Instance Theory is considered to be item-specific.

Transfer and the Instance Theory

According to Logan (1988, 1990, 1992, 2002, 2004) the initial performance of a task is controlled by the execution of an algorithm. Each time an algorithm is executed successfully, the episode is encoded and then stored separately as an instance in memory. More and more instances are stored as a result of continuous practice. Task performance at this level is the result of competition between memory retrieval of matching instances on the one hand, and algorithmic processing on the other. Over practice, the speed of execution of an algorithm remains constant while instance retrieval becomes faster as the probability of retrieving an instance to match with a particular task situation increases. With extensive practice, instances are retrieved directly from memory without any reduction in the attentional resources leading to automatic performance of the task.

It is argued that during initial learning the role of attention is vital for skill automatization (Logan & Etherton, 1994; Logan, Taylor & Etherton, 1996, 1999). However, once a skill is learned with extensive practice, instances are retrieved directly from memory without any demand on attentional resources, leading to automatic performance of the task. Logan's (1988, 1990, 1992, 2002) experiments demonstrated that task speed-up followed the pattern of the *power law of learning*. For example Logan (1998) conducted six experiments using one or two word displays for item categories. His participants were trained on item appearances on the same locations in training, and the locations were changed for training tasks. The results supported the hypothesis that participants encoded the individual locations of each word during automatization, which confirmed Logan's previous studies on Instance

Theory (Logan, 1988, 1990). Most of the research done by Logan involved the use of arithmetic problems, whereas, on the other hand it is argued that the natural order of events controls the acquisition and use of mental operators in the research involving arithmetic problems (Muller, 1999; Muller & Gehrke, 2004).

Logan's (1988) Instance Theory is based on the accumulation of experiences, whereas on the other hand Anderson's (1982) ACT-R Theory claims that with practice, the refinement and *strengthening* of *procedural knowledge* leads to automatic performance and hence the transfer of a skill to a related task (Anderson, 1993a, 1996). Logan claimed that transfer of a skill would only occur between identical tasks, as Instance Theory only accounts for item-specific transfer. Therefore, Instance Theory represents skill acquisition and transfer as a quantitative process, reflecting the acquisition of increasing numbers of item-specific instances in memory.

Logan's (1988) notion of item-specific transfer was contradicted by the research of Kirsner and Speelman (1996) and Speelman and Kirsner (1997). They argued that transfer of a skill is determined by the requirement of different task conditions and the nature of the skill performed. In their research they found that performance of an acquired skill is not fixed from one domain to another, but rather it is dependent on the environment in which it is performed.

In summary, item-specific theories of skill acquisition proposes that transfer between two tasks is the function of previously encountered individual examples. There is no learning of item-general skills. Learning experiences from one type of task will not assist performance of another type of task, hence no transfer of skill can occur if items are changed (Greig & Speelman, 1999).

A Challenge to Skill Acquisition and Transfer Theories

Greig and Speelman (1999) and Speelman (1999) conducted research challenging the underlying assumptions of the general and specific theories suggested by the ACT-R Theory (Anderson, 1982, 1993a) and Logan's Instance Theory (1998). The study conducted by Greig and Speelman (1999) involved participants solving a simple algebraic equation $(x^2 + 2y) = A$, by substituting different values for x and y. This experiment was divided into two phases, training and transfer. The participants were trained on several blocks of trials in the training phase with one set of x and y values. In the transfer phase, participants evaluated the same algebraic equation with a different set of x and y values.

The results from Greig and Speelman's (1999) study indicated that the performance of the participants was significantly slower in the first block of the transfer phase compared to the final block of the training phase. However, performance in the first block of the transfer phase was significantly faster than the first block of the training phase. The acquired training offered some benefit to the participants for the performance of the task in the transfer phase. However, the transfer of the acquired skill between the two phases was not complete. In complete transfer, everything that is learned in training is used to perform similar but different tasks in the transfer phase. The skills acquired in training were general enough to perform the task with the change in items, thus the acquired skills were to some degree item-general in nature. The initial performance on the first transfer block was slower than the last training block, hence the acquired skill was also to some degree item-specific. Participants' initial transfer performance in the task was better than the initial training performance, therefore *positive partial transfer* was observed. Thus the findings were supported by Anderson's (1982) ACT-R Theory. However, the results of this study cannot be accounted for in Logan's (1988) Instance Theory, which predicts that acquired skills are item-specific in nature. Therefore, it predicts zero transfer of the acquired skill from one task to the other if the second task involves entirely new stimuli.

Another experiment conducted by Speelman (1999) challenged both general as well as specific skill acquisition theories. Skill transfer in this experiment could not be explained using Anderson's (1993a) ACT-R Theory or Logan's (1998) Instance Theory. In this experiment participants solved a simple algebraic equation $(x^2 - y)/2 = A$, in both the training and transfer phases. In the transfer phase half the items were repeated from the training phase and the other half were replaced by new items (see Appendix A). Forty blocks of eight trials were presented in both the training and transfer phases. Figure 2 shows the mean reaction time in milliseconds for all the conditions.

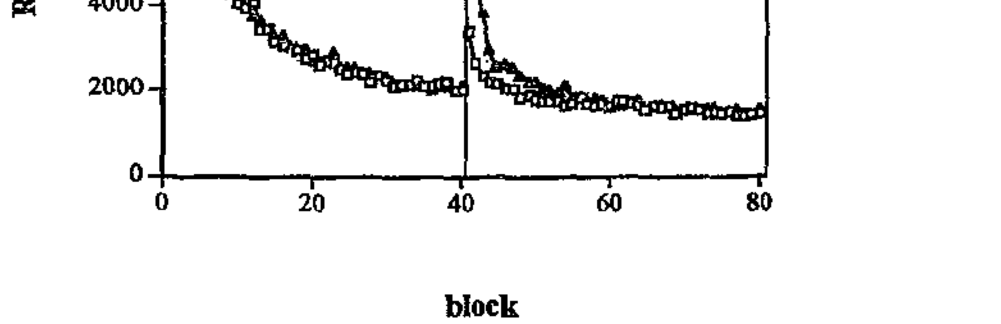

Figure 2. Mean reaction times in milliseconds of the skill acquired in a simple algebraic task in an experiment conducted by Speelman (1999).

The results of Speelman's (1999) study demonstrated that the participants were able to perform better initially in the transfer phase compared to the initial performance in the training phase, for both old and new items. Therefore, some degree of the acquired skill was transferred from the training phase for both the old and new items. However, the performance of the task using old items was better initially than the performance of the task using new items in the transfer phase. That is, the performance on old items was slower in the first block of the transfer phase compared to the last block of the training phase. Partial transfer of skills suggests some general skills were learned during training which helped performance in the transfer phase with a new but similar set of stimuli. This result of partial transfer was not predicted by either of the Anderson's (1982) ACT-R Theory or Logan's (1988) Instance Theory.

In a similar study Speelman and Kirsner (2001) tested the underlying assumption regarding the performance of old skills in new tasks. They designed a series of three experiments to test the proposition that when old skills are performed in the context of new tasks, performance continues to improve as predicted by a power function. Twenty-four first year psychology students were used as participants in this study. Participants were randomly allocated into control and experimental groups. The study involved a fictional water analysis procedure where participants executed simple calculations on a computer on each trial, in a fixed serial order in the training and transfer phases. The results of the study indicated that a change in task could affect the performance of old skills in new tasks. That is, improvements in the performance of earlier acquired skills were disrupted by performance of a new task. Moreover, the disruption effect improved with an increase in the complexity of the new task from three calculations per trial to five.

