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The Effects of Conceptual Change on the Transfer of Established Skills

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USE OF THESIS

The Effects of Conceptual Change on the Transfer of Established Skills

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Abstract

When people practice a task, their performance in terms of speed and accuracy normally improves in a smooth manner that follows a power function. The consistency with which the performance of a wide range of skills conforms to this power function relationship is known as the Power Law of Learning, and has been an important assumption of many of the dominant theories of skill acquisition and transfer. As such, the form of the power function that is derived from the training process has been used to predict performance when task conditions remain constant. However, Speelman and Kirsner (under review) have found that performance can be disrupted by any change in a task, especially with regard to task complexity. The present study sought to more closely examine the nature of the disruption by focusing on whether it related to a change in the conceptual requirements of the task as a function of complexity. Sixty participants were used to examine three aspects of conceptual change on an arithmetic test task consisting of problems drawn from the Six-Times table, all of which could be solved by memory retrieval. The three respective conditions dealt with the influence on the test task of: other memory retrieval problems; algorithmic processing; and a combination of memory retrieval and algorithmic processing. All participants received a common set of 72 test task problems in the training phase of the experiment, which were combined with 72 distractor task problems and presented to participants in exactly the same manner in the transfer phase. Mean reaction times and accuracy were measured for the test and distractor tasks in the training and transfer phases. An analysis of the results supported Speelman and Kirner's findings of a disruption in performance at the introduction of the distractor task problems. Such a disruption was found in the conditions examining algorithmic processing and a combination of memory retrieval and algorithmic processing. In contrast to Speelman and Kirsner's findings, where participants quickly recovered from the disruption, a prolonged disruption was found in all conditions that continued throughout the transfer phase. These findings, together with those of Speelman and Kirsner, challenge some of the assumptions of current theories of skill acquisition and transfer, and provide further avenues of research into the factors affecting the use of skills in a new environment.

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Declaration

I certify that this thesis does not incorporate, without acknowledgement, 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:

Date:

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Introduction

When people practice a task, their performance normally improves in a smooth manner. If task conditions remain constant, performance normally becomes more accurate and faster with practice. Speelman and Kirsner (under review), however, observed a disruption in this improvement that could not be explained by current theories of skill acquisition. The aim of this project was to examine one explanation of this performance disruption, namely conceptual change. In order to demonstrate why this disruption is surprising, the following section describes the fundamental characteristics of skill acquisition. This is followed by a discussion of some of the main theories that have been developed to explain the various phenomena associated with the process of skill acquisition. Finally, after Speelman and Kirsner's experiment is analysed, the current project is described in terms of how it more closely examined the nature of the disruption.

Fundamentals of Skill Acquisition

The Three Phases of Skill Acquisition

How a person acquires a skill is one of the components of the development of expertise, where a person moves from being a novice at a task to a degree of proficiency—perhaps even achieving expert status. This transition from novice to expert is only achieved through extensive practice, and seems to follow a process that can be generalised to different areas of skill.

The initial process of acquiring a skill is generally considered to involve a progression through three developmental stages (Fitts & Posner, 1967). In the initial stage, referred to as the cognitive stage, a person develops what is known as a declarative encoding of a skill. This involves the encoding, or committing to memory, of the facts relating to the performance of the skill. The encoding is declarative in nature

simply because the person concerned is able to identify and state the facts relevant to skill performance. One example cited by Fitts and Posner of this process is that of learning to dance. When a person is learning to dance, they typically attend to kinaesthetic and visual information about the movement and placement of their limbs and feet. This type of information is later ignored as the person develops proficiency at dancing. While all of the stages of skill acquisition must include practicing the skill in order to improve performance, the cognitive stage usually involves more practice than the other stages.

The second stage is known as the associative stage. Fitts and Posner (1967) consider that there are two significant events in this stage. First, the person identifies and corrects errors in their initial understanding of how to perform the skill. Second, the various elements required for the successful performance of the skill are identified, and the connections between these elements are strengthened. This stage marks the shift from declarative knowledge to procedural knowledge, which is knowledge about how to perform an activity (Anderson, 1995). Anderson believes that the outcome of this associative stage is the successful procedure for performing the skill. It is also possible for a person to possess both declarative and procedural knowledge about a skill, however as Anderson notes, skilled performance is governed by procedural knowledge.

The final, third stage of the process of skill acquisition is the autonomous stage. As the person moves into this phase, their performance becomes more automatic and rapid. Indeed, two of the dimensions that improve with practice required for a person to move into the autonomous stage are speed and accuracy. In other words, the procedural knowledge that a person has developed can be applied more rapidly and more appropriately to the circumstances at hand (Anderson, 1995). Anderson (1982)

describes this process of being able to apply the knowledge more appropriately as tuning.

Automaticity

As the final stage of skill acquisition implies, one of the results of the autonomous stage is automaticity. Automaticity is a process that is largely independent of conscious control and attention, and describes the degree to which a person must intentionally consider the requirements and specific application of a skill when the circumstances dictate that it be performed (Reber, 1995). As such, one of the results of increasing practice is the lessening amount of attention that someone needs to pay to the process of completing a task. Indeed, Anderson (1995) notes that processes that have become automatic complete themselves without any conscious control. This is in contrast to controlled processes which, as the name implies, require some form of conscious control over their initiation and execution (Anderson, 1995). Bargh (1984) states that automatic responses are defined by the following criteria: 1. They are unintentional, in that they do not require a goal to be present to be activated; 2. They are involuntary, since they always occur in the presence of an appropriate cue; 3. They are effortless, in that they do not require any cognitive capacity; 4. They are autonomous, since they will run to completion without any conscious monitoring; and, 5. They are outside awareness, which means that they are activated and operated without consciousness.

Automaticity is a common cognitive phenomenon that plays a role in both attention and performance. For example, Shiffrin and Schneider (1977) conducted a number of experiments that examined automaticity and visual search. Their participants were asked to search for either a letter or a number within a series of displays that themselves contained either letters or numbers. As such, the participants were searching

for numbers within letters, numbers within numbers, letters within letters, or letters within numbers. There was a marked difference between each of these conditions, with more time being taken to locate target letters or numbers within similar stimuli (e.g., letters within letters) as opposed to differing stimuli (e.g., numbers within letters). Shiffrin and Schneider believed that the participants were so well practiced at detecting numbers among letters before they even entered the laboratory that this process was automatic. This automatic processing stands in contrast with conditions in the same experiment where participants were asked to detect letters within letters or numbers within numbers. In these cases, they were forced to use a controlled process that involved comparing the target with each letter in the display in a serial fashion.

Other research has identified that automatic processes not only require very little attention to begin execution, they are also difficult to prevent from executing. Included in this research is work on the Stroop effect (Anderson, 1995), which looked at the strong tendency for words to "demand" being processed. Participants in this research are typically asked to state the ink colour that a word is printed in. The word is usually one that relates to a colour other than the one being presented. For example, people would see the word "red" printed in green ink. These experiments have found that reading is so automatic that participants cannot stop themselves from reading the word and stating it in response to a query about what colour ink the word is printed in. That is, they were unable to stop reading the word, even when that is what they were instructed to do (Anderson, 1995).

Given that people progress toward at least a degree of automaticity in a skill, even to the point of being unable to control their response despite instructions to the contrary, the question of the extent to which these skills can be transferred to similar situations arises. It seems that skills are surprisingly narrow in terms of the range of

situations in which they can apply—they often fail to transfer to other activities. Carraher, Carraher, and Schliemann (1985, cited in Anderson, 1995) demonstrated just how narrow skill transfer can be in a study of Brazilian school children working as street vendors. When they were working on the streets, they were able to demonstrate quite impressive mathematical skills when mentally calculating the total cost of orders that involved different numbers of different objects. In their street environment, they were 98% accurate in their calculations. When asked to perform the same tasks in pure mathematical terms (e.g., $5 \times 35 = ?$, as opposed to calculating the total cost of 5 lemons at 35 cruzeiros), their accuracy dropped to 37%. This drop in accuracy continued to be present even when the tasks were stated as word problems that related directly to their work, with performance improving to only 74%. It would appear that the children needed to take account of two factors in order to optimally perform: 1. They needed to correctly conceive of the problem, in that they needed to relate it to some form of practical application; and, 2. They needed to be able to relate the problem at hand to the environment in which they learned their skill.

The Power Law of Practice

The broad process of skill acquisition is a phenomenon that is highly consistent across people. When people practice a task, they get better at it—becoming faster and more accurate at whatever they are doing. However, it is not only improvement in these discrete terms that is well established. The manner in which the improvements take place is so consistent that it is often referred to as one of the few laws of psychology. Indeed, this development of skills is commonly known as the power law of practice or the power law of learning. It is referred to as a power law because the improvements that are made with additional practice diminish as time goes on (see Figure 1) and follow a mathematical power function.

