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Effect of the Specificity of Training Delivery on Skill Acquisition and Transfer

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USE OF THESIS

EFFECT OF THE SPECIFICITY OF TRAINING DELIVERY ON SKILL ACQUISITION AND TRANSFER

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EFFECT OF THE SPECIFICITY OF TRAINING DELIVERY ON SKILL ACQUISITION AND TRANSFER

Abstract

Past research (e.g., Brewer, 1998) has shown that when people learn to solve simple formulae where elements are repeated over and over again, the greater the degree of repetition, the less transferable the skill. The current study tested one explanation for this observation; that training conditions involving little stimulus variation encourage the development of specific skills with low transferability. These habit-encouraging conditions were compared with a habit-breaking manipulation that involved presentation of unfamiliar stimuli throughout training. Participants were randomly assigned to one of 2 groups, the habit-encouraging and habit-breaking groups. The groups had 22 and 20 participants respectively. Participants were presented with the formula $\frac{x^2 - y}{2}$ along with values for x and y, and were required to calculate a solution to the formula and to respond whether the answer was odd or even. The experiment consisted of a training phase of 320 trials, and a transfer phase of 8 trials. The data were analysed using 2 split plot analyses of variance. The hypothesis of partial positive transfer was supported, that is, while participants were slower at responding in the transfer phase of the experiment than they were at the conclusion of training, they were not as slow as at the commencement of training. This result indicates that participants acquired specific as well as general skills. However, results failed to support the hypothesis that transferability was a function of variation in training. The implications of these findings are discussed.

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Declaration

I certify that this thesis does not incorporate, without acknowledgment, any material previously submitted for a degree or diploma in any institution of higher education and that, to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where due reference is made in the text.

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Introduction

The workplace of the millennium is very different from that of a decade or so ago. No longer can one expect to occupy the same job or indeed work in the same company until retirement. Today's work environment is highly pressured and dynamic. Retrenchments, redundancies, multiple career paths, flexibility, multi-tasking and multi-skilling are all the norm. It is in a company's interest to employ staff who are multi-skilled. It is in the worker's interest to keep up to date with the use of the latest technology. This leads to questions with important implications for both the company and the worker. The company might want to determine the best way to multi-skill existing staff and to establish what to look for in new recruits. Workers on the other hand might be disconcerted at the prospect of having to learn new skills and might question their ability to do so.

With issues such as these in mind, the current study was undertaken to contribute to a broader understanding of skill acquisition, in particular cognitive skill acquisition and transfer. Specifically, the aim of this study was to examine the effect of the specificity of training experiences on the performance of a transfer task.

The topic of skill acquisition has attracted considerable research attention. Prior to a discussion of the current study, a review of the literature on this topic and associated concepts is provided.

Automaticity

At the heart of skill acquisition is the concept of automaticity. According to Logan (1992), automaticity is often defined as processing without attention, and an important characteristic of automaticity from any theoretical viewpoint is that it is associated with learning. Schneider and Fisk (1984) noted that automatic processing could semantically filter sensory input and the filter seems to be activated without consuming any measurable resources and can produce large quantitative and qualitative effects on behaviour.

Logan (1988, 1992) held that automaticity is a memory phenomenon. Each encounter with a stimulus is encoded, stored, and retrieved separately, and is assumed to be represented in memory, as a processing episode. When the stimulus is encountered again, the processing episode is retrieved. Support for automaticity as a memory phenomenon was also provided by Grant and Logan's (1993) investigation into repetition priming over time. Priming was found to accumulate as a power function of presentations and to decline as a power function of time. However, when the data were combined, results revealed that increased initial priming was associated with greater losses in priming over time. The researchers argued that just as information in memory is forgotten over time, so too is automaticity.

A two-process theory of human information processing (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) emphasised the roles of automatic and controlled processing. The roles played by these two processes are highlighted in Fitts' (1964) three phases of skill acquisition. In the first stage, the *cognitive* stage, the learner comes to terms with instructions and encodes the skill in a form that is sufficient for the desired behaviour to be generated to some extent. Knowledge is explicit and rule-based, performance is slow, filled with errors, and is resource intensive. Shiffrin and Schneider (1977; Schneider & Shiffrin, 1977) attributed performance in this phase to controlled processing. In the second stage, the *associative* stage, skill performance becomes more refined. Errors are detected and discarded, and performance gets strengthened on the basis of feedback as inappropriate strategies are amended or eliminated. Shiffrin and Schneider (Schneider & Shiffrin, 1977) ascribed performance in this stage to a combination of automatic and controlled processing. In the last stage, the *autonomous* stage, there is continued improvement in performance of the skill. Performance is less governed by cognitive control or external interference and the demand on processing resources decreases. Skills become faster, however the rate of performance improvement slows with practice. According to Shiffrin and Schneider (Schneider & Shiffrin, 1977) performance in this stage is a result of automatic processing.

Theories of Skill Acquisition

Anderson's ACT Theory*

Anderson's ACT* theory (Anderson, 1982, 1983, 1987, 1992) of skill acquisition provides a description of the processes that underlie Fitts' (1964) three phases of skill acquisition. In the ACT* theory, the first stage, the *declarative* stage, corresponds with Fitts' cognitive stage, and involves encoding knowledge directly from experience, in a declarative form. The second stage, *knowledge compilation*, corresponds with Fitts' associative stage, and involves the compilation of declarative knowledge into procedural knowledge. This process is known as the acquisition of production rules, as productions. These rules relate particular stimulus conditions with appropriate responses. Anderson (1987) argued that cognitive skills are encoded by a set of productions that are organised according to a hierarchical goal structure. Problems in new domains are solved by the application of weak problem solving procedures to declarative knowledge possessed about the domain. From these initial problem-solving strategies, production rules are compiled that are specific to that domain and that make use of the knowledge. The third stage, the *procedural* stage, corresponds with Fitts' autonomous stage, and involves strengthening the production rules and declarative facts. Each time a production rule or declarative fact is used, its strength is increased. The strength of a declarative fact determines how active it is. The selection of a production rule is determined by a competition among production rules, and stronger productions do better in the competition.

According to ACT* theory (Anderson, 1982, 1983, 1987, 1992), there are two ways in which skill acquisition can result in automatic performance, that of compilation and strengthening. The first, compilation of declarative knowledge into procedural knowledge is itself made up of two processes, proceduralisation and composition. Proceduralisation is the process whereby factual or declarative knowledge is converted into productions. Composition involves collapsing sequences of productions into single productions. The second way in which skill acquisition can result in automatic performance is that of strengthening, a process that determines the production rule that applies and how rapidly it applies.

Speelman and Maybery (1998) illustrated the process of composition with the following example of solving x in an algebraic equation of the form $a = x + c$:

IF	goal is to solve for x in equation of the form $a = x + c$	
THEN	set as subgoal to isolate x on RHS of equation	(P1)
IF	goal is to isolate x on RHS of equation	
THEN	set as subgoal to eliminate c from RHS of equation	(P2)
IF	goal is to eliminate c from RHS of equation	
THEN	add $-c$ to both sides of equation	(P3)

IF	goal is to solve for x in equation	
	and x has been isolated on RHS of equation	
THEN	LHS of equation is solution for x	(P4)

Composition will collapse Productions 2 and 3 into:

IF	goal is to isolate x on RHS of equation	
THEN	add $-c$ to both sides of equation	(P5)

After further practice, Productions 1, 5 and 4 will compose into:

IF	goal is to solve for x in equation of the form $a = x + c$	
THEN	subtract c from a and result is solution	(P6)

While Anderson characterised how production rules are formed once a suitable declarative representation is present, relatively little was known about the construction of the declarative representation itself. Kieras and Bovair (1986) shed light on this issue by providing an initial identification of the construction of the declarative representation when the input was procedural text. The researchers noted that in the process of acquiring procedures from text, complex comprehension processes that construct the initial declarative form of the production rules can play a major role early in learning. These processes take advantage of prior knowledge and include translating the semantic content of a step-by-step instruction sentence into the declarative representation of a production rule, comparing this production rule to rules already acquired, and monitoring the execution success of each rule in the declarative representation to determine which sentences must be studied again, and which can be skipped.

Once the correct declarative representation of the rule is in place, learning is then controlled by the processes of compilation and tuning.

The relationship between declarative and procedural knowledge, and the long-term status of the declarative knowledge was given a different interpretation by Anderson and Fincham (1994). The original emphasis on declarative memory for instructions changed to declarative memory for examples of execution of the procedures. The researchers argued that analogy is involved in the initial use of these examples and the analogy process is summarised by the compilation of production rules. Anderson and Fincham also held that a declarative representation only needs to be active in working memory during the analogy process and does not have to be permanent and retrievable from long-term memory.

The role of examples and rules in the acquisition of a cognitive skill was investigated further (Anderson, Fincham, & Douglass, 1997). As a result, Anderson et al. argued for a four-stage model of skill acquisition which involves four overlapping stages. The participant starts with analogy to use examples, develops abstract rules, and slowly moves to use of production rules and retrieval of specific examples. The process of skill acquisition does not have to follow these four overlapping stages in sequence. At a point in time, a participant's responses can reflect a combination of methods of varying proportions (Anderson et al., 1997).