The Speelman and Kirsner (2001) study concluded that the disruption in the performance of old skills in the presence of new tasks was related to a *performance overhead* associated with *reconceptualising* the whole task. *Performance overheads* were referred to as any extra burden or stress associated with the change of task complexity. *Reconceptualising* was referred to as complete re-assessment of the old skill in the presence of new tasks. The disruption in Speelman and Kirsner's experiment is closely related to the *proactive interference* phenomena, which states that an individual's performance can be reduced due to the difficulty they encounter in memory retrieval when past experiences interfere with recent learning (Goggin & Wickens, 1971; Wickens, 1972). The most typical example discussed in the literature is when an individual experiences difficulty in remembering a new telephone number, due to the interference from an old known telephone number.

One other explanation for Speelman and Kirsner's (2001) disruption in the performance of old skills may be related to Pashler, Johnson and Ruthruff's (2001) phenomenon of *inhibition,* which can reduce the performance level of a skill at transfer due to the interference from the processing of another operation at the time of memory retrieval for a particular event. They argued that at one given time only one operation of memory retrieval could take place while all other operations have to wait in a queue to be called for processing at a later time. This waiting time for processing is referred as the *psychological refractory period* (Horstmann, 2003; Lien & Ruthruff, 2004; Lien, Schweickert & Proctor, 2003; Van Selst, Ruthruff & Johnston, 1999). Horstmann's (2003) findings may suggest that initiation for a new environment in the transfer phase of the current experiment constituted a *psychological refractory period.*

The results of Speelman's (1999) and Speelman and Kirsner's (2001) study challenge some of the basic assumptions of Anderson's (1993a) ACT-R Theory and

Logan's (1998) Instance Theory of skill acquisition and transfer. According to Anderson's (1982) ACT-R Theory, the performance of an acquired skill using old items should continue with the same level of performance on the learning curve in the transfer phase, as there is no change in the task, and no change in the productions required. Logan's (1988) Instance Theory also would predict a complete transfer of a skill for old items, due to the availability of previous episodic memory traces. Both theories would predict a complete transfer as all old items have been practiced before. The prediction of no initial increase of reaction time for old items in the transfer phase is not supported by the results. Therefore, the findings of these studies cannot be accounted for by either Anderson's (1982) ACT-R Theory or the Logan's (1998) Instance Theory.

Rationale for the Current Study

The findings of Speelman's (1999) and Speelman and Kirsner's (2001) studies can be explained neither by Anderson's (1982) ACT-R Theory nor by Logan's (1988) Instance Theory. An alternative explanation of the results of these experiments is that the participants used the set of all previous experiences acquired during the training phase along with the contextual change clues, to execute the same algebraic task in the transfer phase with old items. Anderson's (1996) ACT-R Theory and Logan's (1998) Instance Theory would predict that the performance level of old skills should continue to be the same between the two phases as nothing has been changed in respect to the structure of old items.

As soon as the participants enter into the transfer phase of the experiment, they encounter new items they have not seen before. Contrary to the two major theories of skill acquisition, the addition of these new items impacted on all items including the old items seen before in the training phase. Participants did not acquire the skill just to do each item individually in the transfer phase. Rather, the performance in the transfer phase was dependent on the sets of all trials previously performed in the training phase. The studies concluded that skill acquisition and transfer is highly context-specific. In Speelman's (1999) experiment the context was altered to a large extent by changing half the items, whereas in the current experiment only one or two items are changed to investigate the possibility that varying the extent of change in context affects the level of skill transfer for old items carried over from the training phase.

The hypothesis of Speelman's (1999) experiment that performance of old items will be affected by a change in environment is further tested in this current experiment. Speelman's findings provide further avenues of research into the factors affecting the use of acquired skills in a new task environment. An important question to be answered here is whether the extent to which an acquired skill can be transferred depends on the task environment (in particular the number of new items presented along with the old items on which transfer is assessed), or whether it is independent of that environment. In the current experiment, the pattern of skill acquisition and transfer in the same algebraic task but using different values were compared with a power function to determine the amount of transfer between two phases.

The purpose of the current experiment was to investigate how many new items are required to produce a, *positive partial transfer* effect and whether the transfer effect can be produced with a smaller set of new items than Speelman's (1999) study. The current study is similar to Speelman's (1999) study. In this experiment the participants evaluated a simple algebraic equation, $(x^2 - y)/2 = A$, and responded whether the answer was odd or even in both the phases. In the transfer phase of Speelman's (1999) experiment, there were four new values for x and y in the set of eight trials, whereas in the current experiment there are either one or two new items in the eight trials, with only the values of y being new. Reaction time to the different blocks of trials will be recorded. It is hypothesized that, as more items are changed in the task, the transfer of the previously acquired skill will decrease.

Method

Participants

The participants consisted of 40 undergraduate psychology students of Edith Cowan University, randomly assigned to two experimental groups, with 20 participants per group. Participation in the current experiment was on a voluntary basis, selected from the school of psychology's research participation register. However, written consent was obtained from the participants before the commencement of the experiment. A ticket for a raffle draw with a $50 prize, and a participation certificate were presented to all participants for their participation in the experiment. In the sample were 16 males and 24 females. The education level of participants ranged between completion of high school and tertiary qualifications. The age range was 18 to 56 years, with a mean age of 26 years. All participants had a basic knowledge of algebra.

Research Design

The current study involved a mixed design with two independent variables: group and practice. The between-subjects factor involved participants being assigned to one of the two groups. These two groups undertook identical training but different versions of the transfer phase. The two versions differed in the number of new items presented in each block of trials, either one or two. Participants practiced the task in blocks of eight trials in both the training and transfer phases. Each block was repeated 40 times in each phase.

Measures

The dependent variables were the reaction time (RT) for correct trials measured in milliseconds and accuracy. RT was defined as the time taken by the participants to press the appropriate key on the computer keyboard following the presentation of an item. The overall accuracy rate was assessed as the number of correct trials performed within the 40 blocks of each phase, and was measured in percentage. Only the participants whose accuracy rate was above 80% were considered for data analysis. The accuracy rate in the transfer phase was assessed for old trials only.

Apparatus and Materials

Superlab Pro software (Version 1.74) was used on a standard Apple Macintosh G3 computer to run the experiment and collect the data. RTs in milliseconds were recorded on the computer from the responses made on the computer's keyboard. Data recorded by Superlab Pro were further analysed using Microsoft Excel (Version XP). The statistical analyses were conducted using SPSS (Version 11.5). The algebraic equation $(x^2 - y)/2 = A$, used in the current experiment was adapted from Greig and Speelman (1999). In the transfer phase, for Group 1 each block of eight trials included 1 new item, whereas for Group 2 each block included 2 new items. The values of x and y used in Groups 1 and 2 of the current experiment along with the correct responses are presented in Tables 1 and 2.

Table 1

Values for x and y, in the Equation $(x^2 - y)/2 = A$, and the Correct Response in Training and Transfer Phases for Group 1

Training				Transfer			
Group 1 (1 New Item)							
x	*y*	*A*	Response	*x*	*y*	*A*	Response
5	7	9	Odd	5	15	5	Odd
5	11	7	Odd	5	11	7	Odd
5	13	6	Even	5	13	6	Even
5	17	4	Even	5	17	4	Even
6	10	13	Odd	6	10	13	Odd
6	12	12	Even	6	12	12	Even
6	14	11	Odd	6	14	11	Odd
6	16	10	Even	6	16	10	Even

Table 2

Values for x and y, in the Equation $(x^2 - y)/2 = A$, and the Correct Response in Training and Transfer Phases for Group 2

Training				Transfer			
Group 2 (2 New Items)							
x	*y*	*A*	Response	*x*	*y*	*A*	Response
5	7	9	Odd	5	9	8	Even
5	11	7	Odd	5	11	7	Odd
5	13	6	Even	5	13	6	Even
5	17	4	Even	5	15	5	Odd
6	10	13	Odd	6	10	13	Odd
6	12	12	Even	6	12	12	Even
6	14	11	Odd	6	14	11	Odd
6	16	10	Even	6	16	10	Even

Procedure

The participants were instructed briefly about the experiment and then requested to read and complete an information sheet (Appendix B) and consent form (Appendix C). Participants were then randomly allocated to one of the two groups. Participants were requested to sit in front of a computer in an isolated laboratory and were given instructions on the computer screen, which outlined the experimental procedure (see Appendix D). Each participant was tested individually. Once the experimenter ensured that all participants understood the instructions, the participants commenced eight practice trials by pressing the space bar. Participants were instructed to respond as quickly and accurately as they could.

