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The Specificity of Skill Acquisition: Is it Task Related?

Dawn Darlaston-Jones

A Thesis Submitted in Partial Fulfilment of the
Requirements for the Award of
Bachelor of Arts (Psychology) Honours
Faculty of Community Services, Education and Social Sciences
Edith Cowan University

29th October 1999

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The Specificity of Skill Acquisition: Is it Task Related?

Abstract

The plethora of research into the area of skill acquisition and transfer has resulted in conflicting conclusions regarding the nature of transfer. Some researchers have found skill transfer to be specific to the items experienced during training (Logan, 1988, alphabet-arithmetic task; Masson, 1986, reverse reading task). Others have found transfer to be general (Speelman & Kirsner, 1997, syllogism task) or both general and specific in the same task (Greig & Speelman, 1999, algebra task). This study investigated the assumption that the task involved dictates the specific nature of skill acquisition and transfer. Sixty participants drawn from the Edith Cowan School of Psychology volunteer register were randomly assigned to four groups, with each group performing one of the afore mentioned tasks. In phase 1, learning was determined by the decreased Reaction Time (RT) for each participant from block 1 to block 8. Phase 2 involved participants being trained on a different task using one set of items and then in the transfer phase (3) participants performed the same task but with new items. Comparing RT data from block 1 phase 2 and block 1 phase 3 and from block 1 phase 3 to block 10 phase 2 assessed transfer. The syllogism task resulted in the most skill transfer due to the generalisability of the strategy employed in solving the syllogisms. This was followed by the algebra task, the alphabet-arithmetic task, and the reversed reading task. The results confirmed the a priori predictions that the nature of transfer is a function of the task involved.

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The Specificity of Skill Acquisition: Is it Task Related?

Given the relevance of learning and skill acquisition to all domains of human endeavour it is hardly surprising that the topic has resulted in a plethora of literature. From birth, humans are learning new skills and achieving milestones in their ability to negotiate their world. Consequently, researchers are equally avid in striving to understand the cognitive processes that enable skill acquisition, be it learning to read, ride a bike, or fly the space shuttle.

Defining what is meant by the term 'skill' has occupied researchers from a variety of domains for several decades (Adams, 1987). One of the earliest definitions of the term came from a British psychologist T. H. Pear (1927), and his interpretation of what defined 'skill' continues to influence current thinking. Pear's definition held that skill was the "...integration of well-adjusted performances, ...skill is acquired and fused with natural aptitude" (pp. 480-481). This definition implies the need for both capacity and ability. But skill acquisition is distinguished from both in that one might have the capacity and ability to perform a task yet be unable to do so because the skill has not been learnt (Adams, 1987).

The importance of understanding the mechanisms underpinning skill acquisition, and arguably more importantly, the transfer of skills to new domains, has never been greater than it is now at the end of the 20th century (for reviews, see Adams, 1987; Masson, 1990; Singley & Anderson, 1989). With the current emphasis on achieving a reliable and competent, multi-skilled workforce the relevance of research in this area has increased. Unfortunately several questions pertinent to this issue remain unresolved. For example, can workers trained in one domain be effectively

redeployed to another task without the need for expensive retraining? Furthermore, are there certain 'generic' skills that can be transferred between roles that would reduce those retraining costs?

Answers to these questions differ depending on the theoretical perspective of the respondent. A number of theories about the way skills are acquired and generalised beyond the training context have been proposed (Anderson 1983, 1993; Logan, 1988; MacKay, 1982; Newell & Rosenbloom, 1988; Rickard, 1997). Each has been developed using a variety of tasks in a range of training situations but researchers have yet to gain consensus.

In reviewing the evidence in support of the major theories, this paper attempts to establish the argument that the specificity of skill transfer is a function the task itself rather than a result of cognitive processes involved in performing a task per se. The review begins by offering a brief overview of the mechanisms involved in skill acquisition. Of particular importance is the role played by memory and immediate feedback. This will be followed by a discussion of Logan's instance theory and Anderson's ACT* theory and the specific tasks involved in generating the transfer literature.

Skill Acquisition

The importance of immediate feedback in terms of its role in skill acquisition has its roots with Thorndike, who, based on his Law of Effect, stated that knowledge of results, or reinforcement, automatically emphasised the connection between the situation and response without conscious processing (Adams, 1987). Thorndike

viewed feedback in terms of a habit-based or behavioural response similar to the stimulus-response mechanism of operant conditioning. The opposing view saw the benefits of feedback as informational or cognitive, based on awareness, planning, reasoning and decision making (Adams, 1987).

The latter framework presents feedback as a component in a loop whereby the person remembers the situation and the given response and combines it with the feedback results. On subsequent trials the person recalls the situation, the response and the feedback given and makes a decision that eliminates any error embodied in the previous response (Anderson, 1987). This argument is a key concept in Anderson's ACT* theory of skill acquisition, which will be discussed in detail later, in that successful application of production rules results in strengthening of the association between the stimulus and the response, leading to faster reaction times. Intuitively this argument makes sense. For instance, dancers train in front of large mirrors in order to correct their posture and technique and gymnasts videotape their routines to refine and improve the fluidity and grace of the performance.

Empirical research has also supported the need for immediate feedback as a factor in improving performance and the acquisition of skill. For example, Lewis and Anderson (1985) performed an experiment involving a 'Dungeons and Dragons' board game. Participants were divided into two conditions, one received immediate feedback on performance and the other received no feedback. The game involved participants proceeding through the various rooms portrayed in the game. Often these rooms would be a dead-end and players had to retrace their path to move forward. Lewis and Anderson (1985) found that participants who received immediate

feedback pertaining to their error on the game performed considerably better than did those who relied on learning by discovery.

R. C. Anderson, Kulhavy and Andre (1972) found that the type of feedback was also crucial to performance. In their view participants needed to arrive at the correct answer by themselves because if participants were provided with the correct solution, they learned only to copy the answer given by the examiner instead of learning the skills to generate the answer themselves. So Anderson, et al. argued it was important to only give feedback indicating that an error had been made rather than giving the solution.

The other significant variable in the skill acquisition equation is the role of working memory. Remembering specific items, concepts, solutions and rules plays a large part in skill acquisition. Practice, accompanied with accurate feedback allows the storage of exemplars, which can be used either as a direct solution to a problem previously encountered, or as analogous to a new problem. This type of learning is referred to as *explicit learning*. It is dependent upon conscious processing and intent to learn and is sensitive to work load (Kirsner & Spelman, 1998).

Working memory is defined as a "system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks" (Baddeley, 1986, p.34) and theories of skill acquisition share common ground on the role of memory in learning. In the novice stage of learning, knowledge and instructions relevant to the performance of a task are held in working memory and assist in the development of a performance strategy or algorithm. With continued

exposure to a task there is a refining and improving of the algorithm and the individual becomes more competent at performing the task. The need to hold large amounts of information in working memory declines and as such both the size and nature of demand is reduced. Over time there is a gradual shift from algorithmic processing to memory retrieval, leading to automatic performance, as experience with the task is increased (Anderson, 1983; Cheng, 1985; Logan, 1988; Newell, & Rosenbloom, 1981).

It is this concept of a transition from algorithmic processing to memory retrieval that forms the basis for Logan's (1988) instance theory of skill acquisition, which will be reviewed in detail later in this review. It also highlights the central issue in the debate over the specificity of skill transfer - is transfer from one task to another based on the number of shared task elements between the two tasks (Frensch, 1991, p. 997) or is it a function of past exposure to the same situation. (Compton & Logan, 1991; Logan, 1988; Logan & Klapp, 1991; Pennington, Nicolich, & Rahm, 1995).

Those theorists who support the 'shared elements' approach to transfer, argue that when a person encounters a new situation or task, he/she would benefit from past experience in proportion to the number of similarities between the old and new situation (Anderson, 1983; Bovair, Kieras, & Polson, 1990; Kieras & Bovair, 1986; Rosenbloom & Newell, 1987; Singley & Anderson, 1989). In contrast, those arguing for the opposite view, state that transfer occurs only when both the old and new tasks are identical.

Edward Thorndike (1874-1949) was the pioneer of the 'shared elements' view of skill transfer. Early in his career, Thorndike moved to the Teacher's Training College at Columbia University, and it was here that his interest in learning was channelled to the domain of education. The assumption inherent in all training programs is that skills learnt in the training environment will transfer to situations outside the classroom.

It was this assumption that led Thorndike to formulate his theory of transfer, which holds that performance on a task is benefited by past experience only to the extent that both tasks share the same components. Based on the foundation laid by Thorndike, other associationists built their own arguments in support of the identical elements theory (Anderson, 1983; Crossman, 1959; Trowbridge & Carson, 1932). Judd (1908), a contemporary of Thorndike, proposed the opposing view of transfer. Judd argued that skills were highly constrained by the context in which they were acquired and transfer from one task to another would only occur between items experienced during training (Gagné, 1966; Hintzman, 1976).

Two modern theories of skill acquisition that characterise this dichotomy are Logan's Instance Theory of Learning, which can be likened to the position held by Judd, and Anderson's Adaptive Control of Thought Theory (ACT*), which is similar to the view held by Thorndike. Both theories can account for most of the changes that occur with learning and skilled behaviour, but they differ in terms of the specificity of transfer (Greig & Spelman, 1999).

Logan's (1988, 1990) instance theory, for example, states that skills are highly specific to the environment in which they were learned. Therefore performance on a new task would not be benefited by past learning. In contrast, Anderson's (1982, 1983, 1987, 1990, 1992) ACT* theory holds that because knowledge is abstract it can be applied to situations beyond the training environment and skills can therefore be general in nature.

Both these divergent positions have found support in empirical research, raising the question of how can both views can be correct. One possible answer is that the nature of the skill acquisition and therefore transfer to new items or events is dictated by the nature of the tasks performed. Those tasks that result in specific transfer do so because they are inherently specific; that is, there are no general features in the task that can be incorporated into a general performance strategy and so no such strategy can be developed that would facilitate transfer to another version of the task. Conversely, a task that demonstrates general transfer does so because it contains properties that can be useful when used to perform a different version of the task.

Logan's Instance Theory

Logan's (1988, 1990, 1992) Instance Theory of Automisation states that learning is based on exposure to specific events and that for each exposure a memory for that event is stored. In this theory these memories are called instances. The more exposure a person receives to a given stimulus the more instances are available for retrieval.

Logan argues that faster reaction times (RT) on a task are a function of the amount of practice with the task a person has experienced. Faster retrieval of information is a direct result of the increased number of instances available for retrieval rather than a refinement of a general solution strategy.

Logan's Instance Theory is fundamentally a memory based theory predicated upon three main assumptions: (1) that encoding into memory occurs as an "obligatory, unavoidable consequence of attention" to a stimulus (Logan, 1988, p. 493); (2) that having attended to a stimulus, retrieval from memory of anything associated with the stimulus is obligatory and unavoidable; and (3) that each individual encounter with a stimulus is encoded, stored, and retrieved separately.

According to the instance theory, in the initial stages of learning, performance is based on algorithmic processing with the person going through a number of steps to find a solution. For example, in learning to multiply 4×5 a child might count 4 piles of counters with 5 in each pile and then add the total number of counters to arrive at the answer, 20. Each time this exercise is performed correctly an instance is stored in memory. So that with repeated exposure to the problem 4×5 the child has more instances of the answer 20 to draw upon and so is less likely to use the algorithm. That is, rather than needing to generate the solution, the child simply remembers it. The algorithm for solving the problem does not change, rather the database of memory instances for the solution increases (Logan, 1988).

In addition to the three primary assumptions, Logan's Instance Theory also assumes that each episode connected with a particular stimulus has an equal chance of

retrieval so that every time a person performs a task, the memory process and the algorithm compete in a metaphoric 'race'; the process that produces a solution first controls the response. Retrieving an instance is simply recalling the past solution to the problem, so the 'race' is in effect between generating a solution (i.e., algorithm) and remembering an answer (i.e., instance). At the novice stage there are fewer instances available to retrieve, and so the algorithm is more likely to win the race and control the response. As the individual becomes more skilled, a greater number of instances are stored and the probability of one of them being retrieved faster than the processing of the algorithm increases so that the memory process eventually dominates the race (Compton & Logan, 1991; Rickard, 1997).

Collectively these assumptions imply a learning mechanism that is based on the "accumulation of separate episodic traces with experience" (Logan, 1988, p. 493) whereby practice, and therefore an increased database of instances, ultimately results in a transition from algorithmic processing to memory-based processing. In addition, it is this accumulation of separate episodes that makes the theory an *instance theory*. According to Logan's theory the only difference between skilled performers and the novice is the number of instances that the expert has to draw upon.

One of the assumptions central to the instance theory is that encoding and retrieval are both "obligatory and unavoidable" consequences of attending. Support for this argument has been found in experiments involving incidental and intentional learning where participants experienced the same stimulus but with one group being instructed to attend to a specific aspect of the stimulus and the other group receiving no specific instruction (Bororat & Logan, 1997; Hyde & Jenkins, 1969; Logan &

Etherton, 1994; Mandler, 1967). For example, in the Boronat and Logan (1997) study participants were presented with word pairs presented in a 16 block training session. Participants searched these word pairs for members of a target category. The results of these experiments supported the assumption that information is encoded whether it is specifically attended to or not.

Another important aspect of Logan's theory concerns the strength of encoding. Although Logan argues that encoding occurs automatically, and can offer experimental support for his assertion, he counters this statement by saying that not all information is encoded to the same degree (Logan, 1988). Consequently the fact that an individual is unable to retrieve information relevant to a stimulus does not mean necessarily that the information was not encoded, just that it was inadequately encoded.

Due to the nature of the instance theory, Logan predicts that there can not be any transfer between tasks. According to Logan, skill acquisition is based on an accumulation of instances that are highly specific to the stimuli encountered. As a result, performance on new, albeit similar items, would not be enhanced by past learning. Logan demonstrated this with his alphabet-arithmetic task (Logan, 1988; Logan & Klapp, 1991) and with a spatial numerosity task (Lassaline & Logan, 1993). Both these tasks presented participants with a set of items in a training phase and a mix of old and new items in a transfer phase. Reaction time for the old items were faster than for the new items, which demonstrated that learning from the training phase of the experiment could not be of benefit to the participant when they were presented with new items in the transfer phase. This implies that new problems,

regardless of any similarity between them, are treated as if they are totally new (Greig & Speechman, 1999).