Logan's Instance theory

Logan's Instance theory (Logan, 1988, 1990, 1992) is a memory-based theory of skill acquisition, in contrast to the process-based ACT* theory. According to the Instance theory, automatisation is the result of a shift from reliance on a general algorithm developed through conscious deliberation, to reliance on memory for past solutions, and reflects the development of a domain-specific knowledge base. Each time the algorithm is successfully executed, the solution is remembered. The whole processing episode is represented in memory and is termed an instance. Performance on a task is the result of a race between the algorithm and memory for past solutions and the winner controls the response. With practice memory dominates the algorithm as the number of instances increases and so too the probability of an instance winning the race.

Support for the Instance theory was provided by Logan and Klapp's (1991) examination of the necessity of extended practice in producing automaticity. These researchers developed an alphabet-arithmetic task in which their participants learned to add digits to letters of the alphabet to produce other letters of the alphabet, for example A + 2 = C, indicating C was two letters down the alphabet from A. Results of their study revealed that automatisation depended on the number of presentations of individual items rather than the total amount of practice on the task. Logan and Klapp observed that their participants reported resorting to memory rather than counting, as practice progressed. The Instance theory's assumptions of obligatory encoding and instance representation were examined to determine the role of attention in automatisation (Logan & Etherton, 1994). The task involved participants searching two-word displays for members of a target category in divided-attention, focused-attention, and dual-task conditions. Results revealed that participants were sensitive to co-occurrence when the task required them to pay attention to both words (i.e., the divided-attention and dual-task experiments) and insensitive to co-occurrence when the task allowed them to pay attention to one word and ignore the other (i.e., the focussed-attention experiments). The results supported the Instance theory's attention hypothesis that attention determined the encoding of an instance and performance was based on instance retrieval.

The Instance theory was further examined in studies investigating the development of automaticity. One investigation was undertaken by Palmeri (1997) who focused on the effects of exemplar similarity. In this study participants judged the numerosity of random patterns of between 6 and 11 dots. Results of this study suggested limitations in the pure single race version of Logan's Instance theory, and from the results rose the Exemplar Based Random Walk Model that extended Logan's model by incorporating a similarity-based memory retrieval process and response competition in the form of a random walk decision process. Another investigation of the development of automaticity was undertaken by Rickard (1997) whose participants had to solve a pseudoarithmetic task. Results of the study did not support the Instance theory and instead Rickard developed the Component Power Laws theory to provide a better account of the mechanisms underlying the shift to automaticity. These two theories are described below.

Palmeri's Exemplar Based Random Walk (EBRW) Model

The EBRW model (Palmeri, 1997) combines elements of Logan's (1988, 1990, 1992) Instance theory of automaticity and Nosofsky's (1986, cited in Palmeri) generalised context model (GCM) of categorisation. It incorporates a dynamic similarity-based memory retrieval mechanism within a competitive random walk decision process. The theory is similar to the Instance theory in that a race between algorithmic and memory-based processes determines the response, and automaticity is the result of a change in processing from primarily algorithmic to primarily memory-based. The theory's similarity with the GCM is that memory retrieval is based on similarity, and responses are based on the similarity of a stimulus to members of various response categories.

According to Palmeri (1997), memory retrieval is the result of a competitive random walk process instead of a first-instance race process. Categories, or response classes, are stored in the form of exemplars, and these exemplars are depicted as points in some multidimensional psychological space. Similarities are an exponentially decreasing function of distance in that space. In the EBRW, there is a race between exemplars for retrieval, with rates in proportion to their similarity to the stimulus, and each retrieval provides incremental evidence to drive a random walk. A response is made once sufficient evidence accumulates. The actual overt response is the result of a race between this memory retrieval process and an algorithmic process.

Rickard's Component Power Laws (CMPL) Theory

Rickard's (1997) CMPL theory differs from the Instance theory with respect to the assumptions about the processes and representations that underlie the shift from algorithmic to memory-based performance. The CMPL theory assumes that memory retrieval is strongly dependent on attention, and that only one event can be retrieved at any one time. Hence in contrast to the Instance theory, the CMPL theory claims that either an algorithm or memory retrieval process is chosen at the start of each trial and that a prototype representation for each item is strengthened with practice. Also in contrast to the Instance theory's claim that automatic processing is the result of memory retrieval, is the CMPL model's assertion of a continuum from more goal-driven to more stimulus-driven retrieval from memory. The stimulus-driven retrieval is associated with automaticity, in that it can occur outside the control of attention.

According to Rickard (1997), even the stimulus-driven, or automatic, retrieval cannot occur in parallel for two or more stimuli. Although multiple responses are activated in parallel in the early stages of retrieval, according to the CMPL model, selection of one response always results in suppressing all other competing responses. The CMPL model claims that strategy choice is determined only by item-specific processes (the strength of connections from the external stimulus items to the problem nodes) and strategy-specific processes (strength of connection from the general solve problem goal to the strategy sub-goal).

The Power Law

Newell and Rosenbloom (1981) observed that performance improvements as a result of practice, denoted by performance speed up and reduction in error rate, show up as power functions. According to VanLehn (1996), the power law of practice is the time needed to do a task which decreases in proportion to the number of trials raised to some power. A power function equation is of the form:

$$\mathrm{RT} = a + bN^{c}$$

In this equation, RT is the time to perform the task, N is the number of practice trials, a is performance time at asymptote, $a + b$ is the time on trial 1, and c is the rate of learning. Anderson (1982) described the power law of practice as a plot of the logarithm of the time to perform a task against the logarithm of amount of practice and this approximates a straight line. According to Anderson (2000), while performance speeds up with practice, such functions also show that the benefit of extended practice rapidly decreases. The power function has been confirmed in a number of studies including lexical decision tasks (Kirsner & Speelman, 1996), alphabet-arithmetic tasks (Logan & Klapp, 1991), and fact recognition (Pirolli & Anderson, 1985). Research has also demonstrated that any decline in automatic performance over time appears to follow a power function (Grant & Logan, 1993). Research has also revealed that the amount of forgetting is relatively small in comparison to the amount of improvement with practice (Anderson, 1992; Loftus, 1985).

The ACT* theory (Anderson, 1982, 1983, 1987, 1992) posits that power law improvement is the result of accumulation of strength in individual productions. The strength of memory structures is determined by the amount of activation received. As a result of strength accumulation, individual productions speed up as a power function.

According to the Instance theory (Logan, 1988, 1990, 1992), performance on a task is the result of a race between the algorithm and memory for past solutions. As practice increases, the number of instances in memory also increases, resulting in a speed up of retrieval of instances. Hence, speed increases with automatisation. Logan also observed that not only do reaction times decrease as a power function of practice, but the standard deviation of these reaction times also decreases as a power function. Similar to the Instance theory, the EBRW (Palmeri, 1997) predicts that the underlying race components of memory retrieval result in power law reductions in reaction time. Memory retrieval is faster as more instances enter the race. In addition to predicting power law decreases in reaction time, this theory also predicts power law reductions for standard deviations. In contrast to the above theories, the CMPL theory (Rickard, 1997) makes process-based predictions of when the power law holds for both reaction times and standard deviations and when it does not. Rickard predicted that the power law of practice does not hold in the overall data for either reaction times or standard deviations, but does hold generally within each of the component strategies.

<u>Transfer of a Skill</u>

According to Adams (1987) transfer of training is the learning of a response in one situation that influences the response in another. Transfer of skills has been demonstrated in a number of studies including research on the role of processing strategies (Doane, Sohn, & Schreiber, 1999), transfer of knowledge in a multistep serial task (Frensch, 1991), lexical decision tasks (Kirsner & Speelman, 1996), basic arithmetic skills (Rickard, Healy, & Bourne, 1994), letter search (Schneider & Fisk, 1984), and syllogisms (Speelman & Kirsner, 1997). The different theories make different predictions about the transfer of a skill. The ACT* theory (Anderson, 1982, 1983, 1987, 1992) predicts the development of both general and specific skills. That is, skills developed are specific to tasks previously encountered but also generalisable to new tasks that share some similarity with previous tasks. In the ACT* theory transfer can be positive or negative. Positive transfer, that is prior knowledge of a skill that facilitates learning another skill, occurs between similar tasks, and negative transfer, in which learning a skill interferes with learning another skill, occurs occasionally. Anderson (2000) noted that the only clearly documented example of negative transfer is that of the Einstellung effect or mechanisation of thought. Luchins (1942, cited in Anderson, 2000) demonstrated the way in which this effect can create a powerful bias for a particular solution when solving a series of problems. Singley and Anderson (1989, cited in VanLehn, 1996) found that negative transfer generally occurs during the early stage of learning the transfer task. With immediate feedback regarding incorrect responses, correct responses can be acquired quickly whereas lack of feedback about incorrect responses results in negative transfer persisting even in the later stages of learning the transfer task.