After the completion of eight practice trials, the experimenter left the computer room and instructed each participant to start the experiment by pressing the space bar. In all trials participants were required to solve the simple algebraic expression $(x^2 - y)/2 = A$, for different values of x and y and determine whether the solution was an odd or even number. Each trial was presented individually in the centre of the computer screen. Each participant was required to press the 'z' key labelled as "odd" for odd responses and press the '/' key labelled as "even" for even responses on the computer's keyboard. To maintain the interest of the participant in the experiment, feedback regarding the correctness of the response was provided immediately on the computer screen after each trial. The feedback message also included a prompt to press the space bar to continue on to the next trial. The presentation order of trials within a block was random. Three hundred and twenty trials were presented in the training phase before the commencement of the transfer phase.

Participants were required to complete the training phase and one version of the transfer phase. There was no time gap between the training and transfer phases except the usual space bar press that separated trials. Three hundred and twenty trials were presented in the transfer phase. The duration of the experiment was typically around 50 minutes. The experimental aims were not disclosed to any participant before the completion of this experiment. On completion of the transfer phase, participants were debriefed and any questions answered. Participants were then thanked for their participation, and were provided with a ticket for the raffle draw along with the participation certificate.

Results

Data consisted of RT in milliseconds and accuracy rate in percentage. Mean RT was calculated for each block for each participant and these means were then used as the unit for data analysis, whereas percentage correct was calculated for each participant over the 40 blocks in each phase. Mean accuracy of performance in the training phase was assessed for each participant with respect to the learning criterion. The cut off score for accuracy was 80%, which is well above chance level of 50%. The accuracy rate for each of the 40 participants was above 80%. The mean accuracy for Group 1 was 93.91%, whereas the mean accuracy rate for Group 2 was 92.54% (see Appendix E). Only correct responses were used in calculating the mean RT within each block. All the collected data were analysed with an alpha level of .05.

A 2 (group) by 40 (training block) split plot analysis of variance (SPANOVA) was conducted on the mean RTs of the training phase. The assumption of sphericity for the SPANOVA was not violated. There was a significant main effect for block, $F(39, 1482) = 154.73, p < .001$, eta squared = .80. That is, with practice both groups improved over time. There was no significant main effect for group, $F(1, 38) = 1.51$, $p > .05$, eta squared = .04, and the interaction between group and block was not significant, $F(39, 1482) = .39, p > .05$, eta squared = .01. There were no significant effects of group in the training phase since the two groups completed identical items in this phase. Mean RTs during the training phase are presented in Figure 3. Descriptive statistics are presented in Appendix F.

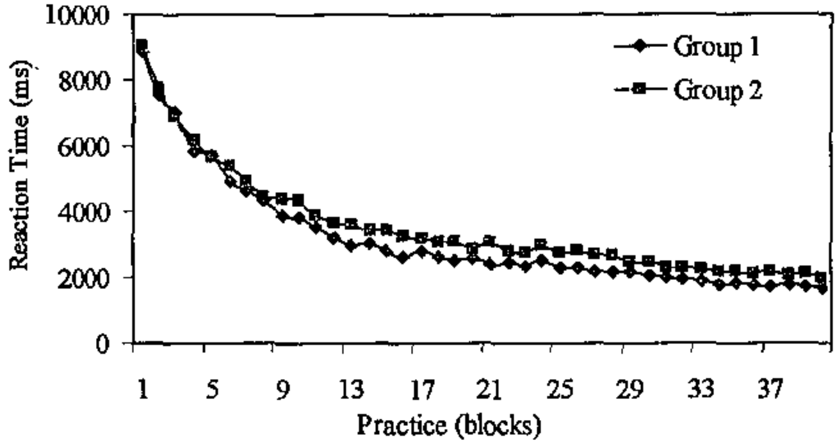

Figure 3. Mean reaction time in milliseconds for each block in the training phase.

To determine the effect of transfer condition on performance on old items during the transfer phase, a 2 (group) by 40 (transfer block) SPANOVA was conducted on the mean RTs of the transfer phase. In each block of eight trials in this phase, Group 1 was presented with 7 old items and 1 new item, and Group 2 was presented with 6 old items and 2 new items. Only correct RTs on old items for both groups were analysed. The assumption of sphericity for the SPANOVA was not violated.

There was a significant main effect for block, $F(39, 1482) = 82.21, p < .001$, eta squared = .68. That is, with practice both groups improved over time. There was a significant main effect for group, $F(1, 38) = 7.29, p < .05$, eta squared = .61. The group effect was such that Group 2 was slower than Group 1. The interaction between group and block was significant, $F(39, 1482) = 11.66, p < .001$, eta squared = .24. There was more of an elevation in RT for Group 2 than for Group 1 at the start of the transfer phase. This difference between the groups then narrowed with further practice. Mean RTs during the transfer phase are presented in Figure 4. Descriptive statistics are presented in Appendix G.

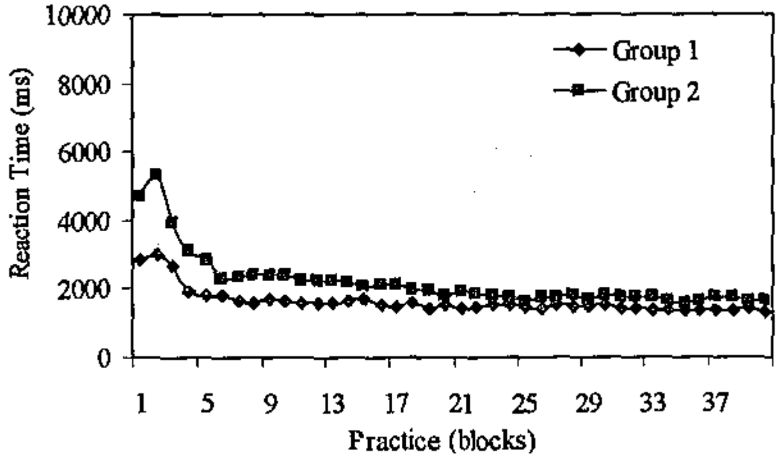

Figure 4. Mean reaction time in milliseconds for each block in the transfer phase.

To reveal the effect of the new items introduced in the transfer phase, the last block of the training phase was compared with the first block of the transfer phase in a further analysis of the RTs for old items. A 2 (group) by 2 (block) SPANOVA was conducted on the mean RTs of the last block of the training phase and the first block of the transfer phase. The assumption of sphericity for the SPANOVA was not violated.

There was a significant main effect for block, $F(1, 38) = 198.49, p < .001$, eta squared = .84. Both groups were slowed in the first block of the transfer phase compared to the last block of the training phase. There was a significant main effect for group, $F(1, 38) = 19.77, p < .001$, eta squared = .34. The group effect was such that Group 2 was slower than Group 1 when the novel items were introduced in the first block of the transfer phase, and hence an interaction was also observed, $F(1, 38) = 34.92, p < .001$, eta squared = .48. Mean RTs during the last block of the training phase and the first block of the transfer phase are presented in Figure 5. Descriptive statistics are presented in Appendix H.