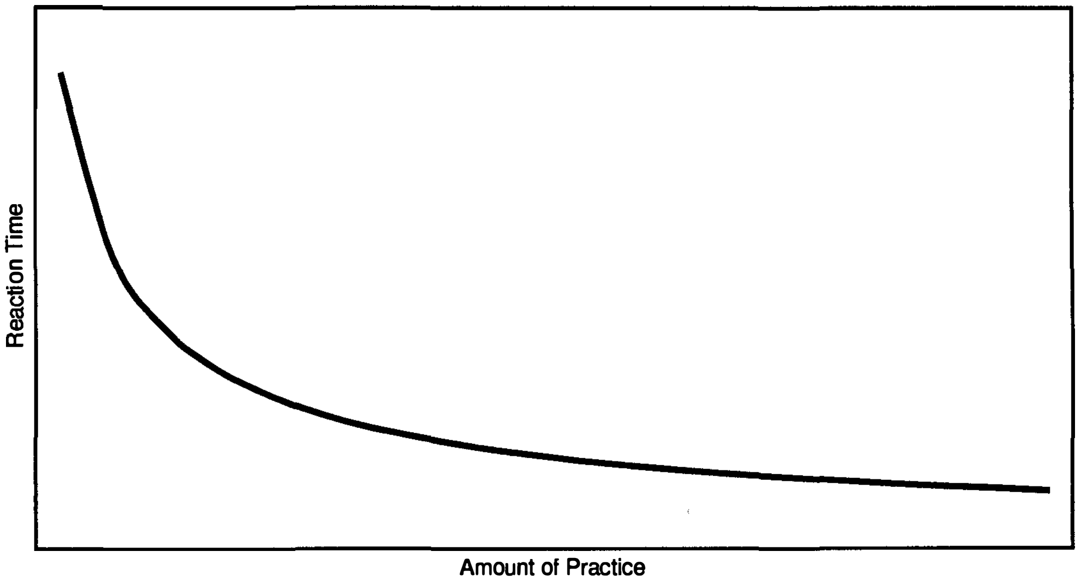

Figure 1. Illustration of the power law of practice

The time to perform a task decreases as a power function of the number of trials (Anderson, Fincham, & Douglass, 1999). The form of the power function is: latency = $A + BP^{-c}$. In this formula, A represents the asymptotic latency, B represents the latency that can be reduced through practice, P reflects the number of practice trials, and c is the learning rate. The value for c normally falls between 0 and 1, with a value close to zero indicating that very little learning is taking place, and a value close to one indicating that a significant amount of learning is taking place. While strong, the support for the power law of practice as being applicable in all practice situations is not absolute. For example, Rickard (1997) considers that it does not apply where there is a distinct transition from applying an algorithm to retrieval of the desired outcome from memory. He argues that the power law of practice is only relevant where a single memory retrieval event is being examined, or where there is some qualitative change in the skills being applied. In this last case, however, the power law may only be an approximation of performance when it is averaged over the events being examined and the participants involved.

More recently, Heathcote, Brown, and Mewhort (2000) have claimed that the power curve is, in fact, an artefact of the method by which data in the field of skill acquisition are analysed. They point out that much of the research that has supported the power law of practice uses averaged data from many people, and then attempts to extrapolate these findings to individual learners in individual learning conditions. They claim that when the data from individual participants is analysed, an exponential function produces a better fit than does a power function. The main implication of their research is that the type of mathematical function that is considered to best fit the empirical observations affects conclusions about the nature of learning.

When examining skill acquisition and learning, unless the aim of the research is to discriminate between models of underlying processes, applying power functions to group data provides a useful summary of learning trends. Indeed, even Heathcote, Brown, and Mewhort (2000) acknowledge that such techniques are useful for reducing noise and revealing general trends. They are also useful for avoiding the systematic distortions that can arise by averaging raw data.

Theories of Skill Acquisition

Anderson's Adaptive Control of Thought (ACT-R) theory (Anderson, 1982) and Logan's Instance Theory (Logan, 1988) dominate the theoretical basis of the area of skill acquisition. However, they are by no means the only theories that have sought to explain the phenomena of skill acquisition and transfer. Other theories include Rickard's (1997) CMPL Theory of Automaticity, Palmeri's (1997) EBRW Theory, and the SOAR model by Laird, Newell, and Rosenbloom (1987, cited in Johnson, 1997)

Anderson's ACT-R Theory. According to the ACT-R theory, people develop expertise at a task as declarative knowledge becomes procedural knowledge. Declarative knowledge can be represented as facts that are explicitly known, along with

their interrelations such as propositions, images, or temporal strings (Müller, 1999). Procedural knowledge deals with how something is done or achieved, is usually outside a person's conscious awareness, and is often inferred from a person's performance (Anderson, 1993; Reber, 1995). The two types of knowledge are not mutually exclusive, since people are able to maintain declarative and procedural representations of the same knowledge. In fact, Anderson (1993) believes that it is possible to maintain multiple, differing representations of the same knowledge.

With practice at a task, the declarative information is compiled into productions, which are normally represented in the format of "if…then" rules (Müller, 1999), also known as "condition-action" pairs (Anderson, 1993). These productions operate on the facts contained in a person's range of declarative knowledge, and contain the circumstances under which a given production can apply along with what should occur when the production is invoked (Anderson, 1982). An example of this is the general process of generating the past tense of a word: IF I want to use the past tense of a word THEN I add '-ed' to the end of the word. This example can also account for the overgeneralised language forms often heard in infants (Waring, 2000).

Productions read and write information from working memory, with the information in working memory consisting of declarative knowledge, and the information in the productions consisting of procedural knowledge. The use and status of working memory is an important part of ACT-R. In the case of many other cognitive theories, once knowledge leaves working memory it is lost forever. With ACT-R, the knowledge remains but is inactive. It is reactivated when required by a spreading activation process (Anderson, 1993). This is not to say that ACT-R does not recognise any limitations on working memory, however. It simply considers that the limitation on the capacity of working memory is related to access to declarative knowledge rather

than any restrictions that apply to the total amount of declarative knowledge that can be stored. Anderson considers that declarative memory contains a complete record of the past, extending from events that are seconds old to years old. While the most recent events are probably still active, the older events can be resurrected through spreading activation (Anderson, 1993).

Anderson (1993) believes that a distinction should be drawn between two types of knowledge because it is necessary to account for the most flexible use of knowledge, rather than simply a need for efficiency. By possessing a declarative system, it is possible to rapidly acquire knowledge in a form that is not committed to a particular use. The ability to optimise the application of knowledge for a particular use is provided by possession of a procedural system. Thus, declarative and procedural knowledge enables flexibility and efficiency.

Anderson (1993) considers that cognitive skills are acquired in three steps, which approximate the three stages of skill acquisition described by Fitts and Posner (1967). The first step involves a general method (such as an analogy) being applied to the declarative encoding of information that is specific to a domain (Müller, 1999). However, the outcome is slow and prone to error because, in effect, three functions need to be performed: 1. A lot of information needs to be held in memory; 2. Inferences need to be drawn from this information; and, 3. General descriptions need to be adapted to the situation at hand (Müller, 1999). In the second step, declarative knowledge is "compiled," which improves performance. This compilation involves taking actions that were successful in the context of the current situation, and storing them in procedural memory by creating a production rule. The final step improves performance even further by strengthening the existing productions. This notion of strength can be thought of as a measure of the odds that any given production will fire (Anderson, 1993). Thus,

strengthening is simply the process whereby a production's chances of being fired increase which, in turn, increases the speed with which a production can be accessed and executed.

In terms of the transfer of skill from one situation to another, the ACT-R theory predicts that this should be a function of the chunks and productions that are shared between the application of the skill in the two situations (Anderson, 1993). Indeed, Anderson's account of skill transfer is based on the identical elements theory of Thorndike (1906, cited in Anderson, 1993), which stated that one skill would transfer to another skill to the extent that stimulus-response bonds were shared. Anderson applies this theory more generally, though, by stating that it can be considered that transfer will occur to the extent that one skill shares knowledge elements with another. Although Anderson acknowledges other avenues of skill transfer, these are predominantly focused on problem-solving skills (which involve the development and use of general strategies) rather than comparatively simple and undemanding skills. Anderson summarises the fundamental levels of transfer in the ACT-R theory by stating that transfer among skills can quite simply be predicted by "counting up knowledge units … and understanding the role they play in the target task. (Anderson, 1993, p. 203)"

Logan's Instance Theory. Logan's (1988) Instance Theory proposes that skill results from increased knowledge, since skill "consists largely of collections of automatic processes and procedures" (Logan, 1988, p. 492). In the Instance Theory, automaticity is considered to be a memory phenomenon, rather than being related to resource limitations. Logan developed the theory in order to describe automatic processing without invoking a single-capacity theory of attention or the concept of resource limitations that had guided research into automatic processing to that point. Indeed, Logan considers automaticity to equate completely to memory retrieval:

"Performance is automatic when it is based on single-step direct-access retrieval of past solutions from memory" (Logan, 1988, p. 493). People in the early stages of acquiring a skill are assumed to employ a general algorithm in order to perform a task. As they gain experience, they link particular solutions to specific problems. This enables them to retrieve the answers to these problems directly from memory the next time they are encountered or use the answer provided by the algorithm. Eventually, the person may have encountered enough task situations to enable a solution from memory to be retrieved in every instance, which means that using the algorithm would, at this late stage of practice, no longer be the most efficient way in which to address the task at hand. It is at this point that Logan considers performance to have become automatic, and that automatisation is the transition from algorithm-based performance to memory-based performance. The theory itself is intended to account for the major quantitative properties of automatisation, which are that there is a speed-up in processing and a reduction in variability that results from practice.