Unlike the ACT* theory, the Instance theory (Logan, 1988, 1990, 1992) predicts the development of specific skills only. According to Logan, specific skills are developed when a person responds over and over again to specific stimuli. Each combination of stimulus and response is stored in memory as a whole processing episode in the form of an instance. The result of this strategy is that when presented with a stimulus previously encountered, a participant retrieves the particular instance from memory and responds based on memory for the past solution. The Instance theory accounts for only zero or complete transfer because learning is linked to specific items encountered during training (Lassaline & Logan, 1993). However, Greig and Speelman (1999) reported that Logan, in a personal communication, had considered the possibility that positive transfer may be accounted for through a modification of an aspect of the Instance theory. Logan's view was that by allowing the general algorithm to change with practice, some item-general skill may be acquired which could be applied in new situations. However, Greig and Speelman noted that this modification changes the nature of the theory and it becomes comparable with the ACT* theory which accounts for both item-specific and item-general skills. The only difference would be that item-specific information would be stored separately to item-general information in Logan's modified model, whereas according to Anderson, both are integrated in productions.

The EBRW theory (Palmeri, 1997) extended the Instance theory and holds that transfer of a skill is influenced by the similarity of new items to original training items. Responses are faster for items that are similar to other items of the same category, and slower for items that are similar to items of other categories. The EBRW predicts that new items will be judged as slowly as they were at the commencement of training and old items will be judged as quickly as they were at the conclusion of training. In the CMPL model (Rickard, 1997), either the algorithm or the retrieval strategy is selected for each trial, but not both. The retrieval strategy is employed for items previously encountered whereas the algorithm is selected for items not previously encountered. The model predicts problem-specific speed up but no general speed up, hence the response times for new items would be slower than the response times for old items.

ACT* and Instance Theories: Empirical Evidence

The different theories of skill acquisition have attracted considerable research attention. In this section, a review of research on the ACT* and Instance theories is presented.

Support for production system models (ACT* theory) of skill acquisition and challenges to the Instance theory have been provided by a number of studies. Carlson, Khoo, Yaure, and Schneider (1990) studied the levels of organisation and use of working memory in the acquisition of a problem-solving skill. Their findings revealed that practice resulted in strategic restructuring of cognitive processes at all levels, suggesting a multiple level analysis of skill acquisition. Carlson et al. noted that their observations were consistent with the hierarchical goal structures and restructuring learning mechanisms proposed in production system models of skill acquisition. An examination of the role of processing strategies in the acquisition and transfer of a cognitive skill (Doane, Sohn, & Schreiber, 1999) revealed that skill acquisition is influenced by the acquisition of both stimulus-specific knowledge and strategic skills, and that the strategic skills acquired serve to optimise processing. A similar finding was obtained in research on a sequential number computation skill that suggested memory for processing sequences general to many instances is more instrumental in the acquisition and transfer of sequential processing skills than sequence memory that is instance specific (Woltz, Bell, Kyllonen, & Gardner, 1996). These findings support the ACT* theory as it predicts the development of both specific and general skills, unlike the Instance theory.

In their investigation of the role of consistency in the development and transfer of automatic processing, Kramer, Strayer, and Buckley (1990), observed that learning was not restricted to items encountered during training, partial positive transfer occurred, and there was some evidence for general process-based learning. These results were similar to Speelman and Kirsner's (1997) findings of performance improvement on a task that did not involve any item repetition, partial transfer, and different training conditions resulting in different performance strategies. Further evidence for partial positive transfer from the training to the transfer task was obtained by Greig and Speelman (1999) who tested the transfer predictions of general and specific theories of skill acquisition.

The above findings pose significant problems for the Instance theory because of its inability to account for these results. The theory does not account for the findings of hierarchical goal structures, performance improvements on tasks that do not involve any item repetition, the development of general and specific skills, and partial transfer to a new task. On the other hand, the ACT* theory can account for each of these results as follows. According to the ACT* theory, cognitive skills are encoded by a set of productions that are organised according to a hierarchical goal structure, and performance improvement on new tasks is the result of refinement and strengthening of productions. ACT* theory also predicts the development of general and specific skills, and hence can account for partial positive transfer. As transfer is dependent on the number of shared productions between tasks, the greater the production overlap, the greater the transfer (Greig & Speelman, 1999).

However, in spite of the above challenges to the Instance theory, some studies have provided support for the Instance theory. The Instance theory's assumptions of obligatory encoding and obligatory retrieval were supported by Boronat and Logan's (1997) examination of the relationship of attention and automaticity which revealed that attention operates at both encoding and retrieval. The role of attention in automatization was examined by Logan and Etherton (1994). Their results revealed that attention determined what got into an instance and performance was based on instance retrieval. In a study of the transition from algorithm to memory (Compton & Logan, 1991), the race model, a component of Logan's Instance theory of automatisation, received support.

Support for the Instance theory was also provided by Logan and Klapp's (1991) investigation of the necessity of extended practice in producing automaticity, as their results suggested that a transition from counting to remembering underlaid the automatisation. A similar finding of memory for specific instances encountered during training was obtained in Masson's (1986) experiments on the development of skill at identifying typographically transformed words, by Rickard et al. (1994) in their study of the transfer of basic arithmetic skills, and by Siegler (1988) in his study of the acquisition of multiplication skill in children. In their article on memory-based automaticity in the discrimination of visual numerosity, Lassaline and Logan (1993) extended Instance theory to account for the development and transfer of automaticity with nonsymbolic stimuli. Instead of a single transition from algorithmic computation to memory retrieval, the memory-assisted algorithm view suggests two transitions: one from the algorithm to memory-assisted algorithm and another, which occurs later in training, from memory-assisted algorithm to instance retrieval.

Speelman and Kirsner (1997) noted that as Logan's experiments are characterised by tasks in which highly specific stimuli and responses are experienced repetitively, participants develop highly specific skills that rely on memory for past solutions rather than generate new solutions. Speelman and Kirsner argued that if training is less constrained and the development of general strategies is encouraged, abstract skills that are highly transferable will result. These researchers explained that if this occurs then the nature of the environment would determine the mechanisms of skill acquisition.

Factors Affecting Skill Acquisition

A number of factors have been shown to influence the extent to which a new skill is acquired. They include cognitive ability (Ackerman, 1992; Eyring, Johnson, & Francis, 1993; Kanfer & Ackerman, 1989), self efficacy (Eyring et al.; Mitchell, Hopper, Daniels, George-Falvy, & James, 1994), motivation (Kanfer & Ackerman), task familiarity (Eyring et al.), age (Mead & Fisk, 1998; Strayer & Kramer, 1994), knowledge of results (Schmidt, Young, Swinnen, & Shapiro, 1989; Swinnen, Schmidt, Nicholson, & Shapiro, 1990; Weeks & Sherwood, 1994), and practice (Landin, Hebert, & Fairweather, 1993; Maring, 1990; Mumford, Costanza, Baughman, Threlfall, & Fleishman, 1994; Piani, 1998; Pirolli & Anderson, 1985; Shute & Gawlick, 1995). In the current study the effect of the type of training on the type of skills acquired, and the type of transfer obtained, was examined.

Introduction to the Current Study

The effect of type of training on the type of skills acquired and type of transfer obtained has received considerable attention. Speelman and Kirsner (1997) reported that whether skill acquisition is specific to past experiences, or general to all similar experiences may be determined by the nature of the situation in which skills are acquired. If training is highly constrained, such that few task variations are experienced and reliance on past solutions is encouraged, highly specific skills will result. If training is less constrained, such that many task variations are experienced and the development of general strategies are encouraged, abstract skills that are highly transferable will result.

Brewer (1998) studied the effect of training mode on skill acquisition and transfer in solving a simple algebraic formula $\frac{x^2 - y}{2}$. Brewer's study focused on 42 undergraduate psychology students who were assigned to one of two groups. The experiment included a training and transfer phase. In the training phase, his participants received one of two levels of the independent variable (number of pairs of values for x and y). One group (the low variation group) was given eight pairs of values for x and y and the other group (the high variation group) was given 16 pairs of values for x and y. Hence the low variation group was presented with each stimulus pair 40 times during training whereas the high variation group was presented with each stimulus pair 20 times during training. The training phase comprised forty blocks of eight trials each, a total of 320 trials that were generated in a pseudo-random order by the computer, so that each pair of values for x and y were encountered only once per block. Participants were required to substitute values for x and y in the formula, calculate the solution, and respond whether the solution was an odd or even number. In the transfer phase both groups were presented with the same transfer task consisting of another two blocks of eight trials based on the original algebra formula. The x and y items in the first transfer block consisted of new values not encountered by either group in the training phase. The second block consisted of a mixture of old and new values for x and y. This block included four x and y stimulus pairs from the training phase, and four x and y stimulus pairs whose x values had been encountered during training, and whose y values were encountered only during the transfer phase.

Brewer's (1998) results revealed the existence of partial positive transfer indicated by the response times for the transfer phase being significantly faster than the response times at the commencement of training, but not as fast as at the completion of training. Furthermore his results concurred with that of Speelman and Kirsner (1997) as he noted that transferability was a function of variation in training, with participants who encountered a greater number of stimulus pairs during training being significantly faster on the transfer items than participants who encountered less variability in training.