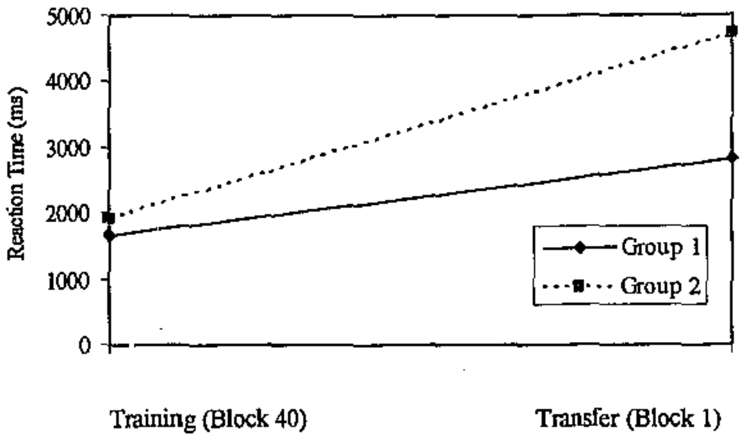

Figure 5. Mean reaction time in milliseconds for the last training block and the first transfer block.

To determine the extent of skill transfer between the training and transfer phases, the first block of training was compared with the first block of the transfer phase. A 2 (group) by 2 (block) SPANOVA was conducted on the mean RTs of the first block of the training phase and the first block of the transfer phase. The assumption of sphericity for the SPANOVA was not violated.

There was a significant main effect for block, $F(1, 38) = 252.62, p < .001$, eta squared = .87. With practice both groups improved over time. There was a significant main effect for group, $F(1, 38) = 5.58, p < .05$, eta squared = .13. No significant difference was observed between groups at the beginning of the training phase, but Group 2 was slower than Group 1 when the novel items were introduced in the first block of the transfer phase, and hence an interaction was also observed, $F(1, 38) = 7.15, p < .05$, eta squared = .16. Mean RTs during the first block of the training phase and the first block of the transfer phase are presented in Figure 6. Descriptive statistics are presented in Appendix I.

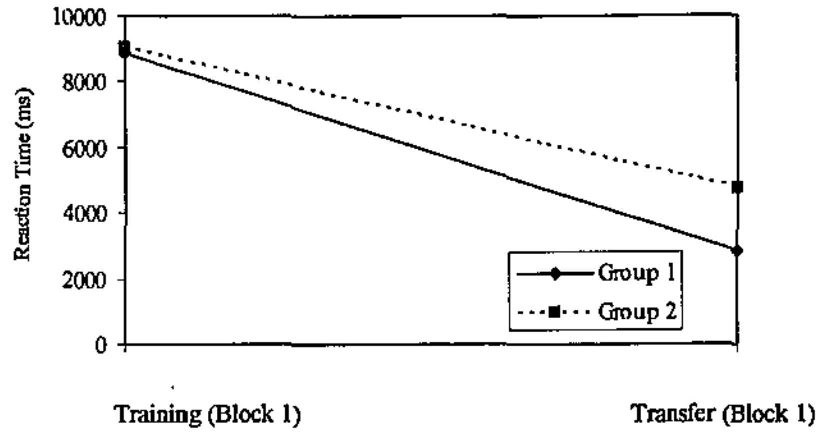

Figure 6. Mean reaction time in milliseconds for the first training block and the first transfer block.

To further investigate whether there were any significant differences involving Blocks 1 and 2 of the transfer phase (see Figures 3 & 7), a 2 (group) by 2 (block) SPANOVA was conducted on the mean RTs from these two blocks. The assumption of sphericity for the SPANOVA was not violated.

There was a significant main effect for block, $F(1, 38) = 5.22, p < .05$, eta squared = .12. Both groups slowed in the performance of the second block of the transfer phase. There was also a significant main effect for group, $F(1, 38) = 91.66$, $p < .001$, eta squared = .71. Moreover, the performance of both groups slowed down together with the introduction of novel items over time and hence no interaction was observed, $F(1, 38) = 1.36, p > .05$, eta squared = .04. Mean RTs during the first block of the transfer phase and the second block of the transfer phase are presented in Figure 7. Descriptive statistics are presented in Appendix J.

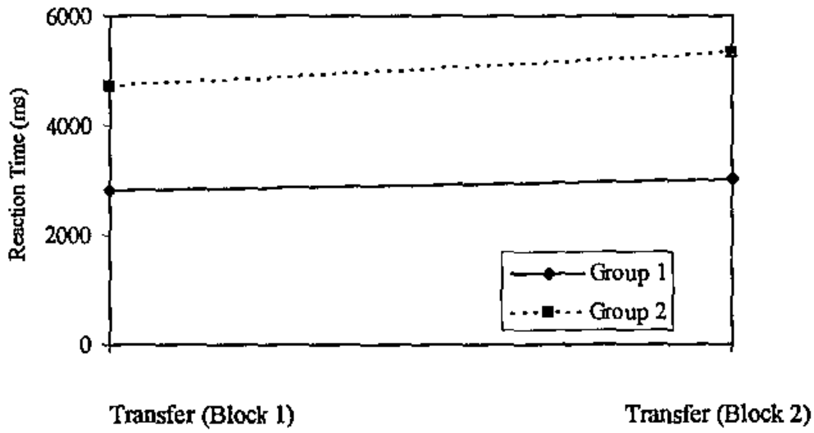

Figure 7. Mean reaction time in milliseconds for the first and the second transfer blocks.

Three simple effects were conducted to compare the two groups at three points in practice, the last block of training, and Blocks 1 and 2 of the transfer phase. The assumption of homogeneity of variance was not violated for any of these tests. There was no significant simple effect for the last block of the training phase, $t(38) = 1.00$, $p > .05$. There was a significant simple effect for the first block of the transfer phase, $t(38) = 6.10$, $p < .001$, and also a significant simple effect for the second block of the transfer phase, $t(38) = 9.58$, $p < .001$. That is, the group differences were present for Blocks 1 and 2 of the transfer phase, but not for Block 40 of the training phase.

Discussion

This study investigated the extent to which an acquired skill can be transferred to another context. In particular, the current experiment investigated how many new items were required to produce a *positive partial transfer* effect. It also considered whether the transfer effect could be produced with a smaller set of new items than Speelman's (1999) study. The results clearly supported the above hypothesis that a small change in context leads to a smaller transfer effect, and further supported Speelman's (1999) findings that a larger change in context leads to a larger transfer effect. In the current experiment the effect size was a function of change in the context of an acquired skill. The results have also confirmed Greig and Speelman's (1999) findings, and Speelman and Kirsner's (2001) findings that a change in task could affect the performance of old skills in new tasks. That is, improvements in the performance of earlier acquired skills were disrupted by performance of a new task. Moreover, the disruption effect increased with increase in the complexity of a new task from one new item to two new items.

Phenomena at the Training Phase

In the training phase the performance of both groups improved over time and followed the pattern similar to the *power law of learning*. As there was no significant difference in the training phase between groups, the performance level of both groups was consistent and concurrent with practice throughout the training phase. Therefore, the performance level by both groups in the training phase was consistent with Anderson's (1982) ACT-R Theory and Logan's (1988) Instance Theory.

According to ACT-R Theory (Anderson, 1982, 1983, 1987, 1989, 1993a, 1993b, 1996, 2000), initial practice of the algebraic equation $(x^2 - y)/2 = A$, started with the processing of *declarative knowledge* and this was evident from high RT levels at the time of commencement of the training phase. Due to progression in the performance of the skill, the *declarative knowledge* was taken over by the *procedural knowledge*. *Automaticity* for a skilled behaviour was achieved through the methods of *compilation* and *strengthening* of the productions. *Compilation* of *declarative knowledge* into *procedural knowledge* was further composed of two main processes, *proceduralisation* and *composition*. Gradual conversion of *declarative knowledge* into productions took place called *proceduralisation*. At this stage *proceduralisation* of the algebraic equation $(x^2 - y)/2 = A$, was not dependent on references from its initial *declarative knowledge*. *Analogy* to the previous experience was item-general in nature and could be applied to any value of x and y in the equation. But with extensive practice the item-general values of x and y superseded the most recent performance into more refined item-specific knowledge by a process known as *composition*.