The Instance Theory relies on three main assumptions. The first assumption is that memory encoding is obligatory, and is an unavoidable consequence of attention. Whether it is remembered well is a separate question, but the encoding will take place. The second assumption states that retrieval from memory is also an obligatory, unavoidable consequence of attention. Simply attending to a stimulus is enough to retrieve from memory whatever has been associated with the stimulus in the past. As with the first assumption, retrieval may not always meet with success, but it will occur. Indeed, Logan (1988) notes that encoding and retrieval are linked by attention, in that the same act of attending that causes encoding also leads to retrieval. The third assumption is that each encounter with a stimulus is encoded, stored, and retrieved

separately—that is, as the name of the theory indicates, every instance is stored separately.

The learning mechanism described by the Instance Theory is one where there is a gradual transition from algorithmic processing to memory-based processing by the aggregation of separate stimulus episodes. This is in opposition to many theories under the modal view (e.g., Anderson's (1982) ACT theory) that assume some notion of strengthening of representations.

In terms of automatisation, Logan notes that the representation of instances in memory implies that it is item-based rather than process-based. As such, it would involve learning specific responses to specific stimuli. Indeed, automaticity is considered to be so specific to the stimuli and the situation in which they are experienced during training that Logan explicitly states that transfer to novel situations should be poor (Logan, 1988, p. 494).

The Instance Theory assumes that each encounter with a stimulus is encoded, stored, and retrieved separately. Every such encounter is termed a processing episode. This instance is thought to consist of the goal a person was trying to attain, the stimulus that arose in the pursuit of the goal, how the person interpreted this stimulus in the context of the goal, and the response that was made to the stimulus. If the person is faced with the same stimulus again in the context of the same goal, he or she will be able to accurately retrieve some of the instances in which it was previously involved. It is then a simple choice for the person to respond on the basis of the retrieved information (if it is sound and consistent with the presenting goal) or to engage the relevant algorithm and develop a response. The manner in which this process is developed can be illustrated by alphabet arithmetic (Logan & Klapp, 1991). In this task, participants were asked to repetitively perform addition calculations using letters of the

alphabet in the form of 'A + 3'. In this case, the correct response would be 'D'. In the initial phases of the experiment, participants would almost definitely have need to employ an algorithm in order to generate a response. However, as they were presented with more and more instances of the same problem being presented, they displayed a shift from algorithm employment to the direct retrieval of answers to previously encountered problems. Logan (1988) argues that the easiest way in which to conceptualise the process is for it to be thought of as a race between memory retrieval and the algorithm, with whichever finishes first controlling the person's response. With increasing practice, memory retrieval is able to win the race more often because there are more instances entering the race. Consequently, the more instances are in the race, the more likely it is that one of them will prevail over the algorithm. Logan contends that the power-function speed-up and the reduction in performance variability are consequences of the nature of this race.

Logan (1988) notes that there is a distinction between his view of automaticity and that of some other researchers. Since he defines automaticity only in terms of memory retrieval, he considers that it is possible to study this phenomenon in a single experimental session. However, this is in contrast to some experiments where automaticity was not noted until participants had completed several thousand trials spanning 10 to 20 sessions. He suggests that this is because other researchers such as Shiffrin and Schneider (1977) define automaticity as not being complete until the slope of the function relating set size to search time reaches zero. He notes that, since each additional instance will have some effect on memory, it may not be possible to ever achieve complete automaticity using the function slope definition. He considers that "there may be a shift in the direction of automaticity after only a few trials, and this shift may be a more important phenomenon to study than the zero slope …" (Logan, 1988,

p. 499). Such a view has relevance for experiments that seek to examine automaticity, or aspects thereof. If Logan's view of automaticity is valid, it indicates that it is possible to use items that are retrieved from memory and consider these in reference to a wider application of automaticity.

These views of skill acquisition are not restricted to only Anderson's (1993) ACT-R theory and Logan's (1988) Instance theory, however. Other research has built on or modified these fundamental theories, particularly in terms of how skill is transferred and how the power law of practice is accounted for—both important aspects of the current research. A consideration of other perspectives of skill acquisition provides an illustration of the extent to which this school of theories share fundamental assumptions that, in turn, affect the nature of their predictions about skill performance and transfer. The next sections discuss some of the more prominent of these models.

Palmeri's EBRW Theory. The Exemplar-Based Random Walk (EBRW) model includes elements of Logan's (1988) Instance Theory, as well as some from Nosofsky's (1986, cited in Palmeri, 1997) Generalised Context Model. It was developed by Palmeri (1997) in order to account for the time course of categorisation judgements. The model assumes that people represent categories in terms of individual instances that they have experienced. Rather than accepting that prototypes, rules, or other abstract forms of knowledge underlie categorisation, the EBRW model proposes that categorisation decisions are made from a comparison of the similarity between a presented item and stored category exemplars.

The EBRW model (Palmeri, 1997) portrays these exemplars as points in a multidimensional psychological space, where the similarity between the objects is a decreasing function of distance in the space. As with the Instance Theory, retrieval of the exemplars is a race process, with retrieval speeding up as the number of exemplars

increases. The EBRW model differs from the Instance Theory in that when an object is presented to a person, all of the stored exemplars race to be retrieved at a rate proportional to their similarity to the presented item.

Palmeri (1997) considers that the EBRW model can, unlike Logan's (1988) Instance Theory, account for qualitative and quantitative changes that take place as cognitive skills become automatised. Palmeri considers that the categorisation process is critical to automatisation, as opposed to a simple accumulation of discrete instances. Consequently, Palmeri challenges the restrictions placed on the conditions conducive to transfer by Logan. The EBRW model considers that transfer is not as specific as Logan claimed. Nevertheless, the EBRW model predicts perfect transfer if the stored exemplars are identical to a presented item.

Rickard's CMPL Theory of Automaticity. Rickard (1997) has proposed a Component Power Laws (CMPL) theory of automaticity. This theory accepts that automaticity reflects a shift from algorithmic processing to memory retrieval (Palmeri, 1999), however it considers that memory retrieval depends strongly on attention, and that only a single retrieval event can be completed at any time (Rickard, 1997). As such, the algorithm and memory retrieval cannot be executed in parallel. Consequently, it is not a race theory as are Logan's (1988) Instance Theory and the EBRW model. The CMPL theory also assumes that both algorithmic and memory retrieval processing times decrease in accordance with a power law of practice (Palmeri, 1999). While the Instance Theory states that each skill episode results in an independent record of the event (an instance), and that each instance competes independently from all the other instances at the time of retrieval, Rickard believes that the memory involved is best considered as a prototypic representation for each item. Aspects of performance episodes that are common across repetitions, and thus critical for later skilled performance, are extracted

and stored. As such, practice serves to strengthen the prototypic representation for each item. Where the Instance Theory states that automaticity arises from direct retrieval of instances from memory, Rickard claims that CMPL predicts a continuum from a goal-driven to a stimulus-driven retrieval from memory. Once the stimulus presented is sufficient to invoke a memory retrieval response, the CMPL model states that item-specific and strategy-specific processes, and no other factors, determine the choice of strategy (Rickard, 1997).

In terms of the power law of practice, the CMPL model states that there are three classes of skill acquisition tasks to which the law applies with differing amounts of accuracy (Rickard, 1997). In a single memory retrieval event, the power function is considered a fundamental property of practice. Where there are marked and discrete strategy shifts between algorithm application and memory retrieval, the power law of practice is not considered to apply for the overall process, even though it may be applicable to each strategy. Thirdly, where there is a degree of qualitative change in the skills being practised, a power function may only be an approximation of the improvements in performance when aggregated over the items and participants involved. That is, the power law of practice may not hold for a single item, but may be a good approximation in many cases if the data are averaged over the items. This is similar to the view of Heathcote, Brown, and Mewhort (2000).

Laird, Newell, and Rosenbloom's Soar. Soar is a rule-based system that was developed by Laird, Newell, and Rosenbloom (1987, cited in Johnson, 1997). Its name was originally derived from State, Operator And Result (SOAR), however this acronym is no longer thought to be adequate, and so the theory is now simply referred to as Soar (Ritter, 1998). It is based on two fundamental assumptions: 1. Humans are knowledge level systems, in that they apply their knowledge in a rational manner in order to

achieve their goals; and, 2. Humans are symbol systems. While Soar's rules can represent both declarative and procedural knowledge, working memory is considered to only deal with declarative knowledge.

Soar is designed around six mechanisms: problem spaces, long-term memory, attribute-value representation, preference-based decision procedure, goal-directed behaviour, and chunking-based learning. These mechanisms are considered to interact to produce general, intelligent behaviour (*Description of the SOAR architecture*, 2000). All events in Soar take place in what is known as a problem space. In response to a particular event, Soar fires every rule that matches this initial state. This process continues in an iterative fashion until a desired goal state is achieved. The process of matching the declarative knowledge held in working memory at any given time, which is used to select which is the most appropriate rule to next apply, controls this progression.