Palmeri (1997) expressed concern over the instance theory's metaphorical "race". The theory states that there can only be one "winner" and so implies that it is the first instance retrieved that dictates the response. This aspect of the theory offers no possibility of comparison of responses where evidence in support of one response automatically negates all others (Palmeri, 1997). This raises the possibility that the first instance retrieved might not be the best or most appropriate solution to the problem.

Palmeri (1997) and Rickard (1997) have both extended the instance theory to include the possibility of retrieving instances that are not identical to the stimulus encountered. Palmeri, with his exemplar-based random walk model (EBRW) states that all examples of an instance are retrieved in direct proportion to their similarity to the presented stimuli. This means that if a new problem is encountered that is *similar* to₂ but not *identical* to₂ an instance held in memory, that instance could be retrieved to assist in solving the new problem.

Rickard's component power laws theory (CMPL) offers an alternative to the parallel competition between algorithm execution and memory retrieval described by the instance theory. Rickard suggests that instead of the two processes competing independently in parallel, that a choice of strategy (i.e., either algorithm execution or memory retrieval) is made at the outset of each trial and a prototype of each item is strengthened with practice. While this model precludes parallel completion it does

not preclude parallel initiation of two or more memory retrieval events, therefore, it allows the possibility of more than one solution being considered (Rickard, 1997).

Anderson's ACT Theory*

Anderson's ACT* Theory proposes that skilled behaviour can be considered as involving the execution of production rules (Anderson, 1995) which Anderson described as one of the "most astounding and important discoveries in psychology" (Anderson, 1993, p. 1). Production rules are 'if - then' or 'condition-action' statements. When the 'if' component is matched with information stored in memory a particular outcome or action is performed - the 'then' component (Anderson, 1993). With practice, execution of these productions becomes more efficient and therefore faster. Thus a general strategy for performing is developed and refined with practice on the task (Pirolli & Anderson, 1985).

Underlying Anderson's theory is the distinction between declarative and procedural knowledge. Declarative knowledge is knowledge about facts, whereas procedural knowledge is the "how" of an action or procedure. Anderson states that these two types of knowledge differ fundamentally in their role in skill acquisition (Anderson, 1982). The use of declarative information to perform a task is slow and ponderous in that every fact relating to a stimulus has to be retrieved from long-term memory before it can be held in short term memory for assessment in terms of its appropriateness to the situation. This declarative information can be operated on by general problem solving processes such as analogy or means-end analysis. These problem-solving processes are referred to as weak because they can be applied to a range of problems and are not tied to any particular problem type. Application of

these processes result in the formation of productions that form the basis of procedural knowledge.

According to the ACT* theory, skill acquisition typically comprises three stages; the *Declarative Stage*, the *Knowledge Compilation Stage*, and finally the *Procedural Stage*. In effect, the ACT* is a reinterpretation of the three stages of skill acquisition described by Fitts (1964). Fitts described the *Cognitive Stage*, which corresponds to Anderson's declarative stage, as involving initial skill acquisition. This stage is characterised as being explicit and rule-based, making it slow, resource intensive and mistake ridden. Schneider and Shiffrin (1977) suggest this stage is highly demanding of attention and is governed by the limits of short-term memory. During this stage the skill is being mastered so techniques such as verbal rehearsal are often employed to aid performance (Shiffrin & Schneider, 1977)

The second stage in Fitts' model is the *Associative Stage* (Anderson's knowledge compilation stage), which involves the refinement of the skill. Initial mistakes are corrected and the individual becomes less hesitant as familiarity with the task increases. Finally, in the *Autonomous Stage*, (the procedural stage in ACT*), skill gradually improves as a direct result of practice on the task and performance becomes more automatic (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Speelman & Maybery, 1998).

According to ACT* any improvement in performance is a consequence of composition, proceduralisation and strengthening. Composition involves several production rules being collapsed or refined into simpler rules that achieve the same

goal. To illustrate the concept Speelman and Maybery (1998, p. 88) presented the following example of five production rules being composed into one in the solution of an algebraic equation:

IF goal is to solve for x in the equation $a = x + c$
THEN set as sub-goal to isolate x on RHS of equation (1)

IF goal is to isolate x on RHS of equation
THEN set as sub-goal to eliminate c from RHS of equation (2)

IF goal is to eliminate c from RHS of equation
THEN add $-c$ to both sides of equation (3)

IF goal is to solve for x in the equation
And x has been isolated on RHS of equation
THEN LHS of equation is solution for x (4)

After performing these production rules for the solution of the equation, composition will result in productions 2 and 3 being collapsed into a new production rule:

IF goal is to isolate x on RHS of equation
THEN add $-c$ to both sides of equation (5)

Further practice would result in productions 1, 4 and 5 being collapsed into a single sophisticated production rule:

IF goal is to solve for x in equation of the form $a = x + c$
THEN subtract c from a and the result is the solution (6)

Thus the goal is achieved with only one production rule as apposed to the original five. The critical aspect to note here is the reduction in the number of processing steps results in faster processing and execution of the task but does not change the goal or nature of the task (Anderson, 1983).

Proceduralisation represents the transition from slow declarative knowledge to faster automatic procedural knowledge. It occurs by integrating domain specific information into general productions, thereby restricting the realm of application of the production and eliminating the need to maintain large amounts of general knowledge in working memory (Anderson, 1983). This reduction in demand on working memory results in an improvement in both speed and accuracy of performance.

Finally, every time a production is successfully applied the production gains strength, resulting in a higher probability that it will be utilised in future. However, unlike compilation and proceduralisation, strengthening does not qualitatively change the productions and is associated with smaller improvements in performance. Hence it is often associated with the flattening of the learning curve as it approaches asymptote (Anderson, 1983).

Contrary to Logan's Instance Theory, ACT* predicts transfer of skills from one domain to another depending on the number of shared productions (Singley & Anderson, 1989). Thus transfer between tasks that share the same strategy should be high although not necessarily complete. Although Anderson (1983) has reported evidence in support of this view of transfer, there has been some criticism of this view. For example, Carlson and Schneider (1989) suggested that it is difficult to identify which productions are actually utilised in any particular task and that production models can be devised post hoc to account for any amount of transfer, making it virtually impossible to falsify the theory.

Anderson (1987) recognises this allegation and agrees that it is difficult to predict the amount of transfer that will occur because participants are unable to verbalise the actual productions in use. However, empirical research has consistently supported the prediction that transfer will occur between tasks as a function of the amount of shared procedural knowledge that exists between the tasks (Corbett & Anderson, 1992; Greig & Speelman, 1999; Frensch, 1991; Kieras & Bovair, 1986; Singley & Anderson, 1989; Speelman & Kirsner, 1997).

Transfer

Skill transfer is referred to as the degree to which skills obtained in one area assist in the acquisition or implementation of skills in another area (Greig & Speelman, 1999). In addition, transfer is considered to be general when the skills acquired on one task can be used to assist in the performance of a different task (Masson, 1986). Conversely, transfer is considered specific when skills cannot be generalised to other tasks (Masson, 1986).

The ACT* and instance theories make different predictions relating to transfer. As mentioned previously ACT* states that transfer between tasks will occur as a function of the number of shared productions between the tasks. The amount of transfer is directly related to how applicable the production rules developed with one task are to the performance of another task; the more closely the two tasks are related the greater the amount of transfer (Anderson, 1982, 1987). This is not to say that the tasks themselves have to be similar. Singley and Anderson (1989) demonstrated that negative and zero transfer can occur between tasks that on the surface appear to be alike. So it is the shared abstract components not superficial similarity of tasks that

dictates transfer (Anderson, 1987; Frensch, 1991; Rosenbloom, & Newell, 1986; Schneider & Fisk, 1984; Spelman & Kirsner, 1997).

In contrast, Logan predicts that there can be no transfer between tasks because skill acquisition is based on past instances of performing a task. Experience of one situation cannot advantage the individual in a new situation because there can be no stored information pertaining to the new situation (Logan, 1988; 1990; Rickard, 1997; Rickard, Healy & Bourne, 1994). Logan (1988) supported this position with a series of experiments based on both lexical decision and alphabet-arithmetic tasks.

In the alphabet-arithmetic task participants were presented with an equation such as $A + 3 = D$ to which they were required to respond "True" or "False". Participants experienced one half of the alphabet in the training phase and the other half in the test phase. Logan found that learning from the first phase of the experiment did not transfer to the second phase - participants were as slow at the beginning of the second phase as they were at the beginning of the first phase. From this he concluded that skill acquisition and transfer were specific to the items experienced during training and that no general learning had occurred (Logan, 1988; Logan & Klapp, 1991).

Similar results were found in the lexical decision task where Logan presented participants with 10 words and 10 non-words, repeated 16 times in the training phase. During the transfer phase participants were shown the old items as well as 10 new words and 10 new non-words again repeated 16 times. Reaction times for the new items demonstrated a slight practice effect over blocks, but the reaction time

data for the old items decreased substantially both absolutely and relative to the new item controls. Because these RT reductions occurred for both words and non-words, Logan interpreted these results as further evidence of the specific nature of skill acquisition.

In a study using typographically transformed words Masson (1986) found skill transfer to be highly specific and occurring only when training and test trials shared the same letters in the same case. The experiment involved participants reading words comprised of letters that had been reversed through their vertical axis and so presented as mirror images of the actual letter. In the training phase of the experiment participants were presented with words using only 13 letters of the alphabet. In the test phase Masson (1986) presented three different conditions; words encountered in training, new words using old letters and new words using new letters. The logic behind the experiment was that if participants developed a general algorithm for reading mirror-reversed letters this should generalise to the new words and assist in the reading. If on the other hand transfer was specific to the words encountered during training, only those words would be recognised. Masson found the latter case to be true in that the ability to identify one set of words did not transfer to another, different set of words even if those words contained previously encountered letters (Masson, 1986).

Research by Rickard (1997) using a pound arithmetic task also offers support for the specificity of transfer. Solving pound arithmetic problems such as $4 \# 17 = ?$, involves the execution of a simple three-step algorithm. The first step is to subtract the left-hand side of the equation from the right-hand side (i.e., $17 - 4 = 13$). Second,

1 is added to the result of step 1 (i.e., $13 + 1 = 14$). Finally the result of step 2 is added to the right-hand number (i.e., $17 + 14 = 31$). The experiment involved six separate sessions and comprised of 15 - 21 blocks of trials. The transfer phase occurred immediately after the fifth session and comprised 18 old and new problems. Mean RT for the old problems were significantly different to the RT for the new problems, which demonstrated that learning on this task was highly specific to the items encountered during training.

Lassaline and Logan (1993) offered further evidence in support of the specific nature of skill transfer with their spatial numerosity task. Spatial patterns of between 6 and 11 items were presented to participants who were then required to judge the number of items in each pattern. In the training phase, reaction times increased in a linear relationship with the number of items in the pattern, which would suggest that participants were counting the items in each pattern and so were using an algorithm to perform the task. After practicing the task with a fixed set of patterns over a number of days, there was no difference in response times regardless of the number of items in the pattern. This implies that participants had ceased counting the items and had remembered the number of items in each pattern and so had begun to use memory recall to perform the task. The transfer phase was conducted 12 days later, at which time participants were presented with new patterns. RT returned to the same level as at the beginning of training indicating that no transfer had occurred between the old and new patterns.

However, Palmeri (1997) extended the Lassaline and Logan task by including in the transfer phase patterns that were similar to the old patterns. So in the training phase

participants saw one set of patterns then in the transfer phase they were presented with the old patterns, new patterns that were similar but not identical to the old patterns, and patterns that were completely different. The results of the transfer phase showed that RT for the old patterns was fastest but RT for the similar patterns were faster than RT for the new patterns. So transfer occurred in the Palmeri study but not in the Lassaline and Logan study which used the same task. The results from Palmeri's study indicate that the specific nature of skill transfer can be influenced by the similarity of stored instances. It also indicates that transfer in a particular task can be influenced by the training conditions.

Further investigation by Spelman and Kirsner (1997) using syllogistic reasoning indicated a more general transfer of skill from training to test situation. Participants were required to respond 'True' or 'False' to a series of syllogisms presented via a computer screen in the format:

All artists are beekeepers
All beekeepers are chemists

All artists are chemists

The first two premises were presented to participants, after which they pressed READY, and the premises disappeared and the conclusion appeared on the screen. At this stage participants had to decide whether the conclusion was 'true' or 'false' based on the information in the first two premises.

Although none of the syllogisms were repeated, they all followed the same format and this allowed a general solution to be applied to all problems. Spelman and Kirsner (1997) found that because the participants improved in their ability to solve

the syllogisms when there was no repetition of items it was an indication of general transfer. Participants had learned the solution technique and applied it to all new syllogisms (Speelman & Kirsner, 1997).

Positive transfer has also been shown to occur in category search tasks (Schneider & Fisk, 1984). During training participants were presented with lists of three words, one of which would be a member of a target category. For example, participants had to identify which word from the list *house*, *tractor* and *sword* belonged to the category *weapon*. In the transfer phase participants were given the same categories but had to search for a different word (i.e., *gun* instead of *sword*). Because participants were easily able to identify the new word as being a member of a particular category it demonstrated high positive transfer had occurred.

Other research shows that transfer can be both general and specific in the same task. Greig and Speelman (1999) developed an algebraic equation task $x^2 + 2y =$ with a range of values being substituted for x and y . In the training phase, participants were presented with a small set of x, y pairs, with each pair being presented several times. Phase two comprised the same equation but with a different set of x, y values each presented several times. The results indicated that although reaction times slowed at the beginning of phase two compared to the end of phase one, participants were still faster than in the initial stages of training, demonstrating that some benefit was obtained from the training. Greig and Speelman concluded that, because RT at the beginning of phase 2 was faster than at the beginning of phase 1, participants must have learned something general about the task that could be transferred to phase 2 when a different set of x and y pairs were presented. However, according to Greig

and Spelman, the fact that performance was slowed from the end of phase one to the beginning of phase two implies that the skills acquired in phase one were to some extent specific to the individual x, y pairs presented during phase one.

