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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

SUZANNE MARY MATTHEWS

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

October 2003

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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 commencement 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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Supervisor: Dr Craig Speelman
Submitted: October 2003
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.

Signature: 

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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, 1991), 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 $x$ \hfill (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 \hfill (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 \hfill (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 subgoal).

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:

$$RT = a + bN^c$$

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 automatization. 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.

Transfer of a Skill

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*
threeory, 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 $\hat{F}(6.799, 271.962) = 85.648, p < .01$. The main effect for Specificity was not significant $\hat{F}(1, 40) = .232, p > .05$. The interaction was also not significant $\hat{F}(39, 1560) = 1.291, p > .05$. 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](image)

**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.**

<table>
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<tr>
<th></th>
<th>Habit-Encouraging Group</th>
<th>Habit-Breaking Group</th>
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<td><strong>SD</strong></td>
<td><strong>M</strong></td>
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<td>Block 40</td>
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<td>1322</td>
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<tr>
<td>Transfer</td>
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<tr>
<td>Block 41</td>
<td>6560</td>
<td>2884</td>
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</table>
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.

**Partial Transfer**

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.
References


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

Table A1

<table>
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<tr>
<th>Training GROUP ONE (HABIT-ENCOURAGING)</th>
<th>Repeated Items</th>
<th>Response (Odd/Even)</th>
<th>Training GROUP TWO (HABIT-BREAKING)</th>
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<th>Response (Odd/Even)</th>
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Transfer GROUPS ONE AND TWO

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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

\[
\frac{x^2 - y}{2} = A
\]

\[
x = 5 \quad y = 5
\]

A is ODD \quad 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 \hspace{1cm} 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
E.2: Data of the habit-breaking group
Appendix F: Mean response times (ms) for the habit-encouraging and habit-breaking groups in the training and transfer blocks

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