Learning in Soar is considered to arise solely through a process of chunking. This represents the conversion of problem solving acts into long-term memory. This learning process is a compilation of the iterative process that proceeds through a series of sub-goals to the desired goal state. It results in a production rule that can produce a result without the need for sub-goals, and is the way in which Soar moves from problematic to routine behaviour (*Description of the SOAR architecture*, 2000). The notion of chunking in Soar should not be confused with the chunks referred to by Anderson (1993) in his ACT-R theory. Anderson (1993) considers that chunking in Soar is akin to the composition process that formed part of his earlier ACT* theory, but which no longer forms a part of the ACT-R theory. This process not only accounts for learning in general, it is also the mechanism through which Soar accounts for the power law of practice. As the need to go through a process of sub-goals in the achievement of

a desired goal state is reduced, so people are able to display the signature improvements in performance accounted for by a power function.

Regardless of which of these major theories of skill acquisition is considered, there is one occasion where both would predict a complete transfer of skills with no effect on performance in terms of reaction time. Were a person to have encountered a particular task in a given context in the past, then both theories would predict that a person should not suffer from any performance degradation if this task was to be performed again as part of another task. As such, a person's performance on that task should continue as an extrapolation of the function shown in Figure 1. However, research by Speelman and Kirsner (under review) has shown that performance can be disrupted in certain circumstances and does not follow the power function extrapolation.

Speelman and Kirsner's Research

The research undertaken by Speelman and Kirsner (under review) concentrated on the degree to which transfer performance could be predicted from training performance. In previous research, the prediction of transfer performance had been relative, since it had only been in terms of stating which conditions would produce the best transfer performance. Any attempts at explicit prediction had mostly been through measuring transfer performance and applying regression analysis. These were *post hoc* efforts to describe performance by considering the features of training and transfer tasks.

Other work by Speelman and Kirsner (1993, cited in Speelman & Kirsner, under review) and Speelman (1995, cited in Speelman & Kirsner, under review) attempted to predict the absolute level of transfer performance on the basis of training performance. While the research was successful in predicting the overall pattern observed (which was a dramatic slowing of performance followed by a gradual improvement with practice),

several *ad hoc* modifications were required in order to provide better approximations of observed performance, especially where transfer performance was slower than initially predicted.

Thus, Speelman and Kirsner (under review) sought to determine the reasons for the failure of this approach by examining more closely one of their assumptions, this being that "when old skills are executed in the context of new tasks, they continue to improve as if stimulus conditions had not changed" (Speelman & Kirsner, under review, p. 7). Specifically, performance improvement will continue to follow the power function indicated by training performance. Speelman and Kirsner note that this behaviour is implied by the ACT-R theory: Skill units that are produced by the compilation mechanism of ACT-R represent component knowledge. Since these skill units are the basis of transfer to new tasks, the more units that apply to performance on the transfer tasks, the greater the transfer. Thus, practice can be considered to determine the speed with which productions are performed once the stimulus conditions indicate that the production should be executed (Speelman & Kirsner, under review). As such, if the skill units were identical, Speelman and Kirsner considered that the speed with which a production is executed would be determined by its previous execution history, and would be described by the power function that could be derived from this history.

However, Speelman and Kirsner (under review) noted that their prediction regarding the behaviour of old skills in new tasks relied on the assumption that component task knowledge behaves in encapsulated wholes, or at least in sub-routines that are applicable in different situations. However, previous research indicated that composed component knowledge does not always behave in this way. These composed skills appeared, at least to some extent, to be related to the context in which they were acquired. As such, Speelman and Kirsner considered that any improvement in old skills

when performed in the context of a new task might not follow the power functions that describe their original improvement.

Speelman and Kirsner (under review) conducted three experiments that tested the assumption about old skills performed in new tasks. Based on an experiment conducted by Elio (1986, cited in Speelman & Kirsner, under review), participants were asked to assess water quality. However, this apparent assessment of water quality was simply a context in which the actual tasks were presented. Even though participants were led to conceive of the task as assessing water quality, the actual experiment was essentially just a series of arithmetic problems.

This process involved training and transfer phases, with all participants undertaking an assessment of the water quality in the training phase by considering three components (see Figure 2a). The 'Results' section represents the place where the answers to the arithmetic problems are entered, with these problems being tested in the 'Equations' section using values obtained from the 'Data' section. In the transfer phase, while the control group continued to assess water quality with reference to three components, the experimental group was presented with a five-component version (see Figure 2b). Although the task appeared to be more complex, this was not the case. All components of the trials were discrete units that could be performed independently of one another. Furthermore, it was necessary for the participants to complete the old components of a trial before the new components. As such, there was no reason why the performance that had been established for the old components in the training phase should not continue with those same components in the transfer phase.

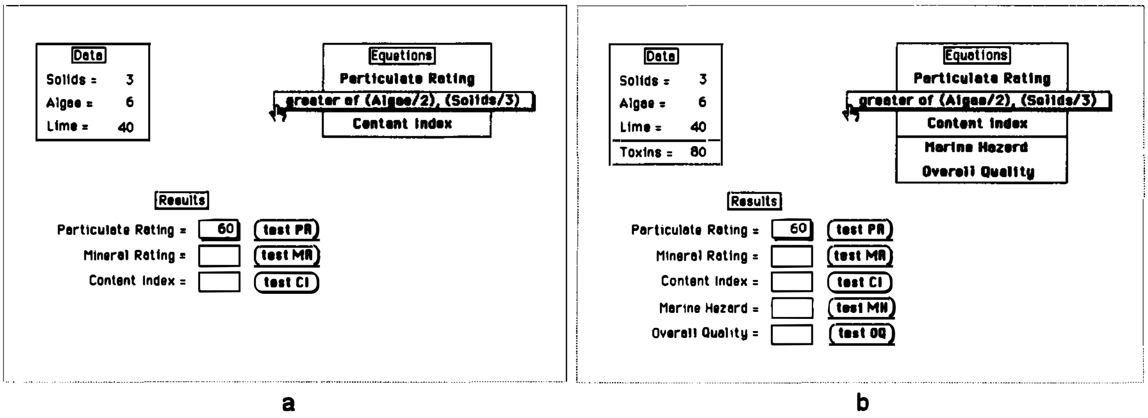

Figure 2. Comparison of the three- and five-component versions of Speelman and Kirsner's (under review) task, mid-trial.

Speelman and Kirsner's (under review) first experiment found that, while performance could be predicted by extrapolating training performance when task conditions remain unchanged, old skills performed as part of a new task (i.e., the first three components in the five-component version) do not continue to improve in a manner consistent with the power functions that best describe their original performance. This finding related only to speed of performance—no effect was noted on accuracy of response. Their second experiment examined whether this disruption was related to an increase in complexity in the task from training to transfer, or whether it might be due to any change in task. The results of this experiment suggested that any change in task might be sufficient to produce the disruptive effect noted in the first experiment. However, it did appear to be larger if the task involved an increase in complexity from the training to transfer phases. The third experiment examined two variables that they considered might influence the magnitude of the disruption, these being the relative change in task complexity from training to transfer, and the amount of practice on a task before any change was introduced. In this experiment, Speelman and Kirsner found that an increase in complexity between tasks is not enough to cause a disruption to the performance of old skills. Rather, it appeared that once a particular

degree of complexity is reached a disruption ensues. However, continuing to increase complexity does not increase the amount of disruption. Thus, Speelman and Kirsner found that performance on the old components slowed when they were in the presence of the new components on a task. Their research demonstrated that while any change in a task may cause some disruption, an increase in task complexity led to the greatest amount of disruption. As noted, the observed disruption related only to reaction times—it had no effect on accuracy.

Current theories of skill acquisition and transfer would not predict the findings of Speelman and Kirsner (under review) since the particular skills being studied in the transfer phase of the experiment were exactly the same as those studied in the training phase. Because the skills being tested were identical, theories such as Anderson's (1993) ACT-R Theory and Logan's (1988) Instance Theory would not predict any change in performance from the training to the transfer phases. The current research was designed to more closely examine the disruption found by Speelman and Kirsner by focusing on the extent and nature of conceptual changes and their influence on established skills.

While Speelman and Kirsner's (under review) experiment demonstrated a disruption in the expected transfer of skills acquired in the training phase, it is important to note that the experimental group was confronted with more than simply extra calculations to determine water quality. The change in the visual presentation from the three-component problem to the five-component problem on the screen might have been a factor in prompting participants to re-assess the requirements of the problem. It is apparent from an examination of Figure 2 that the visual aspects of the three-component and five-component versions of the tasks are quite different. There are more components in each of the "Data," "Results," and "Equations" areas on the screens for

participants to consider, which all contribute to an overall increase in the amount of information being presented at once. Even though the requirements of the training tasks did not change between the phases of the experiment, the participants may in fact have believed that the requirements changed simply because of the extra information being presented. At the very least, they may have felt it necessary to confirm that this information was not always relevant to what they were required to do. As such, the additional visual information may have distracted participants while they worked on the old components of the task. Consequently, it is not possible to isolate whether the disruption was induced by participants assessing complexity in terms of a change in the visual presentation, a change in the conceptual requirements (in terms of the number of calculations apparently required), or a combination of both.