The Relationship between Task and Transfer

Clearly there is some discrepancy in the literature as to the nature of skill acquisition and its transfer. Masson (1986) and Logan (1988) both found that learning was highly specific and that transfer could not occur between old and new items. Spelman and Kirsner (1997) and Schneider and Fisk (1984) demonstrated that transfer was general when a new task could be solved using the same strategy as an old task. Additionally, transfer has also been shown to be both general and specific (Greig & Spelman, 1998).

The theories proposed to account for the way in which skills are acquired is also contradictory in nature. Logan's instance theory states that transfer of learning can only occur when an identical situation to the one involved in training is encountered, which highlights a fundamental flaw in the theory because other research has demonstrated that transfer to new items can occur (Greig & Spelman, 1998; Spelman & Kirsner, 1997). Both ACT* and EBRW suggest that transfer can occur depending on the training circumstances. All this leaves the initial question as to whether skills obtained in the training environment can be generalised beyond the classroom largely unresolved. The conflicting nature of the research results on the subject, as well as the contradictory theoretical opinions, suggests that no equivocal answer is possible at present.

There is an obvious need for clarification of the situation to determine what combination of circumstances during training leads to effective transfer. The conflicting evidence compiled so far suggests that the disparity of results might be due to the disparate nature of the tasks involved. Some tasks such as the syllogism task used by Spelman and Kirsner (1997) may have inherent properties that make transfer from one domain to another more effective. Whereas other tasks like the reverse reading task used by Masson (1986) might not contain these elements and so transfer is restricted to the items experienced during training.

For example the syllogism task could be solved by identifying the common elements in the two premises and drawing a conclusion about the uncommon elements based on their position in the syllogism. Thus when the conclusion was presented, a decision pertaining to its accuracy could be made quickly. Based on the example given earlier

All artists are beekeepers
All beekeepers are chemists

All artists are chemists

the common element is 'beekeeper'. By then reading the uncommon elements (i.e., artist and chemist) from left to right one determines that all artists are chemists so that when the conclusion is presented it is easy to respond 'true' quickly. Once this strategy is identified by a participant the nature and order of the content words becomes irrelevant, and the strategy is applicable to all syllogisms presented in this manner.

Conversely, in the reverse reading task used by Masson, learning to read the word CAT presented in mirror reverse print in the training phase of the experiment represented no value to the participant who had to read PEN presented in mirror reverse print in the transfer phase. The two tasks share no common ground and no strategy could be developed that would assist in the transfer of learning from one phase to another.

The same argument can be applied to the other tasks used to assess transfer. For instance, in the Schneider and Fisk (1984) category search task, identifying that the word *table* belongs to the category furniture when presented with the list *dog, table, and car* is not particularly onerous. So when the participant is presented with the word *chair* in the transfer phase there is no reason why the recognition that it also belongs to the category *furniture* should take any longer than in the training phase. Consequently it can be argued that the knowledge required to perform this task was so general as to not impede performance when the items were changed.

Conversely the pound alphabet task used by Rickard (1997) would require the same level of processing in the transfer phase as in the training phase. Although the solution of the equation involves the same three specific steps in both phases, each time the numbers were changed new calculations would be needed and so it is unlikely that much improvement could be made in reaction times once the algorithm had been mastered. Therefore it is unlikely that learning from the training phase could be beneficial to the participant in the transfer phase and so not such transfer could occur.

By devising an experiment that presented these tasks under uniform administration conditions that allowed direct comparison of the tasks, it might be possible to identify whether or not transfer is predicated upon inherent properties of the task itself rather than the training conditions per se. If transfer occurred in any of these tasks under controlled conditions, it should be possible to identify which properties in the task enabled transfer.

Conclusion

Evidently there is a degree of conflict in the literature as to the specific nature of skill transfer and it begs the question of how can transfer be specific in some experiments but demonstrate general transfer in others. The answer appears to lie with the task itself and whether or not it contains properties that can be incorporated into a general solution strategy for performing the task. When a task does contain those properties, as in the syllogism task and the category search task, transfer is likely to be general. If on the other hand the task contains no such properties, as in the reverse reading task, the pound arithmetic task and the alphabet-arithmetic task, no general solution strategy can be developed and so transfer is likely to be specific to the items encountered during training.

Of greater concern is the evidence obtained from the spatial numerosity task, which demonstrated specific transfer in the Lassaline and Logan (1993) experiment and then showed partial positive transfer in the Palmeri (1997) study. The results from these two experiments cast doubt over the veracity of Logan's instance theory because in its present form, the instance theory is unable to account for the different levels of transfer that occurred using the same task.

Logan (1988, 1990, 1992; Logan & Klapp, 1991) clearly and emphatically states that prior learning can only be beneficial in performing a new task when both the old and new tasks are identical. The Palmeri (1997) study clearly illustrates that past experience can be analogous to a new situation and this presents a serious problem for the instance theory as there is no provision within the theory to account for performance on a new task benefiting from past experiences that are similar to the new task.

Understandably, Logan developed his theory based on the results of his own research. This involved experiments using the lexical decision task, the alphabet-arithmetic task and spatial numerosity task, none of which contain properties that are likely to result in a general solution strategy being developed. Therefore it is not surprising that the experiments resulted in specific transfer. However, when the spatial numerosity task was presented in a format that enabled participants to benefit from prior exposure to the task it resulted in partial positive transfer.

The conflicting results from the Lassaline and Logan (1993) and Palmeri (1997) experiments alone provide the impetus not only for more detailed investigation of the nature of transfer but also for the refinement of the instance theory itself. Presented in concert with the all the other evidence relative to the specificity of transfer, the only logical conclusion to be drawn is that the nature of skill transfer is a function of the task involved.

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The Specificity of Skill acquisition: Is it Task Related?

Skill transfer refers to the degree to which skills obtained in one area assist in the acquisition or implementation of skills in another area (Greig & Speelman, 1999). In addition, transfer is considered to be general when the skills acquired on one task can be used to assist in the performance of a different task (Masson, 1986). Conversely, transfer is considered specific when skills cannot be generalised to other tasks (Masson, 1986).

Research in this area has generated some conflicting results offering no clear understanding of whether skill acquisition and transfer are specific or general or both. On one side of the debate are theorists who support the 'shared elements' approach to transfer, who argue that when a person encounters a new situation or task, he/she would benefit from past experience in proportion to the number of similarities between the old and new situation (Anderson, 1983; Bovair, Kieras, & Polson, 1990; Kieras & Bovair, 1986; Rosenbloom & Newell, 1987; Singley & Anderson, 1989). In contrast, those arguing for the opposite view state that transfer occurs only when both the old and new task are identical (Compton & Logan, 1991; Logan & Klapp 1993; Logan, 1988, 1990, 1992; Pennington, Nicolich, & Rahm, 1995).

Two modern theories of skill acquisition that characterise this dichotomy of opinions are Logan's Instance Theory of Learning and Anderson's Adaptive Control of Thought Theory (ACT*). Both theories can account for most of the changes that occur with learning and skilled behaviour, but they differ in terms of the specificity of transfer (Greig & Speelman, 1999). Logan's theory predicts that skills are specific

to the contexts in which they are acquired and Anderson's ACT* Theory predicts both general and specific skills depending on the training conditions.

Logan's Instance Theory

Logan's (1988, 1990, 1992) Instance Theory of Automisation states that learning is based on exposure to specific events and that for each exposure a memory is stored. These memories are called instances in this theory. The more exposure a person receives to a given stimulus the more instances are available for retrieval. Logan argues that faster reaction times (RT's) on a task are a function of the amount of practice with a task a person has experienced. Faster retrieval of information is a direct result of the increased number of instances available for retrieval rather than refinement of a general solution strategy.

Logan's Instance Theory is fundamentally a memory based theory predicated upon three main assumptions: Firstly that encoding into memory occurs as an "obligatory, unavoidable consequence of attention" to a stimulus (Logan, 1988, p. 493); secondly, that having attended to a stimulus, retrieval from memory of anything associated with the stimulus is obligatory and unavoidable; and thirdly, that each individual encounter with a stimulus is encoded, stored and retrieved separately.

The accumulation of separate memories, or instances, of a particular situation or stimulus results in a learning mechanism whereby practice ultimately results in a transition from algorithmic processing to memory-based processing (Logan, 1988). Logan argues that each episode connected with a particular stimulus has an equal chance of retrieval so that every time a person performs a task the memory process

and the algorithm compete in a metaphoric 'race'; the process that produces a solution first controls the response. Retrieving an instance is simply recalling the past solution to the problem, so the 'race' is in effect between generating a solution (i.e., algorithm) and remembering an answer (i.e., instance). In the novice stage there are fewer instances available for retrieval and so the algorithm is more likely to win. As the individual becomes more skilled, a greater number of instances are stored and this increases the probability of one of them being retrieved faster than the processing of the algorithm. Consequently, instance retrieval eventually dominates the race (Compton & Logan, 1991; Rickard, 1997).

Due to the nature of the instance theory, Logan predicts that there can not be any transfer between tasks. According to Logan, skill acquisition is based on an accumulation of instances that are highly specific to the stimuli encountered. As a result, performance on a new task, albeit with similar stimulus conditions, would not be enhanced by past learning. This implies that new problems, regardless of any similarity to old problems, are treated as if they are completely new (Greig & Speelman, 1999).

Palmeri (1997) extended to the instance theory by allowing past experience to benefit current performance on a task if the two tasks involved similar stimuli. In his exemplar-based random walk model (EBRW), Palmeri incorporates both Logan's instance theory and Nosofsky's (1986) generalised context model of categorisation (GCM). In Palmeri's EBRW model, instances are retrieved with rates proportional to their similarity to the current stimulus, therefore providing the flexibility needed for similarity between stimuli to be of benefit in performing a task.

Anderson's ACT Theory*

Underlying Anderson's theory is the distinction between declarative and procedural knowledge. Declarative knowledge is what an individual knows - knowledge about facts - whereas procedural knowledge is the 'how' of an action or procedure.

Anderson states that these two types of knowledge differ fundamentally in their role in skill acquisition (Anderson, 1983).

The use of declarative information is slow and ponderous in that every fact relating to a stimulus has to be retrieved from long-term memory before it can be held in short term memory for assessment in terms of its appropriateness to the situation.

This declarative information is then operated on by weak problem solving processes such as analogy or means-end analysis. These problem solving processes are referred to as weak because they can be applied to a range of problems and are not tied to any particular problem type. This process results in the formation of production rules that form the basis of procedural knowledge.

Production rules are a series of 'if - then' or 'condition-action' statements such that when the 'if' component is matched with information stored in memory a particular outcome or action is performed - the 'then' component (Anderson, 1983). With practice execution of these productions becomes more efficient and therefore faster. Thus a general strategy for performing is developed and refined with practice on the task (Pirolli & Anderson, 1985).

According to ACT* any improvement in performance is a consequence of composition, proceduralisation and strengthening. Composition involves several

production rules being collapsed or refined into simpler rules. These new rules must occur in sequence and share the same ultimate goal; they just achieve the result in fewer steps (Anderson, 1983). The critical aspect to note here is the reduction in processing steps results in faster processing and execution of the task but does not change the goal or nature of the task (Anderson, 1983).

Proceduralisation represents the transition from slow declarative knowledge to faster automatic procedural knowledge. It occurs by integrating domain specific information into productions, thereby restricting the realm of application of the production and eliminating the need to maintain large amounts of general knowledge in working memory (Anderson, 1983). This reduction in demand on working memory results in an improvement in both speed and accuracy of performance.

Finally, every time a production is successfully applied the production gains strength resulting in a higher probability that it will be utilised in future. However, unlike compilation and proceduralisation, strengthening does not qualitatively change the productions and is associated with smaller improvements in performance. Hence it is often associated with the flattening of the learning curve as it approaches asymptote (Anderson, 1983).

Contrary to Logan's Instance Theory, ACT* predicts transfer of skills from one domain to another depending on the number of productions developed to perform one task that can be utilised in performing a second task (Singley & Anderson, 1989). Thus transfer between tasks that share the same strategy should be high although not necessarily complete. Although Anderson (1982, 1987) has reported

evidence in support of this view of transfer, there has been some criticism of this view. For example, Carlson and Schneider (1989) suggested that it is difficult to identify which productions are actually utilised in any particular task and that production models can be devised post hoc to account for any amount of transfer, making it virtually impossible to falsify the theory.

Anderson (1987) recognises this criticism and agrees that it is difficult to predict the amount of transfer that will occur because participants are unable to verbalise the actual productions in use. However, empirical research has consistently supported the prediction that transfer will occur between tasks as a function of the amount of shared procedural knowledge necessary to perform the task (Corbett & Anderson, 1992; Greig & Spelman, 1999; Frensch, 1991; Kieras & Bovair, 1986; Singley & Anderson, 1989; Spelman & Kirsner, 1997).

Transfer

The ACT* and instance theories make different predictions relating to transfer. As mentioned previously, ACT* states that transfer between tasks will occur as a function of the number of shared productions between the tasks. The amount of transfer is directly related to how applicable the production rules developed with one task are to the performance of another task; the more closely the two tasks are related the greater the amount of transfer (Anderson, 1982, 1987). This is not to say that the similarity of tasks is all that determines transfer. Singley and Anderson (1989) demonstrated that negative and zero transfer could occur between tasks that on the surface appear to be alike. So it is the shared components not superficial similarity of

tasks that dictates transfer (Anderson, 1987; Frensch, 1991; Newell & Rosenbloom, 1986; Spelman & Kirsner, 1997).

In contrast, Logan predicts that there can be no transfer between tasks as skill acquisition is based on past instances of performing a task. Experience of one situation cannot advantage the individual in a new situation because there can be no stored information pertaining to the new situation (Logan, 1988; 1990). Logan (1988) supported this position with a series of experiments based on both lexical decision and alphabet-arithmetic tasks. In the alphabet-arithmetic experiments participants were presented with an equation such as $A + 3 = D$ to which they were required to respond "True" or "False". Participants experienced one half of the alphabet in the training phase and the other half in the test phase. Logan found that learning from phase one did not transfer to phase two of the experiment - participants were as slow at the beginning of the second phase as they were at the beginning of the first phase. From this he concluded that skill acquisition and transfer were specific to the items experienced during training and that no general learning had occurred (Logan, 1988; Logan & Klapp, 1991).