The results indicated that when only a small number of x and y stimulus pairs were encountered during training, participants were encouraged to develop highly specific routines for performing the task. This was reflected by the transfer phase response times being significantly greater for those participants who trained with a smaller number of x and y pairs. When a greater number of x and y stimulus pairs were encountered during training, participants were encouraged to develop a more general routine that was transferable to a new task.

The current study extended Brewer's (1998) experiment by using the same algebraic formula $\frac{x^2 - y}{2}$. In this study the effect of the specificity (highly specific or less specific) of training values on the performance of a transfer task was examined. While participants in Brewer's study had the same amount of task practice but differed considerably in the amount of item practice, participants in the current study experienced the same amount of task practice and almost the same amount of item practice. The habit-encouraging condition was presented with the same set of eight (x, y) values repeated throughout the experiment. The habit-breaking condition was similar except that only seven of these (x, y) values were repeated, and these values were accompanied by a new (x, y) pair in each block of eight trials. It was expected that these new (x, y) pairs in this condition would serve as a habit-breaking trial forcing participants to calculate a solution instead of retrieving the answer from memory, as could be the case when the same values to be calculated are repeated a number of times. Luchins' (1942, cited in Anderson, 2000) use of a habit-breaking trial to break a mental set, or Einstellung, served as an inspiration for the design of the habit-breaking trial in the current study.

The algebra formula used in this study was the same in both the training and transfer phases. If participants acquired the general skill of solving the algebra formula during training, it was expected that while participants would be slower at responding in the transfer phase of the study, because of the impact of the new (x, y) stimulus pairs, they would still be faster than at the commencement of training, a result of partial positive transfer. However, if the response times in the transfer phase of the study were similar to the response times at the commencement of the training, then this would indicate that transfer is zero. The result of partial positive transfer has previously been demonstrated in alphabet-arithmetic tasks (Brewer, 1998; Greig & Speelman, 1999; Piani, 1998) and as a result it was hypothesised that participants in both groups in the current study would acquire some item-general skills during training and this would result in partial positive transfer.

Participants in the habit-encouraging condition were expected to develop skills that were specific to the training experience, while for those in the habit-breaking condition, it was expected that the one habit-breaking trial in each block would be sufficient to force participants to develop more general skills that are applicable beyond the training experience. When participants encountered new values for (x, y) stimulus pairs in the transfer phase, those who developed more general skills or habits were expected to benefit from greater transferability of skills to the solution of the new task, unlike those who developed more specific skills or habits. The amount of partial positive transfer would be influenced by the type of training. In view of this it was hypothesised that participants who encountered greater specificity of (x, y) stimulus pairs during the training phase would have significantly slower response times in the transfer phase than participants who trained with less specific (x, y) stimulus pairs.

The hypothesised findings of partial positive transfer, and performance improvement on a new task, if obtained in the current study, would provide support for the ACT* theory as the theory predicts the development of both item specific and item general skills. Conversely, these findings would pose problems for the Instance theory because the theory predicts the development of item specific skills only and would be unable to account for these results.

Method

Participants

A convenience sample of 44 participants from undergraduate courses at Edith Cowan University, work colleagues, and friends of the researcher participated in this study, of whom 26 were female and 18 were male. The participants' ages ranged between 18 and 55 years, with the mean age being 36.5 years. Participants were approached by the researcher, over the telephone or face to face, and were randomly assigned to one of two experimental groups. They were rewarded for their participation by going into a raffle for $50.

Results of two of the participants had to be excluded from the study because their mean accuracy rate was under the 70% accuracy deemed to be appropriate. As a result, the habit-encouraging condition had 22 participants and the habit-breaking condition, 20 participants.

Design

The study measured the response times (dependent variable) required to solve the algebra formula $\frac{x^2 - y}{2}$ in the training and the transfer phases of this experiment. In the training phase, participants received one of two levels of the independent variable (specificity of the values for x and y stimulus pairs). The habit-encouraging condition involved training with a set of eight (x, y) pairs that was repeated throughout the training phase. The habit-breaking condition was similar to the habit-encouraging condition except there were only seven (x, y) pairs that were repeated, and these were accompanied by a new (x, y) pair in each block of 8 trials. In the transfer phase, both groups were presented with eight sets of new values for the (x, y) stimulus pairs.

Apparatus and Materials

The apparatus included a desk, a chair, an Apple Macintosh computer, and a keyboard. The test was custom designed and administered in the Superlab program. The software enabled participants' responses to be recorded automatically. The algebra formula $\frac{x^2 - y}{2}$ used in Brewer's (1998) experiment was also used in the current study. The values of the (x, y) stimulus pairs (e.g., $x = 4$ and $y = 2$), for the habit-encouraging and habit-breaking conditions in the training and transfer phases of the experiment are presented in Appendix A. The aim of the task is to generate an answer based on the presented x and y values, and then decide if the answer is an odd or even number. The correct response for each (x, y) stimulus pair is also presented in Appendix A.

Procedure

Participants were randomly assigned to either the habit-encouraging or the habit-breaking group. Prior to commencement, they were informed of the procedure, but not the aim of the experiment (see Appendices B and C for Information Sheet and Consent Form). The experiment consisted of a series of trials presented to participants on the computer screen. Each trial consisted of the presentation of the formula along with values for the x and y stimulus pair. Participants were required to calculate a solution for the formula and decide whether the answer to the solution was odd or even, indicating their decision by pressing one of two keys on the keyboard. Pressing the red key marked "E" indicated an "Even" response, and pressing the red key marked "O" indicated an "Odd" response (see Appendix D for on screen instructions).

To allow participants to familiarise themselves with the task, three practice trials were presented in the manner described above (see Appendix D.2), with values for x and y that did not form part of the values for the training or transfer phases of the experiment. When participants registered their answer to each practice trial, they were notified on-screen whether their answer was "CORRECT" or "INCORRECT – TRY AGAIN". After the three practice trials, participants were asked to call the experimenter.

The training phase consisted of 40 blocks of eight trials each, being a total of 320 trials. Within each block, the trials were presented in a random order generated by the computer. Each trial was presented one at a time without any indication of block grouping. When participants registered their answer to each trial, they were notified on-screen whether their answer was "CORRECT" or "INCORRECT" (see Appendix D.3). After a few seconds the screen cleared and a new screen appeared displaying a message prompting the participant to commence the next trial when ready. The trials presented to participants in the habit-breaking group in the training phase differed from that of the habit-encouraging group. Each block of eight trials presented to the habit-breaking group comprised seven of the eight trials presented to the habit-encouraging group, plus one habit-breaking trial that was selected from among 20 new (x, y) stimulus pairs. Each of these 20 habit-breaking stimulus pairs was presented twice throughout the training phase, and all 20 of these items were presented once before the set was repeated.

Participants were not informed of the transition between the training and transfer phases of the experiment. On completion of the training phase, both groups were administered the same transfer phase that comprised one block of eight (x, y) stimulus pairs not previously encountered during training. Within this transfer block, the eight trials were presented in a random order. The trials in the transfer phase were presented in the same manner as trials in the training phase.

The task took approximately 45 minutes to complete. On completion, participants were debriefed, thanked for their participation, and were provided with a ticket for the $50 raffle.

Results

Appropriate accuracy in the task used in this experiment was deemed to be 70%, which is well above chance (50%). The accuracy rate of all participants in the last 10 blocks of training (blocks 31 to 40) was examined. Of the 44 participants, 42 had accuracy rates above 70%. The remaining two participants had accuracy rates of 63.75% and 65%. Results of these two participants were excluded from the study. The mean accuracy rate of the remaining 42 participants was 95.24%. The mean response times of correct responses only were analysed. The mean response times for each participant are presented Appendices E and E.2.

To establish the effect of the specificity of training, the mean response times of the two groups in the 40 training blocks were analysed using a 2 x 40 (Specificity x Block) split plot analysis of variance (SPANOVA). In this analysis, the mean response times of only the correct responses to the seven trials within each block that were common to both groups were analysed. The SPANOVA's assumption of sphericity for Block was violated, therefore new degrees of freedom were calculated using the Huynh-Feldt adjustment. The homogeneity of variance assumption was also violated, therefore the F value was assessed at a more conservative alpha level of .01. The analysis revealed a significant main effect for Block $F(6.799, 271.962) = 85.648$, $p < .01$. The main effect for Specificity was not significant $F(1, 40) = .232$, $p > .05$. The interaction was also not significant $F(39, 1560) = 1.291$, $p > .05$. The plot of the results is displayed in Figure 1. Descriptive statistics are presented in Appendix F.