According to Logan's (1985, 1988, 1990, 1992a, 1992b, 1995, 1998, 2002, 2004) Instance Theory, each episode of the algebraic equation $(x^2 - y)/2 = A$, along with x and y values, was moderated by an algorithmic processing and resulted into separate instances. Through successful execution of the algebraic equation the solution to item-specific values of x and y were encoded into memory for later retrieval. As the number of instances for the values of x and y increased with practice, a race developed between algorithmic processing and instance retrieval, with the winner of the race moderating the execution of the solution. With continuous practice more successful instances were stored into memory. Gradually the direct retrieval of instances from memory took over algorithmic processing leading to speed-up of the performance. Thus performance improvement developed from the representation and retrieval of entire problem instances that had been extensively practiced. Participants could have acquired instance representations of each trial separately during training.

This form of skilled performance described by Logan (1988) accounted for skill acquisition of item-specific knowledge that resulted from repeated exposures to particular stimuli.

Phenomena at the Transfer Phase

An analysis of the transfer phase data revealed that there was a significant difference between the groups in the first block of the transfer phase. The group with two new items performed slower than the group with one new item and the performance level for Group 2 improved more than Group 1 with practice throughout the transfer phase, hence a significant interaction was observed. A further analysis was conducted on the RT of both groups for the first and the second transfer blocks and revealed that both groups were significantly slower at responding in the second transfer block than they were in the first transfer block. That is, the performance level at Block 2 of the transfer phase shows an even greater difference compared to Block 1, which is understandable given that performance on old items in Block 1 would only be affected after at least one of the new items was encountered.

A further analysis of the last block of training with the first block of transfer revealed that there was a significant difference, which can be attributed to initial disruption in performance level. That is, with practice both groups slowed over time in the first block of the transfer phase than compared to the last block of the training phase. An analysis of the data for both the groups in the first block of the training phase at the starting of practice and the first block of the transfer phase confirmed that there was significant *positive partial transfer* of skill between both the phases. The improvement in the performance level of both groups in the training phase of the current study is attributed to the extensive practice. Participants got faster and more accurate on the performance of the algebraic task with the acquisition of both general and specific skills.

Initially in the training phase, participants used item-general skills to perform the algebraic equation. Participants in both groups were able to perform the transfer task faster than the initial performance of the training task, which revealed that the acquisition of skill during the training phase did help to some extent in performing the transfer task. This change in the performance level was observed regardless of change in the items from the training phase to the transfer phase. Therefore, the performance level of participants for both groups can be attributed to item-general skills.

With speed-up in the performance both groups developed item-specific skills in the current study, which were attributed to the repeated exposure to specific stimuli. The acquired skills were item-specific in nature, due to the fact that the initial performance in the transfer task was slower than the final performance level in the last block of training phase. Change in item structure contributed to the disruption in the performance of already acquired specific skills from the training phase. The performance level was analysed only on the old items, which were acquired individually as instances according to Logan's (1988) Instance Theory.

The current study confirmed the findings of Speelman (1999) and Speelman and Kirsner (2001). The *positive partial transfer* effect has also been illustrated in alphabet-arithmetic tasks (Greig & Speelman, 1999), and in tasks involving syllogistic reasoning (Speelman & Kirsner, 1997). The findings of the current study, along with findings of the Speelman's (1999) and Speelman and Kirsner's (2001) studies can be explained neither by Anderson's (1982) ACT-R Theory nor by Logan's (1988) Instance Theory.

According to Anderson's (1982) ACT-R Theory the performance level of old skills should continue to be the same in the transfer phase as predicted by the *power law of learning*. A sudden change of the context in which the old skills were performed induced disruption in the performance level. The item-specific productions used for the solution to the algebraic equation $(x^2 - y)/2 = A$, that were acquired in the training phase, failed to perform at the same level. The use of item-general productions can be accounted for if there were introduction of new items, and the performance on new items were considered. Whereas, nothing has been changed in respect to the structure of *x* and *y* for old skills, and the performance of only old items were considered, therefore the use of item-general skills does not arise at all.

As soon as the participants entered into the transfer phase, they encountered new items they had not seen before, which caused *proactive interference* in the performance of the task, resulting in a time delay as a *performance overhead* (Goggin & Wickens, 1971; Speelman & Kirsner, 2001; Wickens, 972). For the successful execution of the same task the participants of both groups *reconceptualised* the whole task in the presence of changed environment (Speelman & Kirsner, 2001). The extra waiting time caused due to the delay in processing may be contributed to the *psychological refractory period* leading to the disruption in the performance of the task (Horstmann, 2003; Lien & Ruthruff, 2004; Lien, Schweickert & Proctor, 2003; Van Selst, Ruthruff & Johnston, 1999). Under the given circumstances to perform the same old task participants have to completely re-assess the old task in the presence of new situations. Thus, the performance level reduced between the phases as it was not a complete transfer. Therefore, Anderson's (1996) ACT-R Theory was unable to account for the results of this study.

On the other hand Logan's (1998) Instance Theory would predict that the performance level of old skills should continue to be the same between the two phases as nothing had been changed in respect to the structure of old items. Each time a new item value for *x* and *y* was presented, the performance level was dependent on the race between the execution of algorithm, and the memory retrieval of the specific instance and the winner moderating the performance level. With extensive practice, each specific value of *x* and *y* was repeated in the training phase, hence the performance level was moderated by the retrieval of a particular instance from memory. When the participants entered into the transfer phase the addition of new items affected the performance of old items. Whereas according to Logan's (1998) Instance Theory, the performance level should continue at the same level for old items. However, the *positive partial transfer* effect observed in the current study indicated that the transfer was affected and not complete. Hence, even Logan's (1988) Instance Theory is unable to account for the results of the current study.

According to Greig and Speelman (1999) through a personal communication, Logan recommended a modification to his Instance Theory to account for the *positive partial transfer* effect. That is, the performance level in new situations is moderated by a change in general algorithm with practice, which may lead to the acquisition of some item-general skills. However, this modification in Logan's Instance Theory completely changes the bases of purely item-specific theory and makes it similar to Anderson's (1982).

Theoretical Implications

The results of the current study have several implications for theories of cognitive skill. First, the present data pose a challenge to Anderson's (1982) ACT-R Theory and Logan's (1988) Instance Theory of skill acquisition. Second, these results point to the need for more detailed theory of skill acquisition specifying aspects of disruption caused due to the performance of old skills in the presence of new tasks. Third, prediction of a skill improvement only based on the *power law of learning* cannot be absolute. Therefore, any disruption caused should be taken into consideration. Fourth, the current study may help to better understand the effects of changes to specific task requirements in different practical learning methods and may theoretically inform training programs that are designed to develop transferable skills.

The research findings of the current study is based on a controlled laboratory experiment however the findings may be generalized distantly to real life training programs, for example driving and sports, as discussed in the current literature with the game of tennis and video games. Based on the evidence provided by the findings it could be concluded that any form of training provided to humans cannot be guaranteed to achieve the same results in different environments. That is, the performance of a skill is directly related to the context in which it is performed.

It could be suggested that the results of the current study may be compared to many real-life scenarios, such as the performance of any sporting team in its home country being better than its performance in any foreign country, due to the main reason that the home team is trained to play well in their home environment. That is, with changes in the environment and the crowd, the performance of any sporting team reduces in a foreign land. One of the other implications of the current study may be exploring the possibilities by extending the research findings in developing therapies for patients suffering from any form of dementia or long-term memory loss, and even Alzheimer's disease. This study could benefit the patients in improving their memory and thus improving the skill transfer if the same skill is performed in the same environment rather than the performance of the same old skills in a totally new and hostile environment.

Limitations and Future Research

This study was limited by only using visual stimulus as numbers for algebraic equation on the computer screen. Future studies should be carried out using other variables such as music and pictures to better understand the process of skill acquisition and transfer in humans. Thus, future research might include manipulation of additional variables in the current experiment for generalization to the larger population. One of the biggest critiques of this study can be that it was performed in a laboratory in controlled conditions. The results could be different if studies on skill acquisition and transfer were performed in naturalistic settings.