In a different study using typographically transformed words, Masson (1986) found skill transfer to be highly specific, occurring only when training and test trials shared the same specific features. The experiment involved participants reading words comprised of letters that had been reversed through their vertical axis and so presented as mirror images of the actual letter. In the training first phase of the experiment participants were presented with words using only 13 letters of the alphabet. In the test phase Masson presented three different conditions; words

encountered in training, new words using old letters and new words using new letters.

The logic behind Masson's experiment was that if participants developed a general algorithm for reading mirror-reversed letters this should generalise to the new words and assist in the reading. If on the other hand transfer was specific to the words encountered during training, only those words encountered during training would be recognised. Masson found that the ability to identify one set of words did not transfer to another, different set of words even if those words contained previously encountered letters (Masson, 1986).

Further investigation by Spelman and Kirsner (1997) using syllogistic reasoning indicated a more general transfer of skill from training to test situation. Participants were required to solve a series of syllogisms. Although none of the syllogisms were repeated, they all possessed the same structure and this allowed a general solution to be applied to all problems. Spelman and Kirsner (1997) found that because the participants improved in their ability to solve the syllogisms when there was no repetition of items it was an indication of general transfer. Participants had learned the solution technique and applied it to all new syllogisms (Spelman & Kirsner, 1997).

Other research shows that transfer can be both general and specific in the same task.

Greig and Spelman (1999) developed an algebraic equation task $\frac{x^2 + 2y}{2} = A$ with a range of values being substituted for x and y. In the training phase, participants were presented with a small set of x and y pairs with each pair being presented

several times. Phase two comprised the same equation but with a different set of x and y values each presented several times. The results indicated that although reaction times slowed at the beginning of phase two compared to the end of phase one, participants were still faster than in the initial stages of training demonstrating that some benefit was obtained from the training. Greig and Spelman concluded that, because RT at the beginning of phase two was faster than at the beginning of phase 1, participants must have learned something general about the task that could be transferred to phase 2 when a different set of x and y pairs were presented. However, according to Greig and Spelman, the fact that performance was slowed from the end of phase one to the beginning of phase two implies that the skills acquired in phase one were to some extent specific to the individual x and y pairs presented during phase one.

The Present Study

Clearly there is some discrepancy in the literature as to the nature of skill acquisition and its transfer. Masson (1986) and Logan (1988) both found that learning was highly specific and that transfer could not occur between old and new items. Spelman and Kirsner (1997) demonstrated that transfer was general when a new task could be solved using the same strategy as in an old task. Additionally, Greig & Spelman (1998) showed that transfer could be both general and specific.

The hypothesis under test in the present study was that conflicting evidence regarding the specificity of skills is task related. That is, the task itself predicts the amount of learning (skill acquisition) and therefore the amount of transfer that occurs. Those tasks that result in specific skill transfer do so because they are

inherently specific; that is, there are no features in the task that can be incorporated into a general performance strategy and so no such strategy can be developed that could facilitate transfer to another version of the task. Conversely a task that demonstrates general transfer does so because it contains properties that can be useful when used to perform a different version of the task. Each of the four tasks highlighted above differs in its ability to develop general skills. The Masson reversed word task involves people learning to read words with the letters presented in mirror reversed form. It is unlikely that exposure to the letter C presented backwards in the training phase can assist the participant when he/she is presented with the letter F presented backwards in the transfer phase. Thus no general strategy is likely to be developed that can transfer from one phase to the next.

The same appears to be true for the alphabet-arithmetic task used in the Logan experiments. Being presented with $A + 3 = D$ during training is unlikely to provide any benefit when it comes to solving $G + 4 = K$ in the transfer phase. These two problems, for example, involve different regions of the alphabet, and so counting through the alphabet to solve each problem would not involve any of the same letters. The only element that the two problems share is counting and it is likely that for most of the participants in Logan's study, the ability to count was already at the optimal level. Thus there appears little that one could learn about this task with one set of letters that could transfer to performing the same task with a different set of letters.

In contrast the syllogism task developed by Spelman and Kirsner (1997) demonstrated general transfer because all the syllogisms could be solved using the

same strategy, thus making the content and format of the syllogisms irrelevant in terms of the participants ability to solve them. In the Greig and Spelman algebra task transfer was shown to be both general and specific. Participants were able to learn the steps involved in solving the equation in phase one and transfer that knowledge across to phase two because the format of the equation remained constant throughout the equation. However, because the values for x and y changed in the second phase, no learning in terms of the actual $x - y$ pairs from phase one could be transferred to phase two. Thus transfer in terms of the $x - y$ pairs was specific and transfer in terms of the equation was general.

The aim of the present study was to test the two predictions; (1) that if learning occurred in the absence of repeated items it should predict transfer in the task from one set of items to another and; (2) the nature of the task will determine the specificity of that transfer. If learning occurs without repetition of items, this would suggest that participants do not rely on memory for past solutions, but instead use an algorithm to perform the task. That is, in the early stages of performance, when RT is slower, participants develop a strategy to perform the task. With practice on the task the algorithm is refined so that performance is faster and more efficient.

If learning occurs under these conditions it would be logical to assume that when participants are presented with a different version of the task that the likelihood of transfer occurring would be dictated by the efficiency of the algorithm. The specificity of the transfer would depend on the ability of the strategy to generalise to a different item set. If the task lends itself to a general solution strategy, that strategy should apply when different items are presented within the framework of the same

task. If the task generates a strategy that is dependent upon the specific items being presented, then the strategy will not generalise to the new items and transfer would not occur.

To test these assumptions the experiment was divided into three phases and the four tasks highlighted earlier were all compared directly. Phase one of the experiment was designed to examine the amount of learning that occurred in the absence of repeated items. If learning occurred during this phase it would indicate the development of an algorithm that could be used to perform the task regardless of the actual items presented and therefore should predict the amount of transfer that occurred in the transfer phase. Based on the evidence of past research that showed the syllogism task demonstrated the highest degree of transfer it was predicted that the syllogism task would demonstrate the most learning in phase one. With the exception of the syllogism task none of the other tasks had previously been presented using no repetition of items so there was no precedent for anticipating the amount of learning that would occur in each task under these conditions. However, based on the amount of transfer that had occurred with the tasks in previous research it was predicted that the algebra task would show the second highest learning rate followed by the alphabet-arithmetic task and the reverse reading task.

In the training and transfer phases (phases 2 & 3) participants encountered a different task to the one in which they were involved in phase 1. These phases each comprised 10 items repeated ten times making 100 items in total, with different items in each phase. This aspect of the study largely replicated previous experiments using these tasks with the exception of the syllogism task. In the previous studies, the algebra,

alphabet-arithmetic and reverse reading tasks were all presented to participants as a small set of items repeated a number of times. In the original syllogisms task no items were repeated during the training or transfer phases. In the present study in order to maintain uniform methodology across the tasks the syllogism task was presented in an identical format to the other three tasks; namely 10 items repeated ten times.

The design of this experiment allowed a direct comparison of the amount of transfer that occurred across the different tasks. It also enabled examination of the relationship to be made between the pattern of transfer and the pattern of learning that occurred in phase one. The hypothesis under test in this experiment predicts that the more learning that occurred in a particular task in phase one, the greater will be the degree of transfer on that task between phases two and three. Based on the results of previous research using these tasks, it was predicted that the syllogism task would demonstrate general transfer, the algebra task would show general and specific transfer and both the alphabet-arithmetic and reverse words tasks would result in zero transfer.

Method

Design

Participants were randomly assigned to one of four groups with each group comprising 15 people. Each group received training in phase 1 on one of the four tasks (i.e., syllogistic reasoning; alphabet -arithmetic; algebraic equation; mirror reverse words).

Following phase 1 each group was further sub-divided into three, making 12 sub-groups in total, each comprising 5 participants. Each sub-group experienced two more phases (phases 2 & 3) where they performed a different task to the one encountered in phase 1.

Participants

Volunteers were recruited from the Edith Cowan University School of Psychology's research participant's register. A total of 74 individuals were tested. However, 14 failed to meet the performance criterion of 80% accuracy in one or more of the phases and were omitted from the analysis. The remaining 60 participants comprised 46 females aged 17 - 62 years (mean age = 29.22 years) and 14 males aged 17 - 52 years (mean age = 28.14 years). Participants were randomly assigned to groups.

Prior to the commencement of testing each participant was given a written explanation of the study which gave sufficient information pertaining to the study to ensure informed consent without explaining the expected outcomes (See Appendix A).

Materials

Three Apple Macintosh G3 computers running Superlab software were used for stimulus presentation and response recording.

Procedure

General instructions and procedures were the same for all four tasks. Only the instructions pertaining to the solution of the individual problems differed. The basic format of the exercise was explained to each participant verbally. They were told that a problem would appear on the screen that they were required to solve mentally.

When they knew the answer they were to press the spacebar, which would cause the problem to disappear and bring a stimulus on to the screen. The participant then had to decide whether the stimulus was 'TRUE' or 'FALSE' for that particular problem.

For a 'TRUE' response participants were to press the 'Z' button on the keyboard, and for 'FALSE' they had to press the 'X' button. After the participant had made a response, feedback was given in the form of a statement appearing on the screen saying either 'CORRECT' or 'INCORRECT'.

Written instructions reminding the participants which buttons to press were provided and left with the participant. In addition the 'Z' button on the computer keyboard was covered with a green sticker marked 'TRUE' and the 'X' button was covered with a red sticker marked 'FALSE' as a visual reminder of which keys to use. Participants were told to work as quickly as they could without sacrificing accuracy.

Once the general procedure for all the tasks was explained, two practice items were presented in order to illustrate the specific task undertaken in phase 1. Following

these practice items a message appeared on the screen saying "Press spacebar to start experiment" at which stage the participant was given the option of continuing with the experiment or repeating the practice items. Similar practice items were also presented at the beginning of phase 2, but not at the beginning of phase 3 (See Appendix B).

Each phase took approximately 20 minutes so that each participant spent one hour on the computer. They were told that they could rest between phases but not to stop in the middle of a phase. At the end of the session participants were debriefed and thanked.

Syllogism Task. The syllogism task involved participants solving syllogisms such as:

All artists are beekeepers	} premises
All beekeepers are chemists	
All artists are chemists	conclusion

A typical trial started with the presentation of the two premises. When the spacebar was pressed the first two premises disappeared and a conclusion appeared. At this stage the participant had to decide if the conclusion was correct based on the information contained in the premises. For instance, in the above example the conclusion is correct and the appropriate response would be "TRUE". False conclusions were also presented. In the above example, a conclusion that would have required a "FALSE" response would be "All chemists are artists".

The Phase 1 version of the syllogism task comprised 80 trials with no repetition of items or content words. That is, no syllogism appeared more than once and none of the key words (e.g., beekeepers, chemists, artists, etc.) were repeated. The Phase 2 version had 100 trials with 50 having a "TRUE" conclusion (e.g., All artists are chemists) and 50 having a "FALSE" conclusion (e.g., All chemists are artists).

In phase 2 one set of syllogisms was presented that was repeated ten times. Of these syllogisms five were presented as in the order presented earlier. This syllogism has an ABBC order, which refers to the ordering of the elements within the premises (i.e., A for artist, B for beekeeper, and C for chemist). The remaining five syllogisms were presented in a BCAB order which is similar to the previous example but with the premises presented in reverse order, for example:

All beekeepers are chemists
All artists are beekeepers

All artists are chemists

Note that the ABBC and the BCAB syllogisms have the same 'TRUE' conclusion. The "FALSE" trials differed only in that the conclusion was the converse of the 'TRUE' conclusion and hence incorrect (e.g., all chemists are artists). Phase 3 followed the same format as phase 2 except a completely different set of syllogisms was used.

Alphabet- Arithmetic Task. In the alphabet-arithmetic task participants were required to judge statements such as $A + 3 = D$ as "TRUE" or "FALSE". The letter "A" was to be considered a starting point in the alphabet and the number "3" denoted

the number of letters forward in the alphabet from this point that the solution (i.e., the letter D) was supposed to occur. In this example the appropriate response is "TRUE". In the "FALSE" trials the solution letter was either one letter more or one letter less than the correct one. In respect to the previous example, false stimuli would be $A + 3 = C$ or $A + 3 = E$.

In the Phase 1 version of the alphabet-arithmetic task, participants experienced 80 trials with no repetition of number-letter association. Letters from the entire alphabet and numbers 1 to 5 were used in the stimuli. For example if 'A + 3' was presented it would not have been repeated. Instead the letter 'A' would be paired with a different number (e.g., A + 5). In addition if the "TRUE" version of a number-letter pair was presented, (e.g., $A + 3 = D$) the "FALSE" version (i.e., $A + 3 = C$ or E) was not, and vice-versa.

In a typical trial, participants were presented with a statement such as $A + 3 = ?$ on the screen. After the spacebar was pressed the equation disappeared and a solution appeared on the screen. If the problem was $A + 3 = ?$, then a "TRUE" answer would be D and a "FALSE" answer would be either C or E. The participant was required to compare the presented answer with the solution they had generated and respond to "TRUE" or "FALSE" by pressing the appropriate key on the keyboard.

The Phase 2 version of the task involved 100 trials with 50 being "TRUE" and 50 being "FALSE". The "TRUE" condition presented 10 letters (i.e., A-J) always paired with the same number (2-5). So the letters A, E, and I were always paired with the number 2; B F and J were paired with 3; C and G were paired with 4; and D and H

were paired with 5. The "FALSE" trials had the same restrictions as the "TRUE" trials but comprised 25 items where the presented value was one more than the correct value (e.g., $B + 4 = G$) and 25 items where the presented value was one less than the correct value (e.g., $B + 4 = E$). Thus the 100 trials consisted of the 10 letter-number pairs repeated 10 times. Phase 3 involved 100 trials under identical conditions to phase 2 but used a different set of letters (e.g., K-T).