Current Research

The current research sought to determine the extent to which only conceptual change is responsible for producing the disruption noted by Speelman and Kirsner (under review). This research aimed to more closely examine the disruption detected by Speelman and Kirsner by eliminating any possible influence of visual presentation changes. This enabled the extent and nature of conceptual changes and their influence on established skills to be assessed, particularly with respect to whether the disruption noted by Speelman and Kirsner was induced by a change in visual presentation, a change in the apparent conceptual requirements of the task at hand, or a combination of both. The visual change aspect was controlled by presenting participants with only one problem at a time on the computer screen. The conceptual change component in the experiment was examined with reference to the context in which the training task problems were presented to participants in the transfer conditions. The study employed a common set of test task problems in both the training and transfer phases of the

experiment against which performance (in terms of reaction time and accuracy) was measured. The transfer phase involved re-presenting the test task problems as well as problems that differed from them in terms of the nature of the processing involved.

It was considered that making use of single-digit multiplication problems from the times-tables as the common test tasks (e.g., $6 \times 3 = \_\_$) would enable participants to display skills that have been established since childhood, and have thus been reinforced over many years. These are actually simple number facts rather than problems in themselves, and are usually learned through drill early in a child's schooling (Campbell & Graham, 1985). Pesta, Sanders, and Murphy (1999) note that adults usually solve small-product-size problems using memory retrieval. That is, they rely on the facts memorised during childhood rather than develop new strategies. This also indicates that these facts are long-established skills that were strongly reinforced throughout childhood, and continue to be reinforced through fairly regular use. Pesta et al. provide further support for retrieval by also stating that the familiarity of a problem is a factor in determining whether an answer is retrieved from memory or calculated. Because children are exposed to more small-product-size problems (i.e., where the size of the problem's answer is small) in their early years of schooling, these are more often retrieved from memory than are large-product-size problems (i.e., where the answer is large enough to prompt a computational strategy requiring intermediate steps).

Employing tasks that are likely to involve retrieval controlled for any effects relating to the recency of acquisition of the skills, since participants often learn and develop expertise in a skill specifically for a given experiment (e.g., Anderson et al., 1999; Blessing & Anderson, 1996; Müller, 1999; Speelman & Kirsner, under review). It also ensured that only firmly established memory retrieval skills were examined, thus minimising any learning component related to the tasks themselves. It was considered

that any apparent learning would be related more to the nature of the task and the equipment rather than the skill itself. As such, it was thought unlikely that any disruption detected would have resulted from the fragility of the skills employed in terms of the degree to which a person has practiced them or the confidence that the participant would have in applying them. It also enabled examination of the nature of the conceptual change required to induce the disruption by allowing the type of conceptual change being applied to be tightly controlled and closely related to the test tasks.

There were three conceptual change conditions in the transfer phase. These were comprised of tasks that relate to memory retrieval, algorithmic processing, and a combination of memory retrieval and algorithmic processing. These conceptual changes were based directly on the processes employed to perform the type of test task problems being used to measure the two dependent variables. That is, when a person performs arithmetic calculations, they either retrieve the answer directly from memory, or they use facts retrieved from memory and combine these facts using algorithms (Campbell, 1987). Consequently, these conceptual changes account for the possible types of processing that relate directly to the mathematical skills being studied.

In the training phase of the experiment, participants were required to repeatedly solve problems from the Six-Times table (see Appendix G). These same problems were presented again in the transfer phase. The aim was to determine whether participants being required to solve these and other problems during the same phase affected performance on these Six-Times table problems. The old and new problems in the transfer phase were presented in a random order. The new problems varied in terms of the degree of conceptual difference between them and the old problems.

The first conceptual change condition of the transfer phase involved examining the effect on the test task of the retrieval from memory of related items. In this case, the responses to single-digit multiplication tables other than the Six-Times table were used (see Appendix G). This involved, for example, presenting problems such as 3 × 4 = __ and 8 × 7 = __. The second conceptual change condition involved examining the effect of algorithmic processing on the test tasks. This involved prompting participants to generate a response to a double-digit addition problem (see Appendix G). For example, problems such as 11 + 45 = __ and 34 + 62 = __ were presented. Geary, Widaman, and Little (1986) reported research that suggests that people use an algorithmic strategy to solve problems such as these. They noted that for multi-column addition problems (i.e., double-digit addition problems of the kind outlined above) an encoding and search/compute process is cycled through until sums are obtained for each column and, ultimately, the final result. The third level of conceptual change involved using both algorithms and retrieval to generate a response. In this case, the participants were asked to solve problems that extend the Six-Times table beyond single digits (see Appendix G), such as 6 × 23 = __. In this case, it was expected that participants would generate answers using components of single-digit multiplication tables, and then add the subsidiary answers in order to calculate the overall answer. Pesta, Sanders, and Murphy (1999) support the possibility of such an approach being employed, by noting that this strategy is likely in cases where intermediate answers are possible. Since determining the solution to single-digit multiplication problems almost definitely does not involve intermediate steps (Geary et al., 1986; Koshmider & Ashcraft, 1991; LeFevre et al., 1996; Lemaire, Barrett, Fayol, & Abdi, 1994; Siegler, 1988), direct memory retrieval alone is the most likely strategy for the intermediate steps of the larger

problem, with additions being used to combine the steps. This strategy was confirmed with participants in this condition after they had completed the experiment.

The conceptual change conditions were designed to encourage participants to conceive of the transfer phase as being different to the training phase to varying degrees. For instance, participants may have perceived the training task as simply retrieving answers to only the Six-Times table from memory. When faced with the first conceptual change condition, however, they may have conceived of the task as now involving the retrieval of answers for all the multiplication tables. With respect to the second and third conceptual change conditions, although participants could view the training task problems as involving memory retrieval only, they would soon realise that the transfer task problems also required some form of algorithmic processing. If the transfer disruption observed by Speelman and Kirsner (under review) is due to conceptual change, then in this experiment it can be predicted that the disruption should be greatest where the conceptual change is greatest. As such, this disruption should be greater in conditions two and three than in condition one.

Design

This research involved the manipulation of variables both between and within subjects. The between-subjects aspects involved participants being assigned to one of three different conditions. Within-subjects components included participant performance being assessed during two phases of the experiment. By mostly restricting the tasks to multiplication tables learned during childhood, it was not anticipated that there would be any significant confounding factors (such as educational differences, use of different or idiosyncratic techniques, cohort effects, or age differences) since the tasks were expected to utilise well-established skills (Campbell, 1987). A possible confound was that of the relative arithmetic abilities of the participants, however this

was controlled by employing a screening process that ensured a minimum level of competency. In order to prevent any priming of participants' arithmetic responses by applying all levels of the independent variable to each participant, the pool of participants was split into three groups, each of which was exposed to a single level of the independent variable.

While only test task problems were presented in the training phase, the transfer phase presented both test task problems and distractor problems in random order. The only aspect of the experiment that changed between the two phases was the conceptual nature of the task. All other aspects of the presentation of the task remained the same. Moreover, the test tasks were presented in exactly the same manner in the transfer phase as they were in the training phase—they looked exactly the same as when they were presented in the training phase. This controlled for the possibility that visual change in the manner of presentation explains the disruption noted by Speelman and Kirsner (under review). In addition, both the ACT-R theory (Anderson, 1993) and the Instance Theory (Logan, 1988) would predict complete transfer of performance in this case. Thus, the only change that the participants notice relates to what is required of them at some time during the transfer phase. Thus, this experiment examined the effect of this realisation on participant performance of the test task problems presented in the transfer phase.

Variables

The variables examined included two dependent variables and one independent variable. The dependent variables were the reaction time of the participants to the items presented (both old and new) and the accuracy of their answers. Reaction time was measured in milliseconds, with accuracy being assessed as the percentage of correct responses for each participant. The independent variable was the type of conceptual

change that each participant was exposed to after having established a baseline for the test items from the Six-Times table.

The conceptual changes used in the experiment were developed so that they were consistent with the theoretical underpinning of arithmetic problems. That is, they were based on retrieval, algorithmic processing, and a combination of retrieval and algorithmic processing. The first conceptual change condition involved examining the effect on the baseline data of the retrieval from memory of related items. In this case, it used the responses to single-digit multiplication tables other than the Six-Times table (see Appendix G for a complete list of problems). The second conceptual change condition involved examining the effect of algorithmic processing on the baseline data. This was induced by prompting the participant to use an algorithm to generate a response to a double-digit addition problem (see Appendix G for a complete list of problems). The third conceptual change condition involved both the use of algorithms and retrieval to generate a response. In this case, the participants were asked to solve problems that extended the Six-Times table beyond single digits (specifically, beyond $6 \times 13 = \_\_$ since most children learn the multiplication tables up to 12, see Appendix G for a complete list of problems). For this condition it was expected that participants would generate answers using multiplication table retrieval, and then add the intermediate answers in order to calculate the overall answer. In the example of $6 \times 17 = \_\_$ participants would probably calculate $7 \times 6 = 42$ and $10 \times 6 = 60$, and then add 42 and 60 to give the answer of 102. However, regardless of the actual process used, it was considered very unlikely that the participants would be able to retrieve answers from memory for these tasks as they would for the established multiplication tables. The process used is likely to have employed a combination of retrieval and algorithmic processing.