The goal of this study was to present a new explanation, for the phenomenon of skill acquisition and transfer, and explain that transfer is a complex phenomenon and is context-specific, along with all other predictions of Anderson's (1982), ACT-R Theory and Logan's (1988), Instance Theory. In a nutshell, it can be proposed, as discussed in the literature of the current study, that there is no single theory in cognitive psychology, which can cover the phenomena of skill acquisition and transfer as a whole. Thus a comprehensive further research is needed, firstly to explain the disruption in the transfer of this current study, and secondly to come up with a complete theory, which can explain all underlying assumptions related to current theories of skill acquisition and transfer.

Conclusion

In conclusion, the results of the current study were consistent with Speelman's (1999) findings that performance of a skill is based to some extent on the context in which it is performed rather than simply on the extent of practice with old items.

Whereas Speelman (1999) demonstrated a disruption with the presence of new items on the performance of old items, the results of the current study further show that the size of the disruption is related to the number of new items included as context for old items. Findings of the current study pose a challenge to Anderson's (1982) ACT-R Theory and Logan's (1988) Instance Theory as both the theories are unable to account for the *positive partial transfer* of an acquired skill.

Based on the evidence provided so far it can be concluded that performance of a skill can be predicted based on the performance of previously acquired skills and according to the learning function, as long as there is no disruption in the performance of old skills through the introduction of new items. The performance level of the old skills was reduced with an increase from one new item to two new items in the context provided in the transfer phase. Thus, the results revealed that skill acquisition and transfer is highly *context-specific*.

References

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review, 89*(4), 369-406.

Anderson, J. R. (1983). A spreading activation theory of memory. *Journal of Verbal Learning and Verbal Behavior, 22,* 261-295.

Anderson, J. R. (1987). Skill acquisition: Compilation of weak-methods problem solutions. *Psychological Review, 94*(2), 192-210.

Anderson, J. R. (1989). Practice, working memory, and the ACT* Theory of skill acquisition: A comment on Carlson, Sullivan, and Schneider (1989). *Journal of Experimental Psychology: Learning, Memory, & Cognition, 15*(3), *527-530.*

Anderson, J. R. (1993a). *Rules of the mind.* Hillsdale, NJ: Erlbaum.

Anderson, J. R. (1993b). Problem solving and learning. *American Psychologist, 48*(1), 35-44.

Anderson, J. R. (1996). ACT: A simple theory of complex cognition. *American Psychologist, 51*(4), 355-365.

Anderson, J. R. (2000). *Cognitive psychology and its implications* (5th ed.). New York: Worth.

Anderson, J. R., & Fincham, J. M. (1994). Acquisition of procedural skills from examples. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*(6), 1322-1340.

Anderson, J. R., Fincham, J. M., & Douglass, S. (1997). The role of examples and rules in the acquisition of a cognitive skill. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 23*(4), 932-945.

Anderson, J. R., Fincham, J. M., & Douglass, S. (1999). Practice and retention: A unifying analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(5), 1120-1136.

Anderson, J. R., & Reder, L. M. (1999a). Process, not representation: Reply to Radvansky. *Journal of Experimental Psychology: General, 128*(2), 207-210.

Anderson, J. R., & Reder, L. M. (1999b). The fan effect: New results and new theories. *Journal of Experimental Psychology: General, 128*(2), 186-197.

Besner, D., & Care, S. (2003). A paradigm for exploring what the mind does while deciding what it should do. *Canadian Journal of Experimental Psychology, 57*(4), 311-320.

Blessing, S. B., & Anderson, J. R. (1996). How people learn to skip steps. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(3), 576-598.

Carlson, R. A., Sullivan, M. A., & Schneider, W. (1989). Practice and working memory effects in building procedural skill. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 15*(3), 517-526.

Cheng, P. W. (1985). Restructuring versus automaticity: Alternative accounts of skill acquisition. *Psychological Review, 92*(3), 414-423.

Cohen, N. J. (2003). Declarative memory. In J. H. Byrne (Ed.), *Learning and memory* (pp. 105-108). New York: Gale.

Corbett, A. T., & Anderson, J. R. (1992). LISP intelligent tutoring system: Research in skill acquisition. In J. H. Larkin & R. W. Chabay (Eds.), *Computer-assisted instruction and intelligent tutoring systems: Shared goals and complementary approaches.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Day, E. A., Arthur, W., & Gettman, D. (2001). Knowledge structures and the acquisition of a complex skill. *Journal of Applied Psychology, 86*(5), 1022-1033.

Dennis, I., & Schmidt, K. (2003). Associative processes in repetition priming. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 29*(4), 532-538.

Doane, S. M., Alderton, D. L., Sohn, Y. W., & Pellegrino, J. W. (1996). Acquisition and transfer of skilled performance: Are visual discrimination skills stimulus specific? *Journal of Experimental Psychology: Human Perception & Performance, 22*(5), 1218-1248.

Doane, S. M., Sohn, Y. W., & Schreiber, B. (1999). The role of processing strategies in the acquisition and transfer of a cognitive skill. *Journal of Experimental Psychology: Human Perception & Performance, 25*(5), 1390-1410.

Eyring, J. D., Johnson, D. S., & Francis, D. J. (1993). A cross-level units-of-analysis approach to individual differences in skill acquisition. *Journal of Applied Psychology, 78*(5), 805-815.

Fitts, P. M. (1964). Perceptual-motor skill learning. In A. W. Melton (Ed.), *Categories of human learning*. New York: Academic Press.

Fitts, P. M., & Posner, M. I. (1967). *Human performance*. Monterey, CA: Brooks/Cole.

Goggin, J., & Wickens, D. D. (1971). Proactive interference and language change in short-term memory. *Journal of Verbal Learning and Verbal Behavior, 10*, 453-458.

Gopher, D., Armony, L., & Greensphan, Y. (2000). Switching tasks and attention policies. *Journal of Experimental Psychology: General, 129*(3), 308-339.

Greig, D., & Speelman, C. P. (1999). Is skill acquisition general or specific? In J. Wiles & T. Dartnal (Eds.), *Perspectives on cognitive science: Theories, experiment, and foundations.* Volume 2. Stamford, Connecticut: Albex.

Heathcote, A., Brown, S., & Mewhort, D. J. K. (2000). The power law repealed: The case for an exponential law of practice. *Psychonomic Bulletin &Review, 7*(2), 185-207.

Horstmann, G. (2003). The psychological refractory period of stopping. *Journal of Experimental Psychology: Human Perception & Performance, 29*(5), 965-981.

Jenkins, L., & Hoyer, W. J. (2000). Instance-based automaticity and aging: Acquisition, reacquisition, and long-term retention. *Psychology & Aging, 15*(3), 551-565.

Johnstone, K. M., Ashbaugh, H., & Warfield, T. D. (2002). Effects of repeated practice and contextual-writing experiences on college students' writing skills. *Journal of Educational Psychology, 94*(2), *305-315.*

Kirsner, K., & Speelman, C. P. (1993). Is lexical processing just an ACT*? In A. F. Conway, S. E. Gathercole, M. A. Conway, & P. E Morris (Eds.), *Theories of memory.* Hillsdale, NJ: Erlbaum.

Kirsner, K., & Speelman, C. P. (1996). Skill acquisition and repetition priming: One principle, many processes? *Journal of Experimental Psychology: Learning, Memory, & Cognition, 22*(3), 563-575.

Landin, D. K., Hebert, E. P., & Fairweather, M. (1993). The effects of variable practice on the performance of a basketball skill. *Research Quarterly for Exercise and Sport, 64*(2), 232-238.

Lehrer, R., & Littlefield, J. (1993). Relationships among cognitive components in logo learning and transfer. *Journal of Educational Psychology. 85*(2), 317-330.

Lien, M. C., & Ruthruff, E. (2004). Task switching in a hierarchical task structure: Evidence for the fragility of the task repetition benefit. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30*(3), 697-713.