Algebra Task. The algebra task involved participants solving the equation

$$\frac{x^2 - y}{2} = A \text{ with supplied values for the } x \text{ and } y \text{ parameters. For example with } X = 5$$

and $Y = 9$ the equation becomes $(25 - 9) \div 2 = 9$. On a typical trial, the equation was presented in the centre of the screen with the values for x and y presented below the equation. Participants were required to calculate a value for 'A' and to press the spacebar when this was completed. When the spacebar was pressed the equation and $x - y$ values disappeared and a value for 'A' was presented. For the "TRUE" trials the value for A was correct. In the example above $A = 8$. For the "FALSE" trials the value for 'A' that was presented was either one more or one less than the correct response (i.e., in the above example $A = 9$ or $A = 7$).

The Phase 1 version of the task comprised 58 trials, which involved repetition of individual values for x and y but not $x - y$ pairings. So a participant saw $X = 5$ and $Y = 9$ in only one trial, but would see $X = 5$ and $Y = 7$ in another trial. In the phase 2 version of the task there were 100 trials comprising 10 specific $x - y$ pairings (See Appendix B for specific x and y values). Each of these $x - y$ pairs were repeated 10 times in random order, in addition, if the "TRUE" version of a specific $x - y$ pair was presented the "FALSE" version of that $x - y$ pair was not and vice versa. Of the 100

trials 50 required a "TRUE" response (5 in each block of 10 trials). That is, the presented value for A was correct (e.g., $A = 8$). The remaining 50 trials were "FALSE" trials (5 in each block of 10 trials), where the presented value for A was either one more (25 trials) or one less (25 trials) than the correct value (e.g., $A = 9$ or $A = 7$). The Phase 3 version of the task was similar to the phase 2 version but different values for x and y were used.

Mirror Reversed Reading Task. In the mirror reversed reading task participants were presented with words, which were in correct letter order but each letter appeared in mirror reversed form (reversed through the vertical axis). On each trial participants were required to read the word and be prepared to make a rhyming judgement about the word. When they were ready to make this judgement the participants pressed the spacebar on the keyboard causing the original word to be replaced by another word in normal type font.

The Phase 1 version of the task was comprised of 80 trials with no repetition of words. Trials consisted of four to seven letter words using all letters and both upper and lower cases. In the phase 2 and phase 3 versions the alphabet was divided into two groups, duplicating the division made by Masson (1986), who reported four experiments, all of which used the same division of letters. The Phase 2 version was comprised of 100 trials with words constructed from the letters ABDGIJKNQS with no repetition of words. The phase 3 version was similar but the letters CEFHLMOPRTWYZ were used. All three task versions contained equal numbers of both "TRUE" (i.e., word pairs did rhyme) and "FALSE" (i.e., word pairs did not

rhyme) trials. Although there was no repetition of stimulus words in this task there obviously needed to be repetition of letters.

Results

Median scores for each block of ten trials were calculated for each participant for all tasks. In phase 1 of the experiment the focus was on the amount of learning that occurred in the absence of repeated items. A measure of the amount of learning that occurred in phase one was calculated in terms of a percentage rate (i.e., $(\text{block 1 mean} - \text{block 8 mean}) \div \text{block 1 mean} \times 100$) for each task. An additional percentage was calculated to determine the amount of learning that occurred in each block by dividing the overall learning rate by the number of blocks of trials in each task. Descriptive statistics, along with the percentage learning rate by block and the overall percentage learning rate by task are presented in Table 1. A one-way analysis of variance (ANOVA) was also conducted to compare learning rates between the tasks.

In phases 2 and 3 of the experiment the emphasis was on whether any transfer occurred and, if so, to what degree. To identify whether transfer occurred in a particular task, a t test was conducted to compare the mean RT for block 1 of phase 2 with the mean RT for block one of phase 3. Any differences between these mean RT's for each task were converted to percentage transfer values (i.e., $(\text{block 1 phase 2} - \text{block 1 phase 3}) \div \text{block phase 2} \times 100$). A comparison of the extent of transfer that occurred in each task needed to take into account the different nature of the tasks. Thus it was important to interpret the amount of transfer that occurred on a particular task between phases 2 and 3 in terms of the amount of learning that occurred on that task in phase 2. In this way individual differences in degree of difficulty between the tasks would be equated and a comparison of the amount transfer that occurred in each task could be made. To achieve this a savings measure was used that calculated

the amount of time saved in phase 3 due to the learning that occurred in phase 2. This entailed identifying where in phase 3 participants regained the RT speed that they had at the end of phase 2 (e.g., (total number of blocks in phase 3 - phase 3 block at which phase 2 trial RT achieved) ÷ total number of blocks in phase 3 x 100). A further t test was conducted to assess the amount of slowing in RT between the start of phase 3 and the end of phase 2 (i.e., block 10 phase 2 and block 1 phase 3). An ANOVA was also conducted using the percentage measures to compare transfer between tasks.

Table 1. Descriptive Statistics by Task, Percentage Learning by Block and Overall Learning Rate By Task for Phase 1 Data.

Task	Block	Mean (ms)	SD (ms)
Syllogism	1	10657	7747
	2	9441	8061
	3	8922	10710
	4	5447	3444
	5	3977	1958
	6	3645	2185
	7	4085	2235
	8	4169	2463
% Learning (total)		61%	
% Learning (block)		7.6%	
Alphabet-Arithmetic	1	5078	1365
	2	4302	1310
	3	4008	1200
	4	4068	1937
	5	3657	1334
	6	4035	2123
	7	3291	1447
	8	3319	1002
% Learning (total)		35%	
% Learning (block)		4.3%	
Algebra	1	11201	4117
	2	7446	3924
	3	9666	2763
	4	9164	3316
	5	8952	2856
	6	8571	3564
% Learning (total)		24%	
% Learning (block)		3.9%	
Reverse Reading	1	2729	1804
	2	1875	848
	3	1754	667
	4	2375	3029
	5	1624	676
	6	1782	1015
	7	1486	612
	8	1432	743
% Learning (total)		48%	
% Learning (block)		5.9%	

Phase 1

The focus of phase one of the study was to assess the amount of learning that occurred in the absence of repeated items. The results indicated that the greatest amount of learning occurred in the syllogism task where participants exhibited an overall learning rate of 61% and a learning rate per block of 7.6%. This was followed by the reverse reading task with an overall learning rate of 48% and a learning rate per block of 5.9%. The alphabet-arithmetic task showed a learning rate of 35% overall and 4.3% by block, with the algebra task demonstrating the least amount of learning with an overall learning rate of 24% and a per block rate of 3.9%. The differences in learning rate per block, however, were not significant $F(56) = .176, p = .912$.

Because learning occurred when no items were repeated during this phase of the experiment, the results suggest that participants were able to develop a strategy to perform the tasks. Due to the lack of significant difference between the learning rates of each task caution should be exercised in drawing conclusions from these results. However, the results suggest a trend that implies the effectiveness of the strategies developed by participants, varied between the tasks as illustrated by the different learning rates. These results also call into question Logan's (1988) assertion that learning can only occur when items are repeated.

Phase 2 and 3

Transfer occurred in the syllogism and algebra tasks because performance was faster in block 1 phase 3 than in block 1 phase 2 (syllogism task: $t(14) = 2.262, p = .040$; algebra task $t(14) = 5.551, p = .000$). The comparative measure of transfer indicated

that in the syllogism task there was 48.4% of transfer between the two phases and in the algebra task there was 38% transfer. The alphabet- arithmetic task demonstrated transfer but it was only 8.2% and the t test was not significant $t(14) = 1.163$, $p = .264$. There was zero transfer in the reverse reading task $t(14) = -1.913$, $p = .076$, the percentage of transfer was -15%. The pattern of transfer in this phase of the study from most to least was syllogism, algebra, alphabet-arithmetic and reverse reading. This pattern was not predicted by the pattern of learning from phase one but it was predicted by previous research using these tasks. Mean RT for each block of trials in phase 2 and 3 is shown in Figure 1.

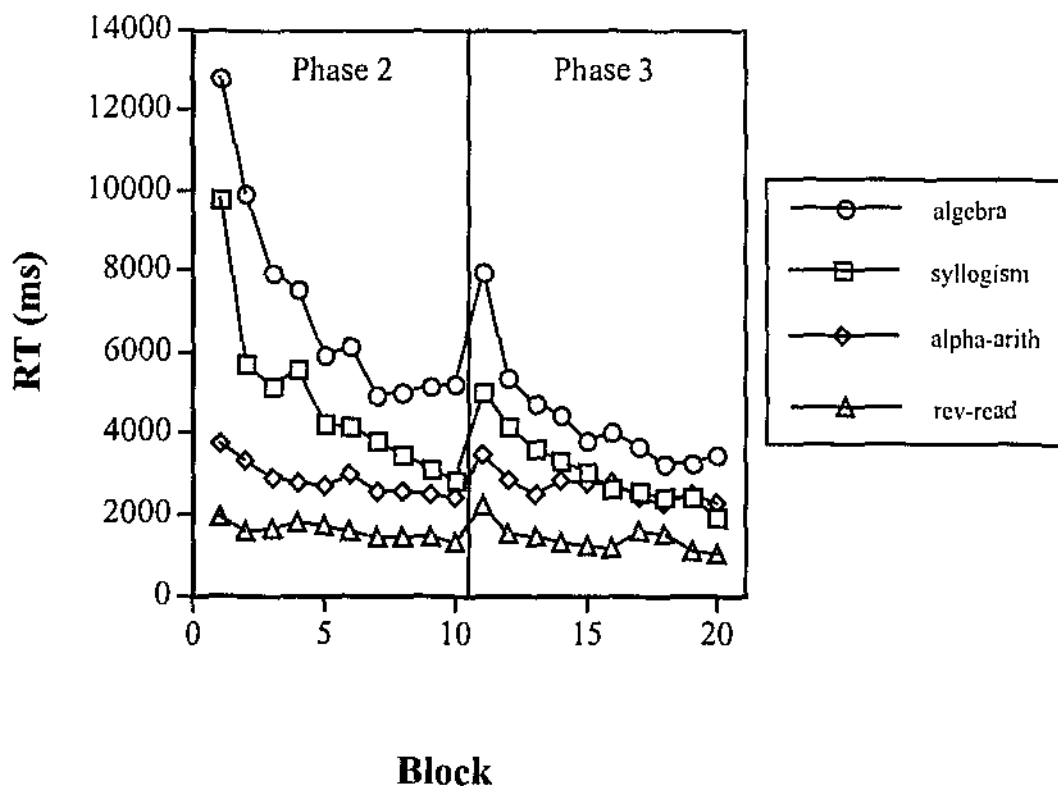


Figure 1. Mean training and transfer reaction times by task

There was a significant effect for the slowing of RT between the end of phase 2 and the beginning of phase 3 in all four tasks. For the syllogism task $t(14) = -2.844$, $p =$

.013.; alphabet-arithmic task $t(14) = 3.214$, $p = .006$; the algebra task $t(14) = -2.316$, $p = .036$; and the reverse reading task $t(14) = -5.666$, $p = .000$. In the case of the reverse reading task RT at the beginning of phase 3 was slower than the beginning of phase 2 indicating that performance on this task was worse at the beginning of phase 3 than at the beginning of phase 2.

In terms of the savings measure to assess how quickly participants were able to regain their phase 2 RT the algebra task demonstrated the most rapid return to pre-transfer RT. Participants achieved their pre-transfer RT by block 3 resulting in 70% savings on this task. The algebra task was followed by the reverse reading task with participants regaining phase 2 RT by block 4 of phase 3, thus resulting in 60% savings. In the syllogism task participants regained their pre-transfer RT by block 6 which indicated 40% savings and in the alphabet-arithmic task participants regained their phase 2 RT speed by block 7 phase 3 resulting in 30% savings.

Discussion

The results failed to support the hypothesis that the amount of learning that occurred in phase 1 would predict the amount of transfer between phase 2 and 3, although this could be the result of the design of the study rather than the hypothesis being incorrect. The second hypothesis; that the type of transfer is directly related to the task involved, was supported by the results of this study as indicated by the different types of transfer observed in the different tasks.

As stated earlier, the results from phase one of this study failed to reach significance; statistically there was no difference between the learning rates of the different tasks. Therefore it would be incorrect to attach too great an importance to the trend of learning in the tasks, and any discussion of this phase must be conducted in the context of there being no significant difference between the tasks. Having said that there are some interesting issues to arise from this phase of the experiment.

On face value, the phase one data suggested a trend of learning in the order of - syllogism task, reverse reading task, alphabet-arithmetic task, and algebra task with the syllogism task demonstrating the most learning and the algebra task the least. This pattern was unexpected because, based on the evidence of past research, it was expected that the reverse reading task would have shown the least amount of learning and the algebra task would have been second highest after the syllogism task.

One possible explanation for this result is that in the original algebra experiment Greig and Spelman (1998) used a small set of x, y values, which were repeated

several times in the training phase. In performing the task in this way, participants were likely to have refined a strategy for performing the task but also developed memories of the specific $x - y$ pairs. This suggests that performance in the original experiment was a combination of refined strategy and efficient memory recall. In the present study, participants were presented with 80 items with no repetition of specific x, y pairs, so performance was based solely on the development and refinement of a strategy.

The results of the present study indicate that it took participants some considerable time to develop an effective strategy to perform the algebra task and this resulted in a learning rate of only 24%. It also suggests that the absence of repeated items encourages the development of an algorithm to perform a task, whereas the repetition of items encourages the use of memory.

In terms of the learning rate in the reverse reading task, this could also be accounted for by the design of the study. Although there was no repetition of words in this phase of the study, there are only 26 letters in the alphabet, consequently there has to be repetition of letters. It is possible that over the course of the 80 items, participants became adept at recognising the shape of the individual letters and so were able to read the reversed word quite easily by the end of this phase.

Conceivably it could be argued that it was the design of the study that resulted in the phase one learning rate failing to predict the transfer in phases two and three rather than the hypothesis being incorrect. If the study was replicated using tasks where

there was no repetition at all, using a much larger sample size, it might be possible to draw a definite conclusion regarding this issue.