Method

Participants

The sample consisted of 61 participants who were drawn from the Edith Cowan University School of Psychology Volunteers Register and from personal requests made by the researcher. The data collected from one of the participants in Condition 3 were not included in the analysis after the person failed to achieve the required degree of accuracy in the training phase (see Results). The following demographic information applies only to those participants whose data was included in the analysis. The mean age of all participants was M = 36.57 years, SD = 12.42 years. There were 34 females (M = 32.29 years, SD = 10.03 years) and 26 males (M = 42.15 years, SD = 13.18 years). The mean years of schooling for all participants was M = 15.00 years, SD = 4.36 years. In terms of formal years of schooling, females had received M = 14.71 years, SD = 3.31 years, while males had received M = 15.38 years, SD = 5.50 years.

Apparatus

The presentation of the experimental tasks and the collection of data was performed by SuperLab Pro version 2.0 running on an IBM Thinkpad i1400 laptop computer. A standard 101-key external keyboard was connected to the computer and used to capture participants' responses.

Materials

The tasks to be completed as part of the experiment consisted of single-digit multiplication problems (see Appendix G for a complete list of problems), double-digit addition problems (see Appendix G for a complete list of problems), and a combination of double-digit and single-digit multiplication problems (see Appendix G for a complete list of problems). Previous research suggests that it is not appropriate to include multiplication by zero, one, five, or ties (which are instances when a number is

multiplied by itself, e.g., 6 × 6 = __) because they are significantly different in terms of ease of calculation, and therefore reaction time, than other problems (Campbell, 1987). In addition, Stazyk et al. (1982, cited in Geary et al., 1986) have demonstrated that reaction time increases as the multiplier increases (known as the Problem Size Effect). That is, a problem such as 4 × 9 = __ takes longer to solve than 4 × 2 = __. In turn, problem size is a good predictor of both reaction time and accuracy for single-digit addition and multiplication problems—with correlations in the order of 0.6 to 0.8 (Campbell, 1997). Given these considerations, the pool of multiplicands from which the single-digit multiplication problems were drawn consisted of 2, 3, 4, 6, 7, 8, and 9. Given the problem-size effect, it was considered that the Six-Times table was the most appropriate single-digit multiplication task to use as the test task since it represented the median multiplicand in terms of reaction time.

Task and Procedure

The experiment involved two phases: a training phase and a transfer phase. All participants were presented with the same problems in the training phase. The transfer phase contained three conditions, with each condition including a repetition of the problems from the training phase as well as additional problems. Participants were only required to complete the training phase and one of the conditions in the transfer phase.

After receiving instructions and some practice trials that were taken from the Five-Times table (problems that were never encountered during the actual experiment, see Appendix G for a complete list of problems), participants were asked to complete a series of individually presented arithmetic problems as quickly and accurately as possible. In the training phase, participants were presented with 72 trials consisting only of single digit problems taken from the Six-Times table. These were 6 × 2 = __, 6 × 3 = _, 6 × 4 = __, 6 × 7 = __, 6 × 8 = __, and 6 × 9 = __. All problems were repeated

12 times and presented in a random order to give a total of 72 training trials. The training phase problems were re-presented during the transfer phase, in addition to 72 other problems whose nature depended on the experimental condition. The new and old problems were presented in a random order.

In the transfer phase, Condition 1 examined the effect of retrieving similar items from memory on performance of the test items. As such, in addition to the test problems, participants received problems from all the other multiplication tables from two to nine, excluding ties, fives, ones, and zeroes (see Appendix G for a complete list of problems). That is, the following single-digit multiplication tables were presented in a similar form to the training phase tasks: 2, 3, 4, 7, 8, and 9. For example, participants were presented with problems such as $3 \times 9 =$ __ and $8 \times 4 =$ __.

Condition 2 examined the effect of employing an algorithm to generate a response on retrieving from memory solutions to the test items. In addition to the test problems, participants received randomly generated double-digit addition problems (for example, $17 + 63 =$ __). Appendix G presents a complete list of the problems.

Condition 3 examined the combined effect of memory retrieval and algorithm usage on retrieving from memory solutions to the test items. As well as the test problems, participants received randomly generated large Six-Times tables problems such as $6 \times 83 =$ __. All of the problems presented involved extending the Six-Times table to include double-digit numbers greater than or equal to thirteen (see Appendix G for a complete list of problems). In this way, it was considered that participants would be able to use the single-digit Six-Times table tasks in conjunction with addition to generate an answer.

In each trial, participants were initially presented with an individual problem (for example, $6 \times 4 =$ __) in the centre of the screen (see Figure 3a). When the participant

thought that they knew the answer, they pressed the space-bar on the keyboard, after which they were presented with two alternative answers, only one of which was correct. The two possible answers were presented on the bottom left and bottom right hand side of the screen respectively (see Figure 3b). The position of correct answers was counterbalanced between left and right across trials. If the participant thought that the left-hand answer was correct, they were instructed to press the 'z' key, marked with a yellow spot. If they thought that the right-hand answer was correct, they were instructed to press the '/' key, marked with a red spot. After a participant made their selection, they were told whether they were correct by having 'Right' or 'Wrong' presented for 500ms in the centre of the screen (see Figure 3c). The next trial commenced automatically at the end of this period. There was no gap between the training and transfer phases. The presentation order of trials within the training and transfer phases was random.

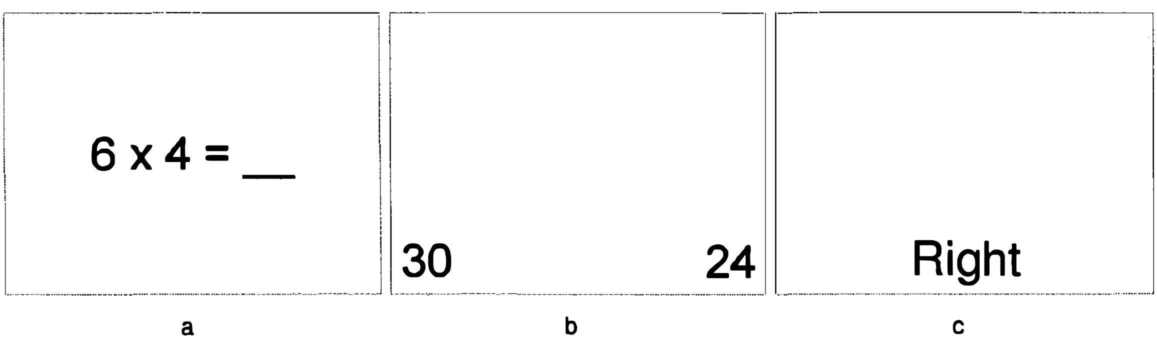

Figure 3. The three screens shown to participants in order of presentation: (a) the problem; (b) correct and incorrect solutions; and, (c) feedback. The relative size and position with respect to the computer screen has been maintained.

Participants were consecutively assigned to conditions as they volunteered. All participants received on-screen instructions and nine practice trials. All were given the opportunity to repeat the practice trials if desired, however no participant chose to

repeat the practice trials. All participants completed the same training task problems in both phases of all conditions. The 72 training trials were included with 72 other distractor trials in the transfer phase. The nature of the distractor problems depended on the condition in which the participants were placed.

Results

All data were analysed in blocks of nine trials. This gave a total of eight data blocks for the test task problems in each phase, as well as eight data blocks for distractor problems in the transfer phase. Analysing the data in this manner is an example of the beneficial effects of averaging data noted by Heathcote, Brown, and Mewhort (2000), and enables noise to be reduced and general trends to be revealed.

Accuracy was assessed as the number of correct trials in each block. For the purposes of deciding whether to use an individual participant's data, accuracy was assessed as the number of correct trials in the entire training phase. The data of one participant who did not achieve 80% accuracy in the training phase were discarded and replaced by another participant's data. The participant whose data were discarded performed in Condition 3, achieving 79.17% accuracy for the entire training phase.

Response time was defined as the elapsed time in milliseconds from initial problem presentation to the selection of a response. This is the combination of the initial problem presentation to when a participant pressed the spacebar to reveal the possible answers, added to the time taken to select an answer by pressing either the 'z' or '/' key. In this way, the experiment was designed to measure production responses (where the participant arrived at a response by their own means) rather than verification responses (where the participant would be able to select the 'best' answer). The decision to combine both aspects of the problem procedure was supported by Zbrodoff and Logan (2000), who consider that problems of this nature presented in a similar manner involve participants assessing their answer using resonance evaluation rather than a strategy that employs production and verification. Zbrodoff and Logan found that when participants were presented with an equation such as (5 + 2 =), they used the whole equation as a retrieval cue, and evaluated a later presented answer in terms of the activation or

resonance that resulted from the retrieval cue. Consequently, by trying to ensure that participants generated a response before they were presented with the possible responses by pressing the space bar, the possibility of participants using resonance evaluation to select an answer was minimised.