Lien, M. C., Schweickert, R., & Proctor, R. W. (2003). Task switching and response correspondence in the psychological refractory period paradigm. *Journal of Experimental Psychology: Human Perception & Performance, 29*(3), 692-712.

Logan G. D. (1985). Skill and automaticity: Relations, implications, and future directions. *Canadian Journal of Psychology, 39*(2), 367-386.

Logan, G. D. (1988). Towards an instance theory of automatization. *Psychological Review, 95*(4), 492-527.

Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology, 22*, 1-35.

Logan, G. D. (1992a). Attention and preattention in theories of automaticity. *American Journal of Psychology, 105*(2), 317-339.

Logan, G. D. (1992b). Shapes of reaction-time distributions and shapes of learning curves: A test of the instance theory of automaticity. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 18*(5), *883-914.*

Logan, G. D. (1995). The weibull distribution, the power law, and the instance theory of automaticity. *Psychological Review, 102*(4), 751-756.

Logan, G. D. (1998). What is learned during automatization? II. Obligatory encoding of spatial location. *Journal of Experimental Psychology: Human Perception & Performance, 24*(6), 1720-1736.

Logan, G. D. (2002). An instance theory of attention and memory. *Psychological Review, 109*(2), 376-400.

Logan, G. D. (2004). Cumulative progress in formal theories of attention. *Annual Review of Psychology, 55*, 207-234.

Logan, G. D., & Etherton, J. L. (1994). What is learned during automatization? The role of attention in constructing an instance. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 20*(5), 1022-1050.

Logan, G. D., & Klapp, S. T. (1991). Automatizing alphabet arithmetic: I. Is extended practice necessary to produce automaticity? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*(2), 179-195.

Logan, G. D., Taylor, S. E., & Etherton, J. L. (1996). Attention in the acquisition and expression of automaticity. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 22*(3), 620-638.

Logan, G. D., Taylor, S. E., & Etherton, J. L. (1999). Attention and automaticity: Toward a theoretical integration. *Psychological Research, 62*(2), 165-181.

Maring, J. R. (1990). Effects of mental practice on rate of skill acquisition. *Physical Therapy, 70*(3), 165-173.

Masson, M. E. J. (1986). Identification of typographically transformed words: Instance-based skill acquisition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*(4), 479- 488.

Muller, B. (1999). Use specificity of cognitive skills: Evidence for production rules? *Journal of Experimental Psychology: Learning, and Cognition, 25*(1), 191-207.

Muller, B., & Gehrke, J. (2004). Acquisition and use of mental operators: The influence of natural order of events. *Experimental Psychology, 51*(1), *33-44.*

Mumford, M. D., Costanza, D. P., Baughman, W. A., Threlfall, K. V., & Fleishman, E. A. (1994). Influence of abilities on performance during practice: Effects of massed and distributed practice. *Journal of Educational Psychology, 86*(1), 134-145.

Newell, A., & Rosenbloom, P. S. (1981). Mechanisms of skill acquisition and the power law of practice. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition.* Hillsdale, NJ: Erlbaum.

Palmeri, T. J. (1997a). Exemplar similarity and the development of automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23* (2), 324-354.

Palmeri, T. J. (1997b). *An exemplar-based random walk model of perceptual categorization.* Paper presented at the Interdisciplinary Workshop on Similarity and Categorization, University of Edinburgh, Scotland.

Pashler, H., Johnston, J. C., & Ruthruff, E. (2001). Attention and performance. *Annual Review of Psychology, 2001*, 629.

Pirolli, P. L., & Anderson, J. R. (1985). The role of practice in fact retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11*(1), 136-153.

Rickard, T. C. (1997). Bending the power law: A CMPL theory of strategy shifts and the automatization of cognitive skills. *Journal of Experimental Psychology: General, 126*(3), 288-311.

Rickard, T. C. (1999). A CMPL alternative account of practice effects in numerosity judgment tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(2), 532-542.

'kard, T. C., & Bourne, L. E. Jr. (1996). Some tests of an identical elements model of basic arithmetic skills. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 22*(5), 1281-1295.

Ritter, F. E. (1998). *Soar: Frequently asked questions list.* Retrieved June 26, 2004, from University of Nottingham, Web site: *http//www.nottingham.ac.uk/pub/soar/ nottingham/soar-faq.html*

Schacter, D. L. (1996). *Searching for Memory.* New York: Basic Books.

Schneider, W., Fisk, A. D. (1984). Automatic category search and its transfer. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*(1), 1-15.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84*, 127-190.

Shute, V. J. & Gawlick, L. A. (1995). Practice effects on skill acquisition, learning outcome, retention, and sensitivity to relearning. *Human Factors, 37*(4), 781-804.

Speelman, C. P. (1999). Unpublished experiment, Edith Cowan University at Perth, Western Australia, Australia.

Speelman, C. P., & Kirsner, K. (1993). New goals for HCI training: How to mix old and new skills in the trainee. *International Journal of Human-Computer Interaction, 5*(1), 41-69.

Speelman, C. P., & Kirsner, K. (1997). The specificity of skill acquisition and transfer. *Australian Journal of Psychology, 49*(2), 91-100.

Speelman, C. P., & Kirsner, K. (2001). Predicting transfer from training performance. *Acta Psychologica, 108*, 247-281.

Speelman, C. P., Maybery, M. (1998). Automaticity and skill acquisition. In K. Kirsner, C. Speelman, M. Maybery, A. O'Brien-Malone, M. Anderson, & C. MacLeod (Eds.), *Implicit and explicit mental processes* (pp.79-98). Mahwah, NJ: Erlbaum.

Squire, L. R. (1986). Mechanisms of memory. *Science, 232*, 1612-1619.

Van Selst, M. V., Ruthruff, E., & Johnston, J. C. (1999). Can practice eliminate the psychological refractory period effect? *Journal of Experimental Psychology, 25*, 268-283.

Wenger, M. J. (1999). On the whats and hows of retrieval in the acquisition of a simple skill. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 25*(5), 1137-160.

Wickens, D. D. (1972). Characteristics of word encoding. In A. W. Melton & E. Martin (Eds.), *Coding process in human memory* (pp. 191-215). Washington, DC: Winston & Sons.

Williams, A. M., Ward, P., Knowles, J. M., & Smeeton, N. J. (2002). Anticipation skill in a real-world task: Measurement, training, and transfer in tennis. *Journal of Experimental Psychology: Applied, 8*(4), 259-270.

Woltz, D. J., Bell, B. G., Kyllonen, P. C., & Gardner, M. K. (1996). Memory for order of operation in the acquisition and transfer of sequential cognitive skills. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(2), 438-457.

Young, R. M., & Lewis, R. L. (1999). The Soar cognitive architecture and human working memory. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 224-256). New York: Cambridge University Press.

Appendix A

Values for x and y, in the Equation $(x^2 - y)/2 = A$, and the Correct Response in Training and Transfer Phases in an Experiment Conducted by Speelman (1999)

Training				Transfer			
Version 1							
x	*y*	*A*	Response	*x*	*y*	*A*	Response
5	9	8	Even	5	9	8	Even
5	11	7	Odd	5	11	7	Odd
5	13	6	Even	5	13	6	Even
5	15	5	Odd	5	15	5	Odd
6	10	13	Odd	7	1	24	Even
6	12	12	Even	7	3	23	Odd
6	14	11	Odd	7	5	22	Even
6	16	10	Even	7	7	25	Odd
Version 2							
x	*y*	*A*	Response	*x*	*y*	*A*	Response
5	9	8	Even	6	10	13	Odd
5	11	7	Odd	6	12	12	Even
5	13	6	Even	6	14	11	Odd
5	15	5	Odd	6	16	10	Even
7	1	24	Even	7	1	24	Even
7	3	23	Odd	7	3	23	Odd
7	5	22	Even	7	5	22	Even
7	7	21	Odd	7	7	21	Odd

Appendix B

INFORMATION SHEET

Dear Participant,

The experiment in which you are about to participate is part of a 4th year Honour program in Psychology research project being conducted by Charan Jit Singh, School of Psychology, Edith Cowan University. The project has the approval of the Faculty of CSESS Ethics Committee.