The amount of learning that occurred in phase 1, in the absence of repeated items cannot be accounted for by Logan's theory in its present form. Because there was no repetition of items no instances could be retrieved, which in terms of the instance theory means there should be no learning. Logan stipulates that instances are stored individually every time a stimulus is encountered, and that those instances are highly specific to the stimulus. However, if the instances were allowed to be more abstract they might be applied to situations where similarities between stimuli exist, in this way the theory could account for learning in the absence of repeated items (Rickard, 1997; Spelman & Kirsner, 1997).

It was this assumption that formed the basis for Palmeri's (1997) EBRW theory of learning, which states that the specific nature of transfer can be influenced by the similarity of examples in memory. According to EBRW, memory exemplars are retrieved in proportion to their similarity to the stimulus presented. In this way items that are similar, but not identical, to the current stimulus could be of benefit in a new version of an old task. This is similar to the propositional theory introduced by Logan and Etherton (1994) that holds instances to be propositions that are capable of expressing similarities between instances. If the instance theory were to be modified in this way it would be able to account for the level of learning that occurred in phase one of the present study when no items were repeated.

However, the improvement in performance witnessed in phase one of the experiment can be accounted for by ACT*. It is evident that participants were able to develop a strategy to perform the various tasks and the refinement and strengthening of the productions used in the performance of the tasks led to the improvement in RT (Anderson, 1983, 1987, 1993; Spelman & Kirsner, 1997). That some tasks demonstrated more learning than others did implies that some tasks were better able to generate a solution strategy than others.

The pattern of results pertaining to the amount of transfer that occurred in phases two and three supports previous research using these tasks. Both the syllogism and algebra tasks demonstrated partial positive transfer, albeit to different levels. The alphabet-arithmetic task showed some transfer but not to a statistically significant level and therefore is considered to be zero. The reverse reading task also showed zero transfer but in this case RT at the start of phase 3 was slower than at the start of phase 2, indicating that performance at the start of the transfer phase was worse than at the start of the training phase.

Although the syllogism task demonstrated transfer it was not complete transfer as demonstrated by Spelman and Kirsner (1997). Again this result could be an artefact of the design of the present study. In the original Spelman and Kirsner experiment there was no repetition of any syllogisms in either the training or transfer phases. Whereas in the present study ten syllogisms, each repeated ten times, were presented in the training and transfer phases. This suggests that the different levels of transfer that occurred in the two studies can be accounted for by the different training and transfer conditions.

The Spelman and Kirsner results suggest that due to the lack of repetition, participants developed an algorithm for solving the syllogisms and this was transferred effectively from the training phase to the transfer phase of the study. In contrast, the repetition of syllogisms in this study indicates that although participants developed an algorithm in the training phase and transferred it to the transfer phase, they also relied on their memory of the correct conclusion to specific syllogisms. Because new syllogisms were presented in the transfer phase those memories would not have benefited the participant in the transfer phase. Therefore, general learning from the training phase (i.e., the algorithm) was beneficial in the transfer phase, but the specific learning (i.e., the correct conclusion to specific syllogisms) was not beneficial in the transfer phase. Consequently, RT slowed significantly at the start of phase three compared to the end of phase two, but was not as slow as at the beginning of training.

This pattern of results was also found in the algebra task and supports the previous research by Greig and Spelman (1998) who found transfer can be both general and specific within the same task. It also supports the suggestion made previously that the repetition of specific items encourages participants to use memory based retrieval to perform the task, whereas lack of repetition forces them to develop and refine an algorithm.

The lack of transfer observed in the alphabet-arithmetic task again supports previous research using the task where transfer was found to be highly specific to items experienced during training (Logan, 1988; Logan & Klapp, 1991; Klapp, Boches, Trabert & Logan, 1991). The results obviously support the instance theory that no

transfer would occur due to there being no stored instances of the new stimulus items. However it can also be accounted for by the ACT*, in that although both phase 2 and 3 involved the same task, the solution strategy utilised in phase 2 was not generalisable to the items encountered in phase 3.

In his original experiment, Logan (1988) remarked that participants reported their strategy as; saying the alphabet to themselves until the target letter was reached and then incorporating the digit addend to arrive at an answer, participants in the present study reported using this same strategy. Naturally if this strategy was applied to the second phase of the study, which utilised letters from the latter half of the alphabet RT is bound to be slower as it would take longer to reach the target letter.

This illustrates Carlson and Schneider's (1989) criticism of ACT* in that it can be made to account for any level of transfer that occurs. Anderson (1983) counters this argument by stating that rather than the theory being manipulated to account for varying amounts of transfer, it is an example of participants adherence to an inefficient strategy. During the training phase, participants were able to develop a solution strategy to perform the task, and because it had proved effective, continued to use the same strategy in the transfer phase. However, because the transfer phase comprised letters from the latter half of the alphabet, the strategy took longer to arrive at an answer and by definition resulted in slower reaction times. Therefore, slower RT was a product of inefficient strategy selection rather than the lack of shared components.

It would be interesting to test this assumption by modifying the experiment slightly. Instead of simply dividing the alphabet in half A - J and K - T as Logan did, the division should be a combination of both early and late letters similar to the division made by Masson (1986) in the reverse words experiment. This would remove the confound of the time taken to reach the target letter in phase 3 and allow a more balanced comparison of the two phases to determine if transfer is affected by the confound.

The fourth task, reverse words showed zero transfer to the degree that RT was slower at the start of phase 3 than it had been at the beginning of phase 2. This implies that participants developed a solution strategy that applied only to the items experienced in phase 2 of the study. When they were presented with new items in phase 3, that strategy was not effective and consequently RT's were significantly slower than at the start of phase 2 and indicates that learning from phase 2 could not be applied to the new situation. Intuitively this result makes sense in that, learning to read the letters CAT backwards would not share any elements with learning to read the letters PEN backwards; therefore it is not surprising that participants were unable to develop a general learning strategy to solve the new problems.

The fact that participants were slower at the start of phase 3 than they were at the beginning of phase 2 raises the issue of what Anderson (1995) called negative transfer. Anderson (1995) states that only one example of negative transfer has previously been reported with regard to cognitive skills, that is the Einstellung effect or mechanisation of thought. This was illustrated by the Luchin's (1942) water jug experiments, where it was shown that participants will persistently use a solution

strategy that has been demonstrated to work in the past, even when a simpler more efficient alternative is available (Anderson, 1995). Consequently, Anderson (1995) argues negative transfer is a case of transferring information that is no longer useful rather than failure to transfer. It is in effect an example of perfect transfer of productions that lead to less than optimal performance and it is an argument that can equally be applied to the results of the alphabet-arithmetic task as well as to the reverse reading task.

Another explanation for negative or zero transfer offered by Anderson (1987) is *working-memory failure*. Based on experiments with students designing computer programmes, Anderson and Jeffries (1985) found that 30% of errors made by students were related to working-memory failure. When the demands of one part of the programming procedure were increased, errors occurred in other parts, suggesting that there were capacity limits to working-memory. Previous research (Jeffries, Turner, Polson, & Atwood, 1981) also points to capacity overload as being a major contributor to individual differences between programmers.

Anderson (1987) argues this is because loss of declarative information from working-memory can "cause good productions to behave badly" (p. 203). In simple terms, if information is lost that is needed in an answer, the answer will not contain that information and so will be deficient. This position also receives support from research comparing novice and expert performance, which appears to indicate the only difference between the two is the ability of the expert to remember larger chunks of domain specific information (Chase & Erikson, 1982; Chase & Simon, 1973; Egan & Swartz, 1979; Reitman, 1976; Spelman & Maybery, 1998).

In the case of the present study it is hard to see how any of these suggestions can account for the poorer performance in phase 3 of the reverse reading task. It can not be a case of loss of information from working memory or the loss of declarative information because phase 3 involved completely new items, therefore no prior knowledge relating to these items existed to be 'lost from memory'. Rather it is more likely that the slower reaction times in phase 3 were an artefact of the task in that it simply took longer for participants to recognise the shapes of the reversed letters involved in this phase of the experiment.

The savings analysis of phase three data was designed to assess the benefit derived from the learning that occurred in phase two. This method of assessing learning identifies unconscious as well as conscious learning, and as such is able to quantify levels of learning even when the participant is unable to verbalise what has been learned (Roediger, 1990). The results from phase three indicate that there was a saving of 70% in the algebra task, followed by 60% for reverse reading, 40% for the syllogism task and 30% in the alphabet-arithmetic task.

This appears to suggest that the measure of transfer does not necessarily represent the entire benefit of past learning. The syllogism task showed the greatest amount of transfer at 48.4% compared with 38% in the algebra task, and yet in terms of the savings measure the two tasks reverse their position with the algebra task demonstrating the greater savings (70% compared with 40% in the syllogism task). This implies that although RT's in the algebra task slowed at the beginning of the transfer phase, participants had learned the equation strategy so well in the training phase that this allowed a faster return to pre-transfer RT's than in the case of the

syllogism task. In other words, participants in this study were better able to learn the algorithm for solving the algebra equation than the algorithm for solving the syllogisms.

It is clear that the nature of skill acquisition and transfer is directly related to the task involved. If a task contains properties that are useful when applied to a different task it will result in general transfer. Conversely tasks that demonstrate specific transfer do so because they are inherently specific, that is there are no general features in the task that can be incorporated in a general performance strategy and so no such strategy can be developed that could facilitate transfer to another domain. Each of the four tasks described above differs in its capability to develop general skills; hence different types of transfer resulted as a function of the task being performed.

The Logan (1988) and Masson (1986) experiments can be characterised as involving tasks where highly specific stimuli were experienced repeatedly. It is reasonable to assume that participants would develop strategies that relied heavily on memory, as this would be more efficient than generating new solutions. In the Spelman and Kirsner (1997) syllogism experiment, relying on memory would have been far more difficult than developing a solution that could be transposed to all new syllogisms. Likewise a reliance on memory in the algebra task as reported by Greig and Spelman (1998) was only beneficial in terms of remembering one's times tables. Because the $x - y$ pairings changed, memory for specific pairings would have been redundant, therefore a more general strategy was needed to solve the problems.

The results of this study are consistent with the Anderson's ACT* theory of skill acquisition but they present difficulties for Logan's instance theory as it presently

stands. The instance theory is unable to account for the level of learning in phase one of the study where all four tasks demonstrated learning to some degree. As stated earlier the instance theory cannot explain how learning occurs in the absence of repeated items. It is also unable to account for the transfer that occurred in the syllogism and algebra tasks when new items were presented in the transfer phase. However, as other researchers have illustrated (Palmeri, 1997; Spelmann & Kirsner, 1998) with slight modification the instance theory can be adjusted to align it with empirical evidence.

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Appendix A Information Sheet

The experiment in which you are about to participate is designed to investigate some of the ways in which we acquire mental skills. It is being conducted as part of an Honours Degree and is being supervised by Dr. Craig Speelman, lecturer in Psychology. This experiment conforms to the guidelines produced by Edith Cowan University Committee for the Conduct of Ethical Research.

In this experiment you will be required to perform some simple problem solving tasks. These will be presented on the computer screen and you will have to respond by using the mouse to click a button on the screen. You do not need to have done anything like this before and most of the participants will never have been involved in an experiment of this kind. The aim of the experiment is to examine the role of practice in mastering a task. Your participation will last approximately one hour.

Please be assured that any information that you provide will be held in the strictest of confidence by the researcher. At no time will your name be reported along with your responses. All data will be reported in group form only. The results of the study will be available at the conclusion of the project, should you wish to have a copy sent to you tick the box at the bottom of the page.

Please understand that your participation in this research is totally voluntary and you are free to withdraw at any time during the study without penalty, and to remove any data that you may have contributed.

Any questions concerning this project can be directed to Dr. Craig Speelman (Supervisor) of the School of Psychology on 9400 5724.

Thankyou for your interest in this project

Dawn Darlaston- Jones

Please send me a copy of the results at the end of the project 

Informed Consent

I (the participant) have read the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this activity, realising that I may withdraw at any time. I agree that research data gathered for the study may be published, provided I am not identifiable.

Participant

Date

Investigator

Date

Appendix B - Stimulus Items

Stimulus Items for Syllogism Task

Phase 1

- 1.1 All of the accountants are blood donors.
All of the blood donors are cynics.
- 1.2 All of the administrators are celebrities.
All of the celebrities are nephews.
- 1.3 All of the estate agents are pilots.
All of the pilots are joggers.
- 1.4 All of the ambassadors are trumpeters.
All of the trumpeters are blondes.
- 1.5 All of the footballers are fathers.
All of the arbiters are footballers.
- 1.6 All of the country folk are clairvoyants.
All of the architects are country folk.
- 1.7 All of the travellers are gymnasts.
All of the attorneys are travellers.
- 1.8 All of the musicians are killers.
All of the auctioneers are musicians.
- 1.9 All of the auditors are readers.
All of the readers are tenors.
- 1.10 All of the bakers are lodgers.
All of the lodgers are competitors.
- 1.11 All of the ballerinas are collectors.
All of the collectors are fascists.
- 1.12 All of the bankers are performers.
All of the performers are guardians.
- 1.13 All of the jurors are drunks.
All of the barbers are jurors.
- 1.14 All of the earls are sceptics.
All of the beach inspectors are earls.
- 1.15 All of the intellectuals are lovers.
All of the beggars are intellectuals.
- 1.16 All of the liars are martyrs.
All of the bellydancers are liars.
- 1.17 All of the boot makers are high jumpers.
All of the high jumpers are traitors.
- 1.18 All of the botanists are heirs.
All of the heirs are purists.
- 1.19 All of the builders are Christians.
All of the Christians are uncles.
- 1.20 All of the buskers are graduates.
All of the graduates are perfectionists.
- 2.21 All of the puppeteers are moralists.
All of the butchers are puppeteers.
- 2.22 All of the husbands are skiers.
All of the butlers are husbands.