The participants were highly accurate in answering the test task problems in all conditions. Participants in Condition 1 displayed an overall accuracy of M = 95.87%, SD = 4.89%, while those in Conditions 2 and 3 displayed an overall accuracy of M = 97.01%, SD = 2.79% and M = 97.19%, SD = 4.06% respectively. The accuracy of performance in each condition in the training and transfer phases is presented in Table 1. A 3 (condition) × 8 (block) mixed design analysis of variance was performed on the data for the training and transfer phases. There was a significant effect of block in the training phase, $F(7,399) = 2.40, p < .05$, with a general improvement in accuracy as the training phase progressed (see Figure 4). No effect of condition was noted, nor was there an interaction between block and condition in either phase.

Table 1

Accuracy Results for Both Phases, All Conditions

Condition	Mean Accuracy (%)	Standard Deviation
1: Training Phase	96.46	4.07
1: Transfer Phase	92.64	5.63
2: Training Phase	96.94	2.91
2: Transfer Phase	97.08	2.74
3: Training Phase	97.50	3.89
3: Transfer Phase	96.88	4.30

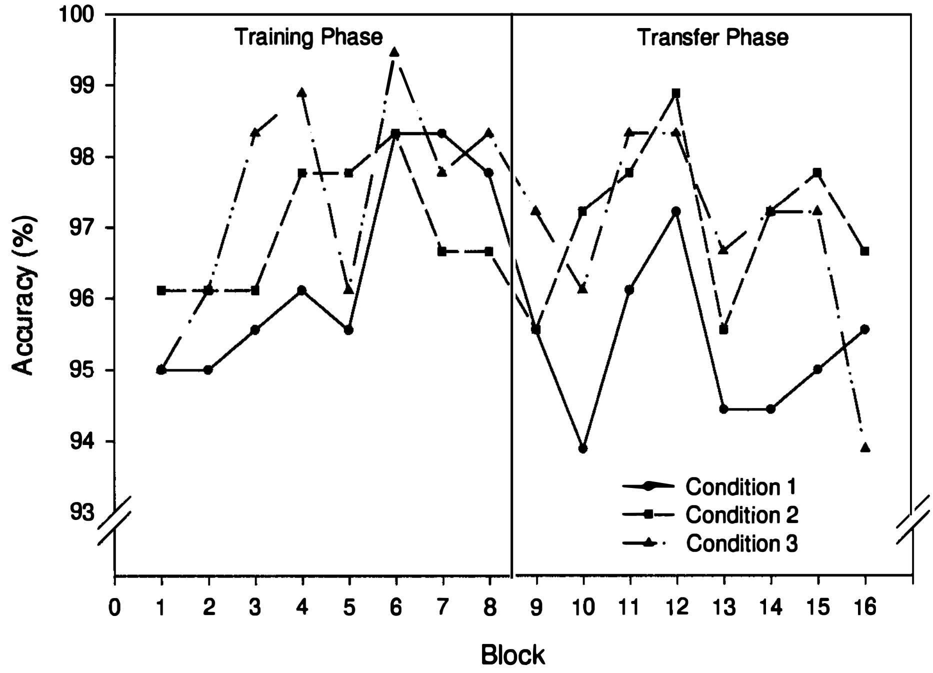

Figure 4. Test task problem accuracy in the training and transfer phases for all conditions.

The reaction time data for the training phase closely follow a power function for each condition, as predicted by the power law of learning (see Figure 5). The nature of the functions and correlations is summarised in Table 2. The absolute values of the learning rates in the power function equations (indicated by the exponential value) are all less than 0.3. Because these values are approaching zero, this indicates that very little learning is taking place, which is evidence that the skills being employed are well established. As a comparison, the learning rates for Speelman and Kirsner's (under review) experiment ranged from –0.39 to –0.60. As well as the high correlations found, further evidence of the goodness of fit of the power function equations was provided by root-mean-squared-deviation (rmsd) values, derived from a comparison of observed versus predicted values for the test tasks (see Table 2). The smaller the rmsd value, the lower the amount of variation between observed and predicted values.

Table 2

Power Function Results for Each Condition in the Training Phase

Condition	Function Equation	R^2 Value	rmsd
1	$y=3067.33x^{-0.27}$	0.99	45.14
2	$y=2854.31x^{-0.25}$	0.97	56.91
3	$y=2772.12x^{-0.21}$	0.92	91.07

In order to determine whether the participants achieved the same level of performance at the end of the training phase, a univariate analysis of variance was conducted on the reaction time data for the last block of the training phase. Condition 1 resulted in a mean reaction time in the last block of M = 1795.88 ms, SD = 451.68 ms. Conditions 2 and 3 resulted in mean reaction times in the last block of M = 1767.78 ms, SD = 519.16 ms and M = 1853.35 ms, SD = 487.05 ms respectively (see data for Block 8 in Figure 5). No significant difference was found between the mean reaction times for the last block of the training phase for any of the conditions. This indicates that the performance of the participants at the end of training was comparable for each condition.

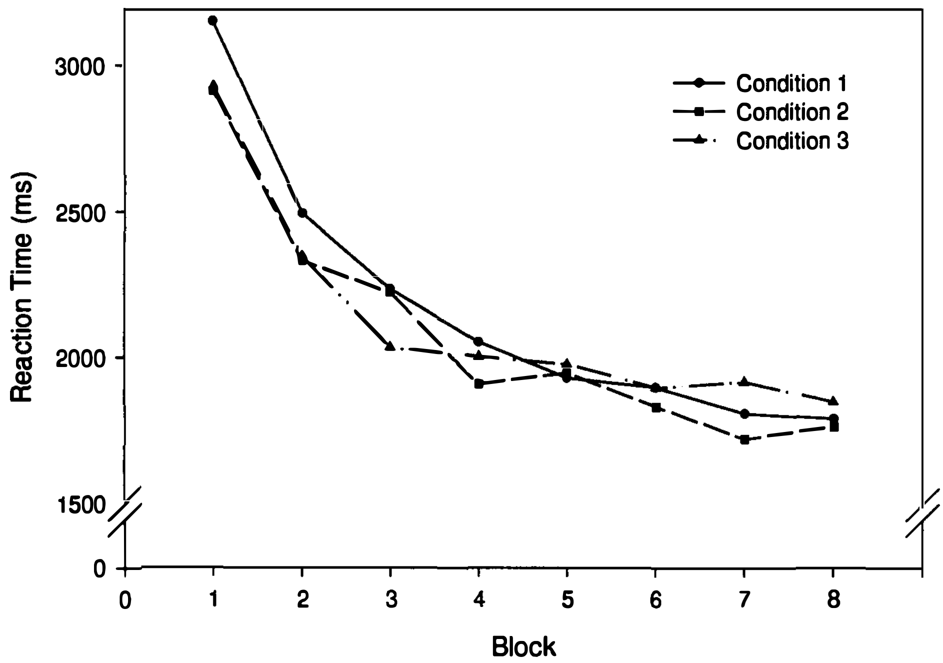

Figure 5. Mean reaction times for each block of training tasks in the training phase.

Performance on the test task problems during the transfer phase was compared with performance that was predicted by training phase performance. That is, the power functions that were fitted to the training phase data were extrapolated another eight blocks to provide predicted performance times in the transfer phase. The degree of fit between the observed and predicted data ranged from very low to high. The R^2 value for Condition 1 was 0.00, while it was 0.76 for Condition 2 and 0.94 for Condition 3. Consequently, power functions can adequately describe the results obtained for the test task problems in Conditions 2 and 3 in the transfer phase. However, the learning rates apparent from fitting power functions to the reaction time performance of the test task problems in the transfer phase were –0.05, –0.05, and –0.14 for Conditions 1 to 3 respectively. This indicates that very little learning took place for the test task problems in the transfer phase. The rmsd figures for Conditions 1, 2, and 3 were 402.20, 477.64, and 340.74 respectively. These figures, especially when compared to the rmsd results

for the test task problems in the training phase, indicate that there is a substantial variation from the results that would have been predicted by the training phase power functions. Figure 6 presents the test task problems' reaction time in the transfer phase, while Figures 7 to 9 compare the predicted and observed values for the training and transfer phases for each condition. The error bars in Figures 7 to 9 represent the 95% confidence limits of performance for each block of mean participant data. This is the range in which there can be a level of 95% confidence that the actual performance level falls within these boundaries. These results indicate that performance in all conditions has been disrupted for an extended period in the transfer phase. Even though Condition 1 does not display an immediate disruption at the introduction of the distractor tasks in the transfer phase, performance is affected to the degree that by the third block it is slower than predicted performance. In the cases of Conditions 2 and 3, not only is performance immediately disrupted by the introduction of the distractor tasks, there is no recovery. Observed performance remains slower than predicted performance for the entire transfer phase. In addition, it is evident that the clear improvement trend demonstrated in the training phase of all conditions disappeared in the transfer phase. Furthermore, the disruption was such that in Conditions 1 and 2 performance did not return to levels achieved at the end of the training phase, and in Condition 3 it took until the seventh block of the transfer phase for performance to be better than at the end of the training phase. Finally, performance in all conditions never reached the levels predicted by training performance.