In this experiment you will be asked to evaluate a simple algebraic equation and respond whether the answer is odd or even on a computer keyboard. A series of algebraic equations will be presented to you on the computer screen and you will be prompted to enter your responses into the computer by pressing the specific keys on the keyboard. Only a basic knowledge of computers is required. The aim of the experiment is to investigate the effects of training in this task. The research may provide some important information regarding learning processes. Your participation would be required once and the session would be of one hour's duration.

Your participation in this experiment is voluntary and you may withdraw at any stage of the experiment, without penalty, in which case your data will be deleted from the research. Any information provided by you will be dealt with in strict confidence by the researcher. Your details along with your performance will be kept confidential. The data collected will be used in collective format only. At the end of this session you will have the opportunity to ask any question you may have regarding this research.

The information collected in this research will only be used by the researcher and his supervisor Dr. Craig Speelman. At the conclusion of the research a report of the results will be made available to you on your request.

For any further questions regarding this research project you may contact the following:

- Charan Jit Singh Research Student 9378 4465
- Dr. Craig Speelman 6304 5724
- Dr. Moira O'Connor 6304 5593
  (Independent Person)

If you would like to participate, please complete the attached consent form.
Your participation is greatly appreciated,

Thank you

Charan Jit Singh
School of Psychology
Edith Cowan University

Appendix C

INFORMED CONSENT

I (the participant) have read the information sheet and any question I have asked has been answered to my satisfaction. I agree to participate in this experiment voluntarily, acknowledging the fact that I may withdraw at any time. I agree that data collected for this experiment may be published provided my confidentiality is maintained.

________________________________ _______________

Participant's Name and Signature Date

________________________________ _______________

Researcher's Name and Signature Date

Appendix D

On screen instruction provided during the current experiment:

You will be presented with a simple algebraic equation several times for example:-

$$\frac{x^2 - y}{2} = A$$

$x = 5$ $y = 7$

A is ODD **A is EVEN**

You are required to evaluate the equation with the given set of x and y values each and every time. You will be prompted to respond with the answer (A) to the algebraic equation as quickly and accurately as you can. You will need to press 'z' for odd responses or '/' for even responses.

Please wait for some practice trials, press space bar or any key on the keyboard to continue.

Note. For every response made by the participant the computer responded back with a message displaying correct or incorrect followed by a prompt to press space bar to continue for the next trial.

CORRECT **OR** **INCORRECT**

Please press the 'Space Bar' to continue

Note. In the end of eighth practice trial and in the end of the transfer phase the following message was displayed on the centre of the screen:

Please call the experimenter

Appendix E

Accuracy in Performance for All Participants in Both the Phases in Percentage

N	Group 1	Group 2
1	91.83	95.36
2	94.67	94.64
3	96.33	98.39
4	96.50	98.93
5	94.33	90.36
6	87.17	83.57
7	95.83	89.82
8	88.00	96.07
9	98.00	82.14
10	97.83	94.82
11	97.83	94.64
12	84.00	99.82
13	93.50	96.79
14	95.33	95.71
15	87.33	92.14
16	94.17	93.57
17	96.33	88.57
18	98.67	87.14
19	94.33	81.25
20	96.17	96.96

Note. The above values have been rounded for 2 decimal places.

Appendix F

Mean and Standard Deviation of Reaction Time in Milliseconds for the Training

	Group 1		Group 2	
	M	*SD*	*M*	*SD*
Block 1	8848	2502	9012	1910
Block 2	7539	1870	7745	2715
Block 3	7020	2339	6920	2389
Block 4	5850	1779	6168	2393
Block 5	5701	1885	5643	2277
Block 6	4897	1609	5378	2197
Block 7	4618	1443	4896	2216
Block 8	4323	1283	4443	1800
Block 9	3899	1324	4379	1859
Block 10	3823	1189	4317	1609
Block 11	3530	1353	3894	1518
Block 12	3190	1185	3667	1455
Block 13	2961	1047	3589	1481
Block 14	3025	888	3451	1472
Block 15	2798	1060	3432	1402
Block 16	2640	960	3267	1456
Block 17	2774	791	3224	1355
Block 18	2644	1084	3109	1012
Block 19	2541	1138	3096	934
Block 20	2547	1015	2854	1147
Block 21	2406	952	3089	1109
Block 22	2451	949	2799	998
Block 23	2361	924	2735	824
Block 24	2488	1030	2988	1063
Block 25	2260	831	2732	1059
Block 26	2261	935	2827	949
Block 27	2170	822	2706	884
Block 28	2161	802	2703	963
Block 29	2166	780	2450	751
Block 30	2036	789	2460	889
Block 31	2006	809	2302	846
Block 32	1925	710	2264	782
Block 33	1863	695	2200	845
Block 34	1783	704	2149	868
Block 35	1811	591	2150	918
Block 36	1761	664	2124	883
Block 37	1715	650	2168	884
Block 38	1770	673	2078	885
Block 39	1700	682	2104	1017
Block 40	1675	635	1917	874

Appendix G

Mean and Standard Deviation of Reaction Time in Milliseconds for the Transfer

	Group 1		Group 2	
	M	*SD*	*M*	*SD*
Block 1	2822	753	4721	1171
Block 2	3013	637	5310	863
Block 3	2689	665	3932	654
Block 4	1926	746	3132	645
Block 5	1786	693	2821	875
Block 6	1783	790	2298	759
Block 7	1625	740	2341	893
Block 8	1592	696	2392	1051
Block 9	1687	758	2412	1025
Block 10	1659	728	2417	1056
Block 11	1585	699	2244	1114
Block 12	1585	645	2245	1015
Block 13	1591	652	2222	1012
Block 14	1656	711	2205	937
Block 15	1672	711	2100	865
Block 16	1549	747	2158	889
Block 17	1501	712	2118	1060
Block 18	1561	771	1945	946
Block 19	1441	699	1952	871
Block 20	1515	652	1817	794
Block 21	1446	711	1926	849
Block 22	1459	689	1834	800
Block 23	1512	650	1778	839
Block 24	1551	591	1752	937
Block 25	1462	671	1665	786
Block 26	1420	628	1751	804
Block 27	1543	698	1746	842
Block 28	1493	583	1825	810
Block 29	1498	705	1709	704
Block 30	1518	706	1801	806
Block 31	1434	625	1726	772
Block 32	1397	503	1733	796
Block 33	1346	543	1763	798
Block 34	1343	566	1635	700
Block 35	1359	488	1596	737
Block 36	1377	670	1646	751
Block 37	1347	638	1723	735
Block 38	1366	614	1734	754
Block 39	1418	653	1663	851
Block 40	1300	542	1636	807

Appendix H

Mean and Standard Deviation of Reaction Time in Milliseconds for the Last Block of the Training Phase and the First Block of Transfer Phase

	Group 1		Group 2	
	M	*SD*	*M*	*SD*
Training (Block 40)	1675	635	1917	874
Transfer (Block 1)	2822	753	4721	1171

Appendix I

Mean and Standard Deviation of Reaction Time in Milliseconds for the First Block of the Training Phase and the First Block of Transfer Phase

	Group 1		Group 2	
	M	*SD*	*M*	*SD*
Training (Block 1)	8848	2502	9012	1910
Transfer (Block 1)	2822	753	4721	1171

Appendix J

Mean and Standard Deviation of Reaction Time in Milliseconds for the First Block of Transfer Phase and the Second Block of Transfer Phase

	Group 1		Group 2	
	M	*SD*	*M*	*SD*
Transfer (Block 1)	2822	753	4721	1171
Transfer (Block 2)	3013	637	5310	863