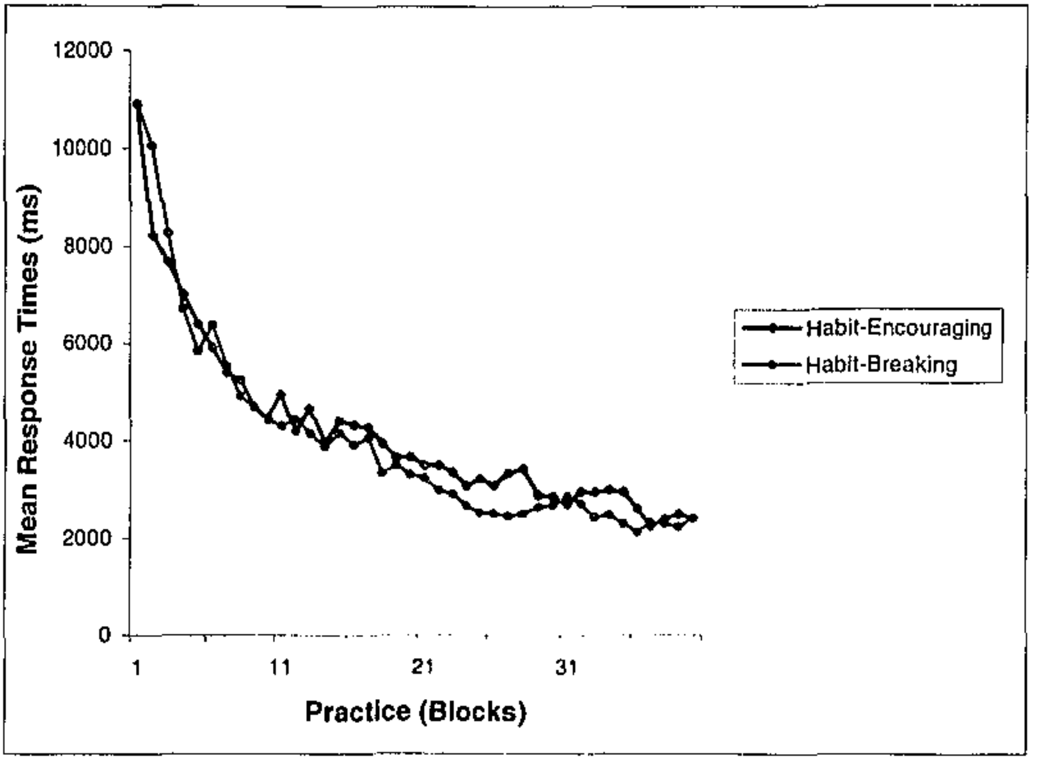

Figure 1. Mean response times of the habit-encouraging and habit-breaking groups in the training phase.

To determine the effect of the specificity of training on transferability of skill, the mean response times of the two groups in Blocks 40 and 41 (the last block of the training phase and the transfer block) were analysed using a 2 x 2 (Specificity x Block) SPANOVA. In this analysis, the mean response times of only the correct responses to the seven trials in Block 40 and all eight trials in Block 41, that were common to both groups, were analysed. The SPANOVA's assumption of sphericity for Block was violated, therefore new degrees of freedom were calculated using the Huynh-Feldt adjustment. The analysis revealed a significant main effect for Block $F(1.000, 40.000) = 78.741$, $p < .05$. The main effect for Specificity was not significant $F(1, 40) = .614$, $p > .05$. The interaction was also not significant $F(1, 40) = 1.005$, $p > .05$. Results are displayed in Figure 2 and descriptive statistics are presented in Table 1.

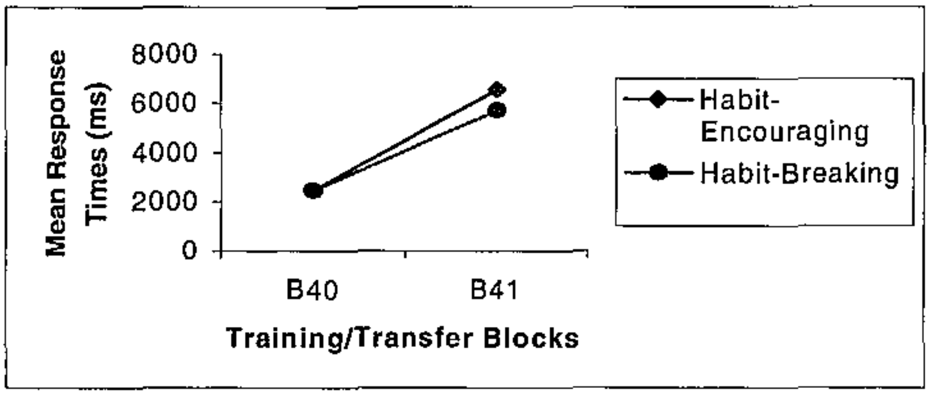

Figure 2. Mean response times of the habit-encouraging and habit-breaking groups in the last block of training and the transfer block.

Table 1.

Mean Response Times (milliseconds) of the Habit-Encouraging and Habit-Breaking Groups in Training Block 1, Training Block 40 and Transfer Block 41

	Habit-Encouraging Group		Habit-Breaking Group	
	M	SD	M	SD
Training				
Block 1	10892	5362	10915	3284
Block 40	2414	1322	2415	934
Transfer				
Block 41	6560	2884	5719	2902

An analysis of the size of the effect of specificity of training in the transfer phase of the experiment using Cohen's (1992) formula revealed that d = .31 and Power = .16. That is, there appeared to have been an effect of the type of training in the transfer phase of the study, but this effect was not significant. Reference to a table of Cohen's revealed that for a study with a Power of .80, at $\alpha = .05$, to obtain a medium effect size, a sample of 64 participants in each group would have been required. Hence a total of 128 participants would have been required to determine whether this was indeed a true effect.

The relative slowing in response times of both the habit-encouraging and habit-breaking groups from the end of the training phase to the transfer phase was examined further. The response times in Block 40 were subtracted from the response times in Block 41 to obtain the difference in response times. The resulting response times were analysed using an independent groups T-Test. The assumption of homogeneity of variance was not violated, hence equal variance estimates of t were consulted. Results revealed that the effect of the specificity of the training condition was not significant $t(40) = 1.002$, $p > .05$. That is, the slowing revealed in the transfer phase compared to the end of the training phase, was of an equivalent amount in each condition.

An inspection of the mean response times in Table 1 revealed the occurrence of partial positive transfer. While participants in both groups were slower at responding in the transfer phase of the experiment (Block 41) than they were at the end of training (Block 40), they were not as slow as at the commencement of training (Block 1).

Discussion

Results of the current experiment provided support for the hypothesis of partial positive transfer. However, the results did not provide support for the hypothesis that participants who encounter greater specificity of (x, y) stimulus pairs during the training phase will have significantly slower response times in the transfer phase than participants who train with less specific (x, y) stimulus pairs.

Training Phase

Data from the training phase of the study revealed that with increased practice participants in both the habit-encouraging and habit-breaking groups grew significantly faster at responding. The finding suggests that extended training provided participants with the opportunity to improve their skills by developing item-specific strategies or habits resulting in significantly faster response times. This result is predicted by the power law of learning (Newell & Rosenbloom, 1981) and has been found in a number of other studies including those on lexical decision tasks (Kirsner & Speelman, 1996), alphabet-arithmetic tasks (Brewer, 1998; Logan & Klapp, 1991; Piani, 1998), fact recognition (Pirolli & Anderson, 1985), and flight engineering knowledge and skills (Shute & Gawlick, 1995).

According to the ACT* theory (Anderson 1982, 1983, 1987, 1992), early in training the formula $\frac{x^2 - y}{2}$ is solved by the application of weak problem solving procedures to declarative knowledge possessed about the solution to the formula. The compilation of declarative knowledge into production rules is made up of two processes, proceduralisation and composition. Through the process of proceduralisation the declarative knowledge is converted into productions.

Initially these productions are general in nature and they can be applied to any values for x and y in the formula. With repeated presentations of specific (x, y) stimulus pairs during training, the sequences of productions that are specific to the presented stimulus pairs collapse into single productions, through the process of composition. Each time a specific (x, y) stimulus pair is presented, the collapsed production rule for the solution is applied and its strength is increased. The stronger the production rule, the faster it applies. This process explains the speed up in performance in the training phase of the study when the (x, y) stimulus pairs are encountered over and over again.

Logan (1988, 1990, 1992) on the other hand, posits that initially in training a general algorithm is performed to solve the formula. Each time the algorithm is successfully executed, the solution to the specific (x, y) stimulus pair is remembered and the whole processing episode is represented in memory and is termed an instance. Throughout the training phase, each time a trial is presented, the response results from a race between execution of the general algorithm and retrieval of the specific instance from memory, and the winner controls the response. With practice, the number of instances increases and so too the probability of an instance winning the race. As the (x, y) stimulus pairs are repeatedly encountered in the training phase, responses are dominated by retrieval of the solution from memory rather than execution of the general algorithm, and this results in the speed up in performance in the training phase.

Palmeri's (1997) EBRW model is similar to the Instance theory in that a race occurs between algorithmic and memory-based processes and the winner determines the response. Automaticity results from a change in processing from primarily algorithmic to primarily memory-based. According to the EBRW model, responses to the (x, y) stimulus pairs are stored in the form of exemplars, and are depicted as points in some multidimensional psychological space. Similarities are an exponentially decreasing function of distance in that space. When a specific (*x*, *y*) stimulus pair is presented, a race occurs between exemplars for retrieval, with rates in proportion to their similarity to the stimulus. Each retrieval provides incremental evidence to drive a random walk, and once sufficient evidence accumulates, a response is made. The actual manifested response to the specific (*x*, *y*) stimulus pair is the result of a race between this memory retrieval process and an algorithmic process. The speed up in response times noted in the training phase is due to the race being won by memory retrieval processes for previously encountered (*x*, *y*) stimulus pairs.