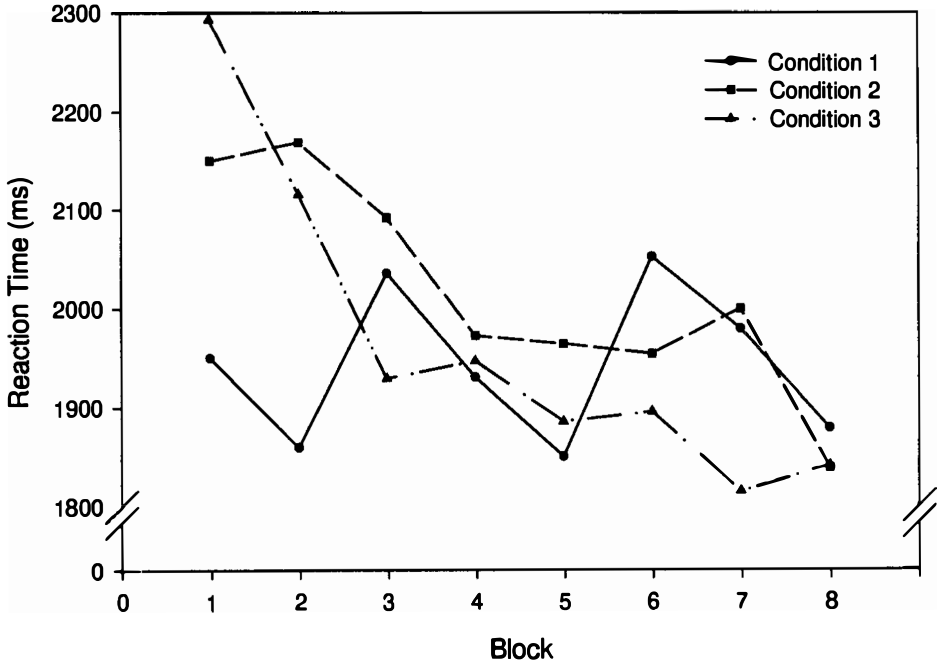

Figure 6. Mean reaction times for each block of test task problems in the transfer phase.

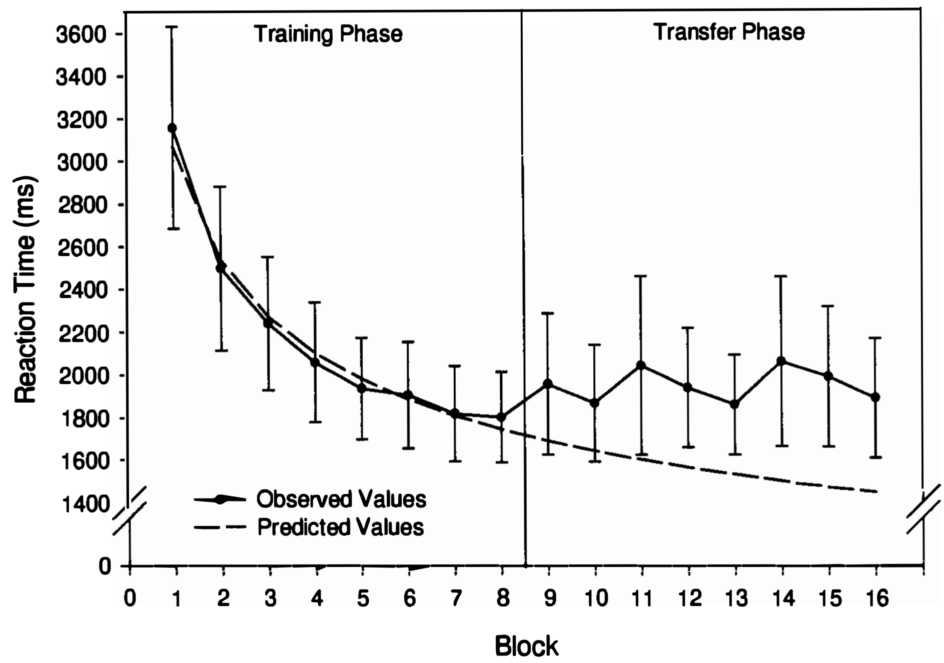

Figure 7. Comparison of observed and predicted reaction times for test task problems in Condition 1. Error bars are the 95% confidence limits.

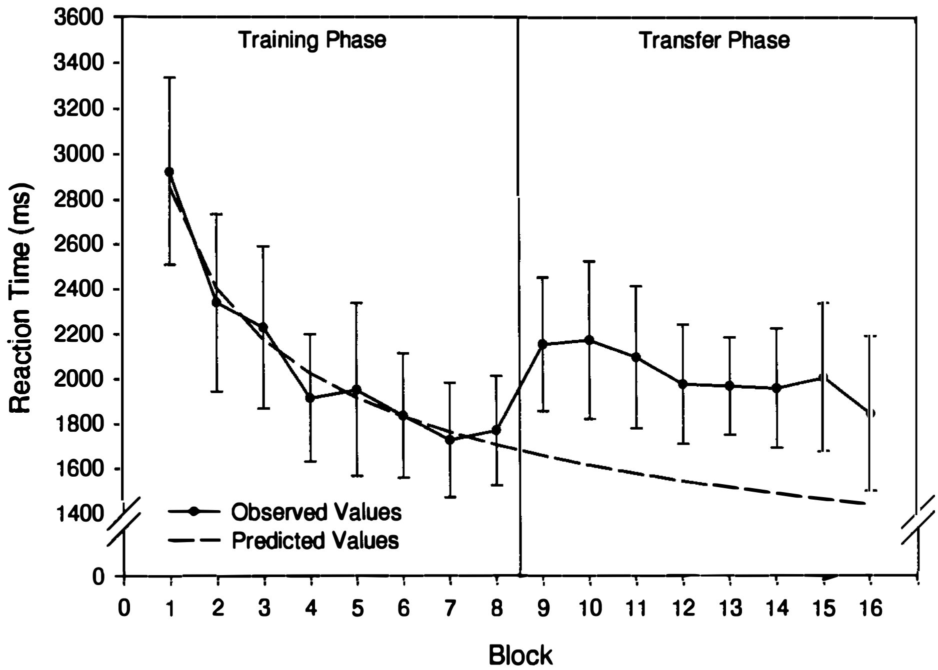

Figure 8. Comparison of observed and predicted reaction times for test task problems in Condition 2. Error bars are the 95% confidence limits.

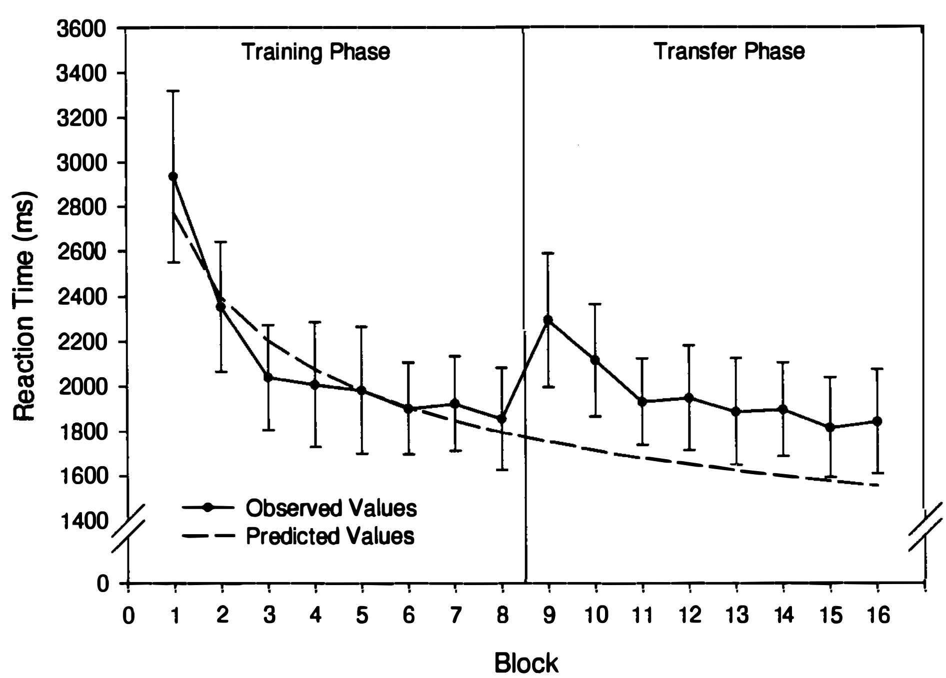

Figure 9. Comparison of observed and predicted reaction times for test task problems in Condition 3. Error bars are the 95% confidence limits