- 2.23 All of the hunters are cricketers.
All of the carpenters are hunters.
- 2.24 All of the mothers are singers.
All of the cashiers are mothers.
- 2.25 All of the chairmen are landowners.
All of the landowners are cowards.
- 2.26 All of the chauffeurs are anglers.
All of the anglers are hedonists.
- 2.27 All of the clerks are gentlemen.
All of the gentlemen are murderers.
- 2.28 All of the clinicians are honeymooners.
All of the honeymooners are prisoners.
- 2.29 All of the nationalists are cardplayers.
All of the cobblers are nationalists.
- 2.30 All of the cooks are drinkers.
All of the colonels are cooks.
- 2.31 All of the multilinguists are drummers.
All of the commissioners are multilinguists.
- 2.32 All of the naturalists are dukes.
All of the comperes are naturalists.
- 2.33 All of the constables are archers.
All of the archers are marxists.
- 2.34 All of the consuls are hurdlers.
All of the hurdlers are extroverts.
- 2.35 All of the coroners are whistlers.
All of the whistlers are optimists.
- 2.36 All of the councillors are marksmen.
All of the marksmen are parents.
- 2.37 All of the bachelors are boxers.
All of the counterfeiters are bachelors.
- 2.38 All of the voters are gardeners.
All of the couriers are voters.
- 2.39 All of the meditators are pragmatists.
All of the chemists are meditators.
- 2.40 All of the baritones are landlords.
All of the curators are baritones.
- 3.41 All of the beans are bilinguals.
All of the bilinguals are communists.
- 3.42 All of the decorators are golfers.
All of the golfers are bullies.
- 3.43 All of the detectives are actors.
All of the actors are sailors.
- 3.44 All of the diplomats are rowers.
All of the rowers are comedians.
- 3.45 All of the connoisseurs are alarmists.
All of the directors are connoisseurs.
- 3.46 All of the authors are puritans.
All of the doctors are authors.
- 3.47 All of the millionaires are budhists.
All of the dramatists are millionaires.

- 3.48 All of the colonists are alcoholics.
All of the draftsmen are colonists.
- 3.49 All of the drovers are aborigines.
All of the aborigines are electors.
- 3.50 All of the engineers are debaters.
All of the debaters are runners.
- 3.51 All of the historians are entrepreneurs.
All of the entrepreneurs are assassins.
- 3.52 All of the evangelists are householders.
All of the householders are longjumpers.
- 3.53 All of the critics are riders.
All of the foremen are critics.
- 3.54 All of the bouncers are aristocrats.
All of the foresters are bouncers.
- 3.55 All of the novelists are acrobats.
All of the gangsters are novelists.
- 3.56 All of the students are behaviourists.
All of the garbage collectors are students.
- 3.57 All of the grocers are housewives.
All of the housewives are pianists.
- 3.58 All of the security guards are capitalists.
All of the capitalists are enthusiasts.
- 3.59 All of the hostesses are knitters.
All of the knitters are impressionists.
- 3.60 All of the industrialists are knights.
All of the knights are orators.
- 4.61 All of the clowns are furriers.
All of the insurance agents are clowns.
- 4.62 All of the beekeepers are drug addicts.
All of the interviewers are beekeepers.
- 4.63 All of the inventers are burglars.
All of the janitors are inventers.
- 4.64 All of the caddies are satirists.
All of the jewellers are caddies.
- 4.65 All of the journalists are conjurers.
All of the conjurers are drives.
- 4.66 All of the lecturers are judges.
All of the judges are organists.
- 4.67 All of the gamekeepers are writers.
All of the writers are draftees.
- 4.68 All of the kitchenhands are pupils.
All of the pupils are sculptors.
- 4.69 All of the abductors are eccentrics.
All of the labourers are abductors.
- 4.70 All of the academics are gypsies.
All of the lawyers are academics.
- 4.71 All of the photographers are thieves.
All of the librarians are photographers.
- 4.72 All of the grammarians are soldiers.
All of the locksmiths are grammarians.

- 4.73 All of the magistrates are hostages.
All of the hostages are violinists.
- 4.74 All of the mathematicians are marines.
All of the marines are barons.
- 4.75 All of the mechanics are spectators.
All of the spectators are ventriloquists.
- 4.76 All of the neurologists are scholars.
All of the scholars are advisers.
- 4.77 All of the criminals are vigneron.
- 4.78 All of the nurses are nutritionists.
All of the nuns are nurses.
- 4.79 All of the physiologists are statesmen.
All of the officials are physiologists.
- 4.80 All of the teachers are vocalists.
All of the opticians are teachers.

Phase I (Version 1) Conclusions

- 1.1 T All of the accountants are cynics.
- 1.2 F All of the nephews are administrators.
- 1.3 T All of the estate agents are joggers.
- 1.4 F All of the blondes are ambassadors.
- 1.5 T All of the arbiters are fathers.
- 1.6 F All of the clairvoyants are architects.
- 1.7 T All of the attorneys are gymnasts.
- 1.8 F All of the killers are auctioneers.
- 1.9 T All of the auditors are tenors.
- 1.10 F All of the competitors are bakers.
- 1.11 T All of the ballerinas are fascists.
- 1.12 F All of the guardians are bankers.
- 1.13 T All of the barbers are drunks.
- 1.14 F All of the sceptics are beach inspectors.
- 1.15 T All of the beggars are lovers.
- 1.16 F All of the martyrs are bellydancers.
- 1.17 T All of the bootmakers are traitors.
- 1.18 F All of the purists are botanists.
- 1.19 T All of the builders are uncles.
- 1.20 F All of the perfectionists are buckers.
- 2.21 T All of the butchers are moralists.
- 2.22 F All of the skiers are butlers.
- 2.23 T All of the carpenters are cricketers.
- 2.24 F All of the singers are cashiers.
- 2.25 T All of the chairmen are cowards.
- 2.26 F All of the hedonists are chauffeurs.
- 2.27 T All of the clerks are murderers.
- 2.28 F All of the prisoners are clinicians.
- 2.29 T All of the cobblers are cardplayers.
- 2.30 F All of the drinkers are colonels.

- 2.31 T All of the commissioners are drummers.
2.32 F All of the dukes are comperes.
2.33 T All of the constables are marxists.
2.34 F All of the extroverts are consuls.
2.35 T All of the coroners are optimists.
2.36 F All of the parents are councillors.
2.37 T All of the counterfeiters are boxers.
2.38 F All of the gardeners are couriers.
2.39 T All of the chemists are pragmatists.
2.40 F All of the landlords are curators.
3.41 T All of the deans are communists.
3.42 F All of the bullies are decorators.
3.43 T All of the detectives are sailors.
3.44 F All of the comedians are diplomats.
3.45 T All of the directors are alarmists.
3.46 F All of the puritans are doctors.
3.47 T All of the dramatists are budhists.
3.48 F All of the alcoholics are draftsmen.
3.49 T All of the drovers are electors.
3.50 F All of the runners are engineers.
3.51 T All of the historians are assassins.
3.52 F All of the longjumpers are evangelists.
3.53 T All of the foremen are riders.
3.54 F All of the aristocrats are foresters.
3.55 T All of the gangsters are acrobats.
3.56 F All of the behaviourists are garbage collectors.
3.57 T All of the grocers are pianists.
3.58 F All of the enthusiasts are security guards.
3.59 T All of the hostesses are impressionists.
3.60 F All of the orators are industrialists.
4.61 T All of the insurance agents are furriers.
4.62 F All of the drug addicts are interviewers.
4.63 T All of the janitors are burglars.
4.64 F All of the satirists are jewellers.
4.65 T All of the journalists are drivers.
4.66 F All of the organists are lecturers.
4.67 T All of the gamekeepers are draftees.
4.68 F All of the sculptors are kitchenhands.
4.69 T All of the labourers are eccentrics.
4.70 F All of the gypsies are lawyers.
4.71 T All of the librarians are thieves.
4.72 F All of the soldiers are locksmiths.
4.73 T All of the magistrates are violinists.
4.74 F All of the barons are mathematicians.
4.75 T All of the mechanics are ventriloquists.
4.76 F All of the advisers are neurologists.
4.77 T All of the conductors are vigneron.
4.78 F All of the nutritionists are nuns.
4.79 T All of the officials are statesmen.
4.80 F All of the vocalists are opticians.

Phase II (Syllogisms A Version 2)

- 1 All of the parliamentarians are pessimists
All of the pessimists are artists.
- 2 All of the pawnbrokers are painters.
All of the painters are candidates.
- 3 All of the pharmacists are senators.
All of the senators are delinquents.
- 4 All of the physicians are researchers.
All of the researchers are umpires.
- 5 All of the spies are waiters.
All of the physicists are spies.
- 6 All of the pedestrians are hockeyplayers.
All of the plumbers are pedestrians.
- 7 All of the observers are customers.
All of the politicians are observers.
- 8 All of the prefects are poets.
All of the porters are prefects.
- 9 All of the priests are pensioners.
All of the pensioners are hermits.
- 10 All of the theoreticians are referees.
All of the psychologists are theoreticians.

Phase 2 Conclusions

1. T All of the parliamentarians are pessimists.
F All of the pessimists are parliamentarians.
2. T All of the pawnbrokers are candidates.
F All of the candidates are pawnbrokers.
3. T All of the pharmacists are senators.
F All of the senators are pharmacists.
4. T All of the physicians are umpires.
F All of the umpires are physicians.
5. T All of the physicists are waiters.
F All of the waiters are physicists.
6. T All of the plumbers are hockeyplayers
F All of the hockey players are plumbers.
7. T All of the politicians are customers.
F All of the customers are politicians.
8. T All of the porters are poets.
F All of the poets are porters.
9. T All of the priests are hermits.
F All of the hermits are priests.
10. T All of the psychologists are referees.
F All of the referees are psychologists.

Phase III

- 1 All of the principals are craftsmen.
All of the craftsmen are philosophers.
- 2 All of the printers are servants.
All of the servants are henchmen.
- 3 All of the professors are scientists.
All of the scientists are apologists.
- 4 All of the statisticians are marriage celebrants.
All of the recruits are statisticians.
- 5 All of the tutors are minstrels.
All of the programmers are tutors.
- 6 All of the communicators are carvers.
All of the secretaries are communicators.
- 7 All of the tenors are accountants.
All of the high jumpers are tenors.
- 8 All of the competitors are administrators.
All of the heirs are competitors.
- 9 All of the puppeteers are drunks.
All of the drunks are arbiters.
- 10 All of the husbands are sceptics.
All of the sceptics are architects

Phase 3 Conclusions

1. T All of the principals are philosophers
F All of the philosophers are principals.
2. T All of the printers are henchmen.
F All of the henchmen are printers.
3. T All of the professors are apologists.
F All of the apologists are professors.
4. T All of the recruits are marriage celebrants.
F All of the marriage celebrants are recruits.
5. T All of the programmers are minstrels.
F All of the minstrels are programmers.
6. T All of the secretaries are carvers.
F All of the carvers are secretaries.
7. T All of the highjumpers are accountants.
F All of the accountants are highjumpers.
8. T All of the heirs are administrators.
F All of the administrators are heirs.
9. T All of the puppeteers are arbiters.
F All of the arbiters are puppeteers.
10. T All of the husbands are architects.
F All of the architects are husbands.

Stimulus Items for Alphabet-Arithmetic task

Assumptions:

Phase 1 - uses all letters a-i & numbers 2-5

80 trials 20 no repetition of letters

60 repetition but item is different

Phase 2 - 100 trials

50 true - 10 letters presented (A-J) always paired with the same number.

50 false - as above except 25 true + 1 & 25 true - 1

Phase 3 - as phase 2 but with letters K-T

Phase 1

- | | |
|-----------------|----------|
| 1. $A + 2 = C$ | TRUE |
| 2. $B + 3 = F$ | FALSE +1 |
| 3. $C + 4 = G$ | TRUE |
| 4. $D + 5 = H$ | FALSE -1 |
| 5. $E + 2 = G$ | TRUE |
| 6. $F + 3 = J$ | FALSE +1 |
| 7. $G + 4 = K$ | TRUE |
| 8. $H + 5 = L$ | FALSE -1 |
| 9. $I + 2 = K$ | TRUE |
| 10. $J + 3 = N$ | FALSE +1 |
| 11. $K + 4 = O$ | TRUE |
| 12. $L + 5 = P$ | FALSE -1 |
| 13. $M + 2 = O$ | TRUE |
| 14. $N + 3 = R$ | FALSE +1 |
| 15. $O + 4 = S$ | TRUE |
| 16. $P + 5 = T$ | FALSE -1 |
| 17. $Q + 2 = S$ | TRUE |
| 18. $R + 3 = V$ | FALSE +1 |
| 19. $S + 4 = W$ | TRUE |
| 20. $T + 5 = X$ | FALSE -1 |
| 21. $A + 3 = D$ | TRUE |
| 22. $B + 4 = G$ | FALSE +1 |
| 23. $C + 5 = H$ | TRUE |
| 24. $D + 2 = E$ | FALSE -1 |
| 25. $E + 3 = H$ | TRUE |
| 26. $F + 4 = K$ | FALSE +1 |
| 27. $G + 5 = L$ | TRUE |
| 28. $H + 2 = I$ | FALSE -1 |
| 29. $I + 3 = L$ | TRUE |
| 30. $J + 4 = O$ | FALSE +1 |
| 31. $K + 5 = P$ | TRUE |