Rickard's (1997) CMPL theory differs from Instance theory with respect to the assumptions about the processes and representations that underlie the shift from algorithmic to memory-based performance. The CMPL theory assumes that memory retrieval is strongly dependent on attention, and claims that either an algorithmic or a memory retrieval process is chosen at the start of each trial. With practice, a prototype representation for each item is strengthened. In the early stages of retrieval, multiple responses are activated in parallel, however selection of one response always results in suppressing all other competing responses. When a specific (*x*, *y*) stimulus pair is presented, a competition occurs between the first step of the algorithm and the direct retrieval strategy. With repeated presentations of the specific (*x*, *y*) stimulus pair, the direct retrieval strategy wins the race and this accounts for the speed up in performance in the training phase.

<u>Partial Transfer</u>

An analysis of the response times of both groups in the last training block and the transfer block revealed that both groups were significantly slower at responding in the transfer phase of the experiment than they were at the end of training. An inspection of the mean response times of both groups at the commencement of training, the conclusion of training, and in the transfer phase, revealed the occurrence of partial positive transfer. That is, while participants were slower at responding in the transfer phase of the experiment than they were at the conclusion of training, they were not as slow as at the commencement of training.

As noted earlier, the speed up in performance of both groups in the training phase of the study is attributed to the participants developing item-specific skills or habits. When faced with new items in the transfer phase, participants could no longer apply the item-specific skills or habits they acquired during training, and were forced to develop new skills or strategies to deal with the new items. This explains the significant increase in response times in the transfer phase of the study.

It appears however, that in addition to item-specific skills or habits, other item-general skills or strategies were also acquired during training. If only item-specific skills or habits were acquired, when faced with new items in the transfer phase, participants' response times would have reverted back to the level at the commencement of training. Instead, the data revealed that response times in the transfer phase were not as slow as at the commencement of training. This outcome can only be accounted for by participants acquiring some item-general skills or strategies.

This result of partial positive transfer has also been demonstrated in alphabet-arithmetic tasks (Brewer, 1998; Greig & Speelman, 1999; Piani, 1998), basic arithmetic skills (Rickard, Healy, & Bourne, 1994), and syllogisms (Speelman & Kirsner, 1997).

The ACT* theory (Anderson 1982, 1983, 1987, 1992) accounts for the finding of partial positive transfer. In the transfer phase of the study, new items were presented for the (x, y) stimulus pairs. The item-specific productions that were developed in the training phase of the study could no longer be applied. However, the item-general productions for the solution to the formula $\frac{x^2 - y}{2}$ that were acquired in the early stages of training took over and applied to the new values for x and y presented in the transfer phase. Hence the response times were slower in the transfer phase than at the conclusion of training, but not as slow as at the start of training when the item-general productions had not yet been developed.

The Instance theory (Logan, 1988, 1990, 1992) asserts that each time a new stimulus is presented, the response results from a race between execution of the general algorithm and retrieval of the specific instance from memory, and the winner controls the response. In the training phase, the repeated presentation of specific (x, y) stimulus pairs resulted in performance being dominated by retrieval of the solution from memory rather than execution of the general algorithm. In the transfer phase, when new (x, y) stimulus pairs were encountered, there was no solution stored in memory that could be retrieved, and hence the responses to these new items were dominated by the general algorithm. The implication then is that the response times in the transfer phase should be similar to the response times at the commencement of the training. However, the results of partial positive transfer observed in the current study revealed this was not the case, and that some transfer of learning did occur. Hence the Instance theory, in its current form, could not account for the finding of partial positive transfer.

Greig and Speelman (1999) revealed that in a personal communication Logan considered the possibility that modification of an aspect of the Instance theory may account for positive transfer. That is, by allowing the general algorithm to change with practice, some item-general skill may be acquired that could be applied in new situations. However, Greig and Speelman noted that this completely changes the nature of the purely item-specific Instance theory making it comparable to the ACT* theory which is both item-specific and item-general.

Palmeri's (1997) EBRW theory holds that transfer of a skill is influenced by the similarity of new items to original training items. Responses are faster for items that are similar to other items of the same category, and slower for items that are similar to items of other categories. The EBRW predicts that new patterns will be judged as slowly as they were during the first training session, and old patterns will be judged as quickly as they were during the last training session. The response times to the new values for the (x, y) stimulus pairs in the transfer phase should be similar to the response times at the commencement of training. Hence this theory is unable to explain the finding of partial positive transfer observed in the current study.

In the CMPL model (Rickard, 1997), either the algorithm or the retrieval strategy is selected for each trial, but not both. The retrieval strategy is employed for items previously encountered whereas the algorithm is selected for items not previously encountered. The model predicts problem-specific speedup but no general speedup, therefore the response times for new items would be slower than the response times for old items. The implication is that the response times in the transfer phase would be the same as at the commencement of training. Hence this model is also unable to account for the finding of partial positive transfer.

Type of Training

Although the pattern of results were as predicted in that there appeared to have been an effect of the type of training in the transfer phase of the study, as depicted in Figure 2, results revealed that this effect was not significant. Further investigation revealed that given the size of the effect, to determine whether this effect was indeed a true effect, 64 participants in each group, that is a total of 128 participants (Cohen 1992) would have been required in this study. However, the current study was an extension of a study conducted by Brewer (1998) who obtained a significant result of the training condition with a sample size of 42 participants. Hence it could not have been foreseen that the size of the effect obtained in the current study, if it was indeed true, would not have been significant.

Implications and Future Directions

As mentioned above, the size of the sample in the current study was a major limitation in determining whether a certain type of training might provide an advantage when performing a new task. Future research with a greater sample size would be needed to determine if the effect is real. Another option would be to amend the design of the study to introduce more than one habit-breaking trial per block.

While the current study focussed on the acquisition and transfer of skills within the same domain, it would be particularly relevant to the work environment of today to establish whether certain types of skills are more conducive to a transfer between domains. For example, research could perhaps focus on whether prior training as mechanics versus train drivers would provide a differential benefit when acquiring general computing skills. Research questions such as this are crucial in the workplace of the millennium where uncertainty about long term employment pervades the workplace, and multi-skilling and multiple career paths are the norm.

Conclusion

The findings of the current study add to the body of research providing support for the ACT* theory (Anderson, 1982, 1983, 1987, 1992), and posing challenges to the Instance theory (Logan, 1988, 1990, 1992) because unlike the ACT* theory, the Instance theory is unable to account for the observed findings of partial positive transfer.

The results of this experiment also shed light on the issues raised by the company and workers in the Introduction. In response to the company's questions, the findings indicate that the company's requirement for multi-skilled staff can be met, as both current staff and new recruits are capable of acquiring new skills with training. Given this, it is particularly important for the company to employ staff who demonstrate flexibility and a willingness to learn. In response to the workers' concerns, the results of this study indicate that not only can workers acquire new skills and their performance improve with practice, but also that the skills they acquire are transferable to new tasks.

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Appendix A: Values for (*x*, *y*) stimulus pairs in the training and transfer phases, with appropriate responses

Table A1

Training

GROUP ONE (HABIT-ENCOURAGING)

Repeated Items

x	*y*	Answer	Response (Odd/Even)
4	2	7	O
4	4	6	E
4	6	5	O
4	8	4	E
9	9	36	E
9	11	35	O
9	13	34	E
9	15	33	O

GROUP TWO (HABIT-BREAKING)

x	*y*	Answer	Response (Odd/Even)
		Repeated Items	
4	2	7	O
4	4	6	E
4	6	5	O
4	8	4	E
9	9	36	E
9	11	35	O
9	13	34	E
		Habit-Breaking Items	
3	1	4	E
3	3	3	O
3	5	2	E
3	7	1	O
4	10	3	O
4	12	2	E
4	14	1	O
5	9	8	E
5	11	7	O
5	13	6	E
5	15	5	O
8	2	31	O
8	4	30	E
8	6	29	O
8	8	28	E
9	1	40	E
9	3	39	O
9	5	38	E
9	7	37	O
9	15	33	O

Transfer

GROUPS ONE AND TWO

New Items

x	*y*	Answer	Response (Odd/Even)
6	10	13	O
6	12	12	E
6	14	11	O
6	16	10	E
7	1	24	E
7	3	23	O
7	5	22	E
7	7	21	O

Appendix B: Information sheet for participants

Dear Participant

I am conducting this study as part of my Honours degree in Psychology at Edith Cowan University, and I would be grateful for your participation. The purpose is to examine the effects of the specificity of training delivery on skill acquisition and transfer. This study has been approved by the Faculty Ethics Committee.

As a participant you will be provided with a set of values and asked to calculate an answer according to a simple algebraic formula and respond whether the answer is odd or even. It is anticipated that the information obtained from this research will contribute to a broader understanding of cognitive skill acquisition and transfer.

All information provided by you will be treated confidentially.

Your participation would be entirely voluntary and should require approximately 50 minutes of your time. You will be free to withdraw your participation at any time, should you wish to do so.

If you wish to find out the results of this study, you may contact me requesting a summary. Should you have any further queries regarding this project, please feel free to contact me, my research supervisor, or the 4th Year and Honours Co-Ordinator at the addresses below.

Thank you for your participation.

Suzanne Matthews, Honours Student in Psychology.
Ph: 0407 358 135

Dr Craig Speelman
Head of School of Psychology
Edith Cowan University
Ph: 9400 5724

Dr Moira O'Connor
4th Year and Honours Co-Ordinator
Edith Cowan University
Ph: 9400 5593

Appendix C: Consent form

I have read the "**Information Sheet for Participants**" and any questions asked have been answered to my satisfaction. I give my consent to participate in this study and realise that I may withdraw at any time. I agree that research data gathered for this study may be published, provided I am not identifiable.

....

Participant's Signature Date

Appendix D: On screen instructions for introduction

In this experiment you will be presented with a small arithmetic problem such as the following:

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

$$x = 10, y = 2$$

Your task is to substitute the values for x and y into the formula to determine a value for A.

Once you have calculated a value for A you then need to decide whether this value is an even or an odd number. If A is an odd number, you should press the red key labelled "O" on the keyboard. If A is an even number, you should press the red key labelled "E" on your keyboard. Please respond as quickly and as accurately as you can.

You will now have some practice trials to make sure that you understand the task.

Please press the 'Space Bar' to begin.

D.2: On screen instructions for practice

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

x = 5 y = 5

A is ODD A is EVEN

Note: The participant's response was greeted with appropriate on-screen feedback as follows:

CORRECT OR INCORRECT – TRY AGAIN

Note: This message was displayed for a few seconds before it was replaced with the following:

Please press the 'Space Bar' to continue

Note: At the end of the practice trials, the following message was displayed:

Please call the experimenter

D.3: On screen instructions for a typical study trial

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

$x = 4$ $y = 2$

A is ODD A is EVEN

Note: The participant's response was greeted with appropriate on-screen feedback as follows:

CORRECT OR INCORRECT

Note: This message was displayed for a few seconds before it was replaced with the following:

Please press the 'Space Bar' to continue

Note: At the end of the experiment, the following message was displayed:

Please call the experimenter

Appendix E: Data of the habit-encouraging group

ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Specificity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Block1	11266	12629	10363	8578	6156	9673	5666	8545	12495	10806	5355	13793	11783	30844	13761	8638	10525	8566	10240	5426	7529	16986
Block2	6874	9696	5811	4848	6863	6105	4670	9007	12720	5700	4847	9709	9642	18837	10490	6329	10328	7020	9549	4388	6049	11395
Block3	7726	12246	6510	8660	5402	5473	3397	6500	11423	5975	5406	9847	7378	10796	8462	6927	7861	9034	7695	5570	5733	11164
Block4	6243	9993	5397	9271	1971	4969	3739	5355	11639	6894	3075	8128	5571	13656	12438	8931	6811	4860	5433	4412	4122	11316
Block5	7033	10889	4768	7070	3443	6256	4721	5175	9744	7594	3038	8553	4982	11766	7285	5768	7480	3686	5106	4037	3392	9058
Block6	5163	6769	6261	5894	3677	4744	3035	5350	8898	5888	3229	6919	6638	10813	8035	7662	6332	4627	5360	3421	3156	8378
Block7	6266	7598	5555	8250	3564	3472	2678	4453	7334	3374	3300	6369	3738	9171	10677	5333	4947	4193	4814	2954	2790	7999
Block8	4926	7392	4970	6488	3381	4134	2566	3695	6637	4344	3388	5524	4589	10824	8228	5440	7438	3168	4527	2931	3456	7525
Block9	3720	5607	5131	3719	2400	3735	2671	4460	6323	3579	2717	4647	4424	11594	5596	7635	4880	3350	4033	3283	2704	7238
Block10	4375	7163	4342	5308	2350	2797	2592	3529	4453	3105	3369	3891	3275	9491	6502	5356	5810	2949	3419	3490	3205	7613
Block11	4140	8662	5240	4615	2211	2962	3583	5213	6790	4991	2533	4870	5195	12399	5710	4954	4306	2381	4232	3000	2005	8979
Block12	3566	7780	4760	4955	2682	3010	2824	4113	5325	1963	2449	5259	3891	8202	6407	3927	3969	2954	3845	2743	2405	5655
Block13	3341	4551	4474	3170	2925	2406	3639	2698	6410	1827	2666	6862	5584	15023	7953	5277	4049	2983	3413	3349	2164	7917
Block14	3292	3724	3766	3765	3181	4242	2018	2794	4648	1799	2459	5821	3248	9963	5074	5081	3926	2781	3432	3085	2545	7154
Block15	3099	4509	5733	3021	3101	4632	2037	2335	9511	2258	2036	4634	4301	12625	6408	4582	3615	2672	3770	2895	3657	5794
Block16	3522	3142	4290	3222	[illegible]	6280	3519	3560	6806	2910	2725	7229	2948	9081	5596	3899	3982	4536	3165	2887	2688	5652
Block17	5388	4509	5379	3910	4961	2829	4775	3976	3388	2678	1629	6070	3507	9489	5626	5230	3036	3287	3272	2761	2782	5998
Block18	2917	4337	5379	3167	2463	2113	4627	2210	5710	1758	2481	5740	2205	9029	6450	5187	3447	2693	4018	2505	3238	5395
Block19	3573	3860	4745	3018	2180	2467	3629	2358	3295	1408	2071	6112	4706	8044	5206	4483	2777	2959	3078	2418	2534	5943
Block20	4976	3717	4162	2675	2260	1782	3086	1914	4034	2080	3140	4283	3026	7859	5329	7955	3146	2509	2810	2439	2874	4895
Block21	2861	4959	4152	2494	2748	2922	2727	963	4195	3730	2241	5124	3877	8028	4869	4498	3421	2308	2795	2167	2029	4064
Block22	2839	3897	5760	3004	2560	2399	2501	1255	3235	1759	2823	4752	3098	9821	5005	4335	3231	2670	2760	2269	3026	4257
Block23	2742	4048	5374	2633	2097	2360	2420	977	3529	2551	2280	4202	3368	9793	5435	4153	4563	2111	2068	1999	2148	3354
Block24	2732	2319	4868	2175	2031	1892	2696	810	3773	1310	1753	4098	3353	8475	5635	4554	3070	2203	2368	1976	1998	3841
Block25	2813	2163	5870	2768	2071	1815	3394	912	3569	2484	1656	4775	2809	8370	5281	4141	3659	2027	3264	1950	2240	3396
Block26	3115	2052	5023	2541	3529	2759	1989	1009	3243	1539	1445	4166	3388	8121	5125	4270	2626	1946	2782	2005	2100	3514
Block27	3174	4125	4036	3687	2171	2541	2424	954	3835	2936	1995	3277	4200	9502	5141	5714	3431	2138	2127	1942	2206	2310
Block28	4242	2196	6888	2054	2254	2172	4559	1442	2564	1370	1373	3273	2596	9740	4978	8297	3428	2212	2010	1901	2654	3697
Block29	2753	1461	4735	3487	1724	1229	2735	848	4079	1383	1251	3466	2828	7363	4147	5544	3043	2147	1880	2026	2128	3405
Block30	2601	1578	4024	2461	2319	1696	1651	989	2318	1373	1721	4095	3440	6408	4818	6127	3203	2176	1941	2016	1657	4367
Block31	3171	1864	3675	1688	2307	1338	1899	1028	2606	1810	1278	3161	2854	4378	6455	4353	2800	2037	2181	2132	1687	4867
Block32	2449	2359	4186	2262	2541	1163	1870	961	2382	2613	1480	4652	2386	8640	4492	6015	3453	1690	1845	1827	1985	4061
Block33	4749	2560	3555	1709	1971	971	1871	1078	3021	4417	1464	3438	3457	6302	5332	5218	2382	2615	2184	2197	1747	2458
Block34	2480	1100	4049	2849	2387	1452	1461	941	10405	1729	1754	3097	2107	4270	4830	5336	3166	1782	1946	2169	2549	4187
Block35	4112	2587	4222	2152	1708	647	1974	801	4227	1552	1429	4264	2268	9267	5000	5076	3452	1786	1452	2938	1489	2911
Block36	3110	987	2634	2043	1839	708	1771	785	2930	1487	1205	4295	2777	7745	4385	5056	2514	1611	1771	2040	1968	3936
Block37	1994	1058	2159	1598	1785	602	1206	1235	3332	1133	998	3778	2309	5302	3780	4157	2719	1676	1500	2194	1505	3653
Block38	2635	990	4177	1488	3119	581	1268	806	2646	2090	873	3240	2082	5026	3723	4540	3087	1763	1547	2217	1889	3019
Block39	4374	1388	4045	2569	1542	629	1137	720	4206	1804	816	3129	2416	4660	4010	5037	2702	1499	1323	2368	1713	3013
Block40	3390	1270	2868	2050	2097	568	1462	1094	2753	2693	779	3189	1657	4892	3306	6032	2949	1264	1345	2190	1934	3335
Block41	4432	11565	8336	3846	3577	5782	5245	5049	6543	11643	3722	8049	7157	14326	6363	6850	5957	3610	5068	3402	5745	8043
Diff40-41	1042	10295	5468	1797	1480	5214	3783	3955	3790	8950	2942	4860	5500	9434	3057	817	3008	2347	3724	1212	3811	4708