32. $L + 2 = M$	FALSE -1
33. $M + 3 = P$	TRUE
34. $N + 4 = R$	FALSE +1
35. $O + 5 = T$	TRUE
36. $P + 2 = Q$	FALSE -1
37. $Q + 3 = T$	TRUE
38. $R + 4 = W$	FALSE +1
39. $S + 5 = X$	TRUE
40. $T + 2 = U$	FALSE -1
41. $A + 4 = E$	TRUE
42. $B + 5 = H$	FALSE +1
43. $C + 2 = E$	TRUE
44. $D + 3 = F$	FALSE -1
45. $E + 4 = I$	TRUE
46. $F + 5 = L$	FALSE +1
47. $G + 2 = I$	TRUE
48. $H + 3 = J$	FALSE -1
49. $I + 4 = M$	TRUE
50. $J + 5 = P$	FALSE +1
51. $K + 2 = M$	TRUE
52. $L + 3 = N$	FALSE -1
53. $M + 4 = Q$	TRUE
54. $N + 5 = T$	FALSE +1
55. $O + 2 = Q$	TRUE
56. $P + 3 = R$	FALSE -1
57. $Q + 4 = U$	TRUE
58. $R + 5 = X$	FALSE +1
59. $S + 2 = U$	TRUE
60. $T + 3 = V$	FALSE -1
61. $A + 5 = F$	TRUE
62. $B + 2 = E$	FALSE +1
63. $C + 3 = F$	TRUE
64. $D + 4 = G$	FALSE -1
65. $E + 5 = J$	TRUE
66. $F + 2 = I$	FALSE +1
67. $G + 3 = J$	TRUE
68. $H + 4 = K$	FALSE -1
69. $I + 5 = N$	TRUE
70. $J + 2 = M$	FALSE +1
71. $K + 3 = N$	TRUE
72. $L + 4 = O$	FALSE -1
73. $M + 5 = R$	TRUE
74. $N + 2 = Q$	FALSE +1
75. $O + 3 = R$	TRUE
76. $P + 4 = S$	FALSE -1
77. $Q + 5 = V$	TRUE
78. $R + 2 = U$	FALSE +1
79. $S + 3 = V$	TRUE
80. $T + 4 = W$	FALSE -1

Phase 2

1. $A + 2 = C$	TRUE
2. $A + 2 = D$	FALSE +1
3. $B + 3 = E$	TRUE
4. $B + 3 = D$	FALSE-1
5. $C + 4 = G$	TRUE
6. $C + 4 = H$	FALSE +1
7. $D + 5 = I$	TRUE
8. $D + 5 = H$	FALSE -1
9. $E + 2 = G$	TRUE
10. $E + 2 = H$	FALSE +1
11. $F + 3 = I$	TRUE
12. $F + 3 = H$	FALSE -1
13. $G + 4 = K$	TRUE
14. $G + 4 = L$	FALSE +1
15. $H + 5 = M$	TRUE
16. $H + 5 = L$	FALSE -1
17. $I + 2 = K$	TRUE
18. $I + 2 = L$	FALSE +1
19. $J + 3 = M$	TRUE
20. $J + 3 = L$	FALSE -1

REPEAT EACH ITEM 5 TIMES = 100 TRIALS
PRESENT IN RANDOM ORDER

Phase 3

1. $K + 2 = M$	TRUE
2. $K + 2 = N$	FALSE +1
3. $L + 3 = O$	TRUE
4. $L + 3 = N$	FALSE -1
5. $M + 4 = Q$	TRUE
6. $M + 4 = R$	FALSE +1
7. $N + 5 = S$	TRUE
8. $N + 5 = R$	FALSE -1
9. $O + 2 = Q$	TRUE
10. $O + 2 = R$	FALSE +1
11. $P + 3 = S$	TRUE
12. $P + 3 = R$	FALSE -1
13. $Q + 4 = U$	TRUE
14. $Q + 4 = V$	FALSE +1
15. $R + 5 = W$	TRUE
16. $R + 5 = V$	FALSE -1
17. $S + 2 = U$	TRUE
18. $S + 2 = V$	FALSE +1
19. $T + 3 = W$	TRUE
20. $T + 3 = V$	FALSE -1

REPEAT EACH ITEM 5 TIMES = 100 TRIALS
PRESENT IN RANDOM ORDER

Stimulus Items for Algebra TaskPhase 1

Item	X	Y	Presented	Response
1	3	5	2	T
2	4	2	6	F
3	5	9	9	F
4	6	10	13	T
5	7	1	24	T
6	8	4	29	F
7	9	3	40	F
8	10	8	46	T
9	11	7	57	T
10	12	6	68	F
11	3	1	4	T
12	4	6	4	F
13	5	5	11	F
14	6	6	15	T
15	7	9	20	T
16	8	10	26	F
17	9	7	37	T
18	10	4	49	F
19	11	9	55	F
20	12	10	67	T
21	3	3	4	F
22	4	4	6	T
23	5	7	9	T
24	6	8	13	F
25	7	11	20	F
26	8	12	26	T
27	9	5	38	T
28	10	6	46	F
29	11	11	55	T
30	12	8	69	F
31	3	7	2	F
32	4	8	4	T
33	5	1	11	F
34	6	2	17	T
35	7	3	23	T
36	8	2	30	F
37	9	9	37	F
38	10	10	45	T
39	11	1	60	T
40	12	12	65	F
41	4	10	4	F
42	6	12	12	T
43	5	11	6	F
44	12	2	71	T

45	7	5	15	T
46	8	8	39	F
47	9	11	34	F
48	10	12	44	T
49	11	3	59	T
50	4	12	3	F
51	12	4	69	F
52	5	3	11	T
53	6	4	16	T
54	7	7	22	F
55	8	6	29	T
56	9	1	39	F
57	10	2	50	F
58	11	5	58	T

Phase 2

Item	X	Y	Presented	Response
1	5	9	8	T
2	5	11	6	F
3	5	13	8	F
4	5	15	5	T
5	8	2	30	F
6	8	4	30	T
7	8	6	29	T
8	8	8	29	F
9	9	17	32	T
10	9	19	30	F

Repeat each item 10 times

Phase 3

Item	X	Y	Presented	Correct Response
1	6	10	13	T
2	6	12	13	F
3	6	14	10	F
4	6	16	10	T
5	7	1	25	F
6	7	3	23	T
7	7	5	22	T
8	7	7	20	F
9	10	18	41	T
10	10	20	41	F

Repeat each item 10 times

Stimulus Items for reverse Reading Task
phase 1

80 words using all letters
first 10 with no letters repeated

1. sky*	HIGH
2. FLY	BUZZ
3. ANT*	PANT
4. bag	HAND
5. RUM*	COME
6. run	HIDE
7. dome*	COMB
8. lick	CALL
9. HIKE*	BIKE
10. PROD	SHOE
11. ARRAY*	AWAY
12. FLEW	CAGE
13. FOAM*	DOME
14. GAIT	FOIL
15. GEAR*	SHEER
16. HERALD	HOLDER
17. HOUSE*	MOUSE
18. HURRY	HEAVY
19. ISSUE*	TISSUE
20. ITEM	IMMUNE
21. JACKET*	PACKET
22. JAPAN	BASIN
23. JUDGE*	BUDGE
24. KEEN	MOON
25. KERN*	TURN
26. KNEE	KNIFE
27. KNIGHT*	BLIGHT
28. LADDER	KILLER
29. LAGOON*	SOON
30. LAID	KIND
31. LAMP*	STAMP
32. LATIN	DANCER
33. LAUNCH*	PAUNCH
34. LEAGUE	SIEVE
35. LEND*	FRIEND
36. MAKER*	BAKER
37. MARBLE	STONE
38. MARINE*	SCENE
39. MASS	MORE
40. MILK*	SILK
41. MINOR	SMALL
42. MONEY*	HONEY

43. NAMELY	HAPPY
44. NATION*	STATION
45. NATURE	INSIDE
46. NUMBER*	SLUMBER
47. NUMERAL	NEVER
48. NURSE*	PURSE
49. OFFICE	CHAIR
50. ORDER*	HOARDER
51. ORGAN	PLAYER
52. PAINT*	TAINT
53. PLACE	PUT
54. PALM*	BALM
55. PAPER	SUGAR
56. PARK*	STARK
57. PENCIL	PEOPLE
58. PICKET*	TICKET
59. PICNIC	PHRASE
60. PISTOL*	BRISTOL
61. POTATO	POWDER
62. QUAIN*	PAINT
63. QUEEN	KING
64. QUILL*	SPILL
65. QUOTE	SPEEK
66. RACE*	FACE
67. RADAR	SAUCER
68. RAISE*	PRAISE
69. RANCH	FARM
70. REMARK*	PARK
71. RESCUE	RETAIN
72. SCALE*	SALE
73. SHARK	SHAPE
74. TANGLE*	DANGLE
75. TEAR	SHOUT
76. TENNIS*	MENACE
77. VACANT	VECTOR
78. WANDER*	PONDER
79. WEIGHT	WATCH
80. YOGA*	TOGA

GROUP 1 -

LETTERS: ABDGIJKNQSUUVX - Phase 2

WORDS MARKED WITH A * ARE THE RHYMING WORDS

<u>WORD</u>	<u>RHYME</u>
1. KINK*	LINK
2. AGAIN	ADULT
3. AID*	MADE
4. AIR	JAR
5. AKIN	POLL
6. AND*	SAND
7. ANNA	ACID
8. ASIAN	PITY
9. ASK*	FLASK
10. ASSIGN	MERRY
11. AVID*	RABID
12. AXIS*	PRAXIS
13. BAD	BLAND
14. BAN*	FAN
15. BANANA	FILE
16. BAND*	PLANNED
17. BANG	PORT
18. BANK*	TANK
19. BASIS	MAGIC
20. BASK*	ASK
21. BASS	RARE
22. BAUD*	FRAUD
23. BIAS	LOOSE
24. BIB*	RIB
25. BID	PINE
26. BIN*	SIN
27. BIND	VIOLA
28. BUD*	DUD
29. BUDDING	MAKING
30. BUG*	MUG
31. BUGGING	TAKING
32. BUN*	SUN
33. BUNK	CALM
34. DAD*	MAD
35. DAIS	SAGE
36. DANK*	THANK
37. DIBS	RAID
38. DIG*	FIG
39. DAUB	DRAG
40. DIN*	SIN
41. DING	DRINK

42. DISDAIN*	REFRAIN
43. DISK	DIVE
44. DIVA*	LEVER
45. DUN	PINK
46. DUNK*	SKUNK
47. DUSK	DREAM
48. GAG*	BAG
49. GAUD	GREEN
50. GAIN*	REMAIN
51. GANG	GAVE
52. GIN*	WIN
53. GUN	DUSK
54. GUNK*	JUNK
55. INK	EAR
56. INNINGS*	WINNINGS
57. ISIS	RELY
58. JAB*	GRAB
59. JAVA	JADE
60. JIG*	RIG
61. JUG	JUMP
62. JUNK*	SUNK
63. KAVA	CAVE
64. KID*	BID
65. KING	HEAD
66. KISS*	MISS
67. NIB	NOSE
68. NUN*	SUN
69. QUAD	YEAR
70. SAGA*	TARGA
71. SAID*	DREAD
72. SAND	POUND
73. SANK*	BANK
74. SANS	HAIR
75. SAVING*	PAVING
76. SIGN	SALE
77. SING*	BRING
78. SINK*	DRINK
79. SIX*	TRICKS
80. SKID	SCRAPE
81. SKIN*	TIN
82. SNUG	SAME
83. SQUAD*	PROD
84. SUDS	BARN
85. SUNG*	TONGUE
86. SUNK	RUSH
87. SUVA*	HOOVER
88. VAIN*	RAIN
89. VAN	BET
90. VISA*	PISA
91. VIVA	VIOLA

92. VIVIAN*	BOLIVIAN
93. VIVID*	LIVID
94. SANG*	BANG
95. SNAG*	DRAG
96. IBIS	OPEN
97. JINX*	LYNX
98. SNAG	CRY
99. BUNG*	LUNG
100. GAS*	LASS

GROUP 2 - LETTERS:

CEFHLMOPRTWYZ - phase 3

1. CELL*	SPELL
2. CHEER	CLIFF
3. CHEF*	DEAF
4. CHEW	CHEAP
5. CHOP*	SHOP
6. CHOW	SAIL
7. CLOT*	BLOT
8. COFFEE	BELLY
9. COLE*	STOLE
10. COLT	COLD
11. COME*	SOME
12. COOLER	FOLDER
13. COPPER*	SHOPPER
14. COPY	COPE
15. CORE*	STORE
16. CLEF	PAPER
17. CREPT*	SLEPT
18. CREW	CROW
19. CROP*	STOP
20. CROW	CLAW
21. ECHO	EDGE
22. ELECT*	SELECT
23. EMPLOY	EMPIRE
24. ERECT*	CORRECT
25. ERROR	ACORN
26. FEET*	FLEET
27. FELLOW	BARROW
28. FELT*	MELT
29. FERRY	BELOW
30. FLEET*	SLEET
31. FOWL	FORK
32. FOOL*	SPOOL
33. FOOT	FEAR
34. FORE*	DOOR
35. FORMER	FERRY
36. FORTY*	NAUGHTY
37. FREE	FROG
38. FROZEN	BOOK

39. HEEL*	SEAL
40. HELL*	SPELL
41. HELM	HOLD
42. HELP*	YELP
43. HERE	SCAR
44. HERO*	ZERO
45. HOLE	PEARL
46. HOLY*	SOLEY
47. HOMELY	ARRAY
48. HOOP	GATE
49. HOTEL*	MOTEL
50. HOPE	LODGE
51. HOWL*	SCOWL
52. LETTER	LUNCH
53. LOOM*	DOOM
54. LOOP	MODE
55. LORE*	SAW
56. MEET	SAID
57. MELT*	FELT
58. MEMORY	AGENCY
59. MERCY*	PERCY
60. MOLE	ARCH
61. MOTHER*	BROTHER
62. LEFT	MILK
63. PEOPLE	PERSON
64. POLE*	SOLE
65. POLL	POND
66. POLO*	SOLO
67. POMP	PUSH
68. POOL*	STOOL
69. POORLY	QUICKLY
70. PORCH*	TORCH
71. PORTER	DECAY
72. PREFER*	REFER
73. PRETTY	TODDY
74. PYRE*	FIRE
75. RECTOR	SANDY
76. REFORM*	PERFORM
77. RELY	TEDDY
78. REMOTE*	PROMOTE
79. REPEL	CANDLE
80. RHYTHM	SHOE
81. ROOM*	TOMB
82. ROOT *	BOOT
83. ROPE*	POPE
84. TEETH	BOX
85. TEMPLE	TOWER
86. THEFT*	LEFT
87. THEME*	TEAM
88. THEORY*	TEARY

89. TORE	SHOW
90. TORY*	STORY
91. TOTE	CALF
92. TROOP*	STOOP
93. TROPHY	JOURNEY
94. TYPE*	WIPE
95. WELL	CAR
96. WEPT*	CREPT
97. WERE	SEEN
98. WHEEL*	REAL
99. WOLF	FOX
100. YELLOW*	MELLOW