E.2: Data of the habit-breaking group

ID	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Specificity	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Block1	8268	7548	9749	7557	22565	9792	9726	11751	10902	10170	8250	12013	14428	8394	11072	10586	10082	11673	10471	13310
Block2	6735	8618	9663	5301	9960	6006	8212	24410	9283	11426	5391	11290	11202	10386	9202	9184	9657	17373	7571	10296
Block3	6052	7169	10248	4658	19083	4902	6722	4843	5234	7149	6401	7845	12506	7985	6955	6508	9447	17443	5822	8303
Block4	7784	5972	8912	4590	11065	5822	5325	3772	4669	5821	5339	5123	12121	6672	6548	4616	7274	12503	3780	6659
Block5	7783	4803	3205	5512	10210	3448	4344	1201	4040	4343	6347	3502	8946	6864	7596	5531	9455	9997	5565	4295
Block6	5557	4872	8188	5137	13939	2944	5702	4379	3435	4420	4541	4537	11000	6239	8589	6463	6447	12101	5518	3651
Block7	6093	4667	2542	3253	5589	4908	6326	3801	3043	5197	4095	3524	8884	6282	7908	5531	6401	13182	5404	3932
Block8	5356	4683	2482	3542	7525	3033	4901	1574	3762	5149	4577	4172	9583	5853	6645	4440	5222	7602	3944	3448
Block9	5162	3661	2852	2786	3934	2971	4674	1782	2804	5962	4897	5666	9389	8134	4300	5127	6014	6230	3425	4177
Block10	3401	4244	2285	3116	4396	2314	3738	1804	2829	6456	4062	3483	9174	6723	8674	4107	5188	6189	3596	2866
Block11	4439	4821	2925	2832	6885	3351	3527	1377	3018	4229	4765	3097	8588	5951	4149	4152	5634	6106	3419	2994
Block12	4721	3596	2974	2130	8009	1926	3284	1755	4339	3774	5211	3401	9402	6029	5042	3119	3577	10098	2669	4182
Block13	6003	3314	1908	2127	7449	2896	3812	1531	2743	4368	3552	3258	7175	5238	5399	4485	4496	6181	2543	4710
Block14	4935	3642	1889	1808	4294	1583	4693	1233	2373	4085	3297	3276	7987	5644	6806	2889	3790	5970	2769	5030
Block15	4598	3621	1801	2012	5573	3336	3531	1201	2394	4429	3929	2609	8267	6555	7926	3148	4978	7401	2550	3664
Block16	4168	4168	4844	2027	4368	1932	3552	1249	2634	4684	3424	3005	6061	5303	7363	3219	3212	6271	2628	4417
Block17	5236	3432	1622	2296	6775	2178	2955	1241	1864	3534	3133	4367	6596	5017	13992	4119	4090	3365	2331	3409
Block18	3645	3078	2573	1801	3543	1967	2414	1178	2338	4050	3224	4195	5689	5205	5951	2746	5016	2800	2608	2889
Block19	3453	2878	1927	2084	3079	1495	4372	1204	1869	3233	3240	6396	6223	5521	4265	2932	4860	4656	3055	3662
Block20	4325	2610	1825	2311	3971	1724	2747	1307	1804	3245	4416	3536	5910	5405	4707	3187	4280	3235	2199	3715
Block21	4287	3380	1208	2591	2807	1848	2505	1359	1887	3064	2756	3011	7095	4266	4690	3405	4042	4385	2653	3607
Block22	3370	3539	1311	2220	2805	1128	2112	1571	1463	1940	2888	3204	6925	4053	4636	3768	2851	4048	2658	3573
Block23	2880	2641	1760	1575	3091	1020	2527	1453	1681	2076	3792	2741	6193	5534	4947	2876	3176	3219	2969	2316
Block24	3380	2721	1581	1701	2828	1058	3030	1770	1569	1750	2519	2986	4541	4433	3710	3029	2644	3416	2551	2421
Block25	3156	2137	1202	1491	3192	935	2333	1675	1382	1719	2499	2105	4930	3933	3508	2488	3490	3123	1994	2633
Block26	2558	2062	1263	1539	2533	915	1606	1296	2082	2203	2669	3539	3682	3754	3181	2483	4125	3092	2241	3354
Block27	3676	1997	1515	1370	2677	831	1729	1191	1729	1643	2024	2790	4708	3948	3043	2867	3521	3681	1979	2237
Block28	2885	2607	1413	1370	2631	1493	1771	1053	1474	1976	3357	2781	3413	3638	3580	2662	2688	3422	2204	3729
Block29	3725	1997	1944	1302	3165	1298	2657	1044	1497	1945	2859	2537	3789	3380	4872	2524	4578	2968	1657	2986
Block30	3454	2306	2811	1289	3508	1027	2914	1141	1525	1703	2711	2561	4180	3503	4094	2986	3661	3153	1900	3092
Block31	4133	2465	1111	1389	4635	814	1861	1071	1539	2676	1770	2757	7807	3688	4523	2930	3250	3346	1645	3999
Block32	3661	2588	1293	1082	4759	792	1815	1145	1637	1776	3429	3066	4490	3560	3498	4051	2973	3540	2027	3017
Block33	3406	2138	1654	1426	2949	883	2349	1351	1229	1423	1993	3340	4932	3385	3636	2199	2515	2180	2451	2885
Block34	3282	2546	1061	1455	3924	1231	2071	1061	1779	2182	2102	3241	3977	3352	3838	2245	2251	3518	1631	2900
Block35	3446	1909	1207	1575	2955	917	1557	1004	1410	1243	2086	2519	3143	4309	3762	2306	3189	2462	1695	3428
Block36	2524	2021	2032	1644	2649	998	1369	1079	1139	1411	1315	2406	3747	3251	2940	2076	2783	3086	2120	2109
Block37	3991	2134	1310	1604	2377	1327	1800	1135	1431	2105	1984	3327	3352	2651	3483	2594	3003	2179	2641	2285
Block38	3896	2622	1467	1352	2664	1181	1670	1021	1173	1845	1694	3427	3209	3637	3447	2228	2935	2210	1894	2728
Block39	3397	2484	1619	1346	2148	767	1799	1047	1666	2131	2174	2966	2949	2614	3341	1969	2860	3061	1748	2769
Block40	3785	3847	1370	2090	3351	869	1685	1208	1515	1577	1572	2780	3519	3348	3564	2674	2710	2550	1924	2371
Block41	5445	4142	4695	5287	7299	1382	12035	2466	5503	2419	8367	3944	11155	5780	4579	5666	5184	10753	317[illegible]	5109
Diff40-41	1660	295	3324	3198	3948	513	10350	1257	3988	842	6795	1164	7636	2431	1015	2992	2474	8203	1251	2738

Appendix F: Mean response times (ms) for the habit-encouraging and habit-breaking groups in the training and transfer blocks

	Habit-Encouraging Group		Habit-Breaking Group	
	M	SD	M	SD
Training				
Block 1	10892	5362	10915	3284
Block 2	8222	3391	10058	4294
Block 3	7689	2318	8264	3934
Block 4	7010	3226	6718	2584
Block 5	6403	2480	5849	2496
Block 6	5920	2043	6383	2970
Block 7	5401	2275	5528	2416
Block 8	5253	2079	4925	1930
Block 9	4702	2103	4697	1874
Block 10	4463	1866	4432	2048
Block 11	4953	2484	4313	1671
Block 12	4213	1696	4462	2331
Block 13	4671	2922	4160	1702
Block 14	3992	1838	3900	1807
Block 15	4428	2525	4176	2051
Block 16	4336	1720	3926	1558
Block 17	4295	1699	4078	2780
Block 18	3958	1817	3346	1314
Block 19	3676	1599	3520	1488
Block 20	3680	1695	3323	1278
Block 21	3508	1486	3242	1347
Block 22	3512	1772	3003	1360
Block 23	3373	1845	2923	1346
Block 24	3088	1705	2682	941
Block 25	3247	1672	2531	978
Block 26	3104	1576	2509	918
Block 27	3358	1784	2458	1046
Block 28	3450	2253	2507	865
Block 29	2894	1584	2636	1080
Block 30	2863	1519	2676	968
Block 31	2708	1342	2870	1664
Block 32	2969	1793	2710	1192
Block 33	2941	1464	2416	998
Block 34	3002	2053	2482	967
Block 35	2969	1938	2311	1004
Block 36	2618	1653	2135	787
Block 37	2258	1239	2336	800
Block 38	2400	1244	2315	902
Block 39	2505	1379	2243	753
Block 40	2414	1322	2415	934
Transfer				
Block 41	6560	2884	5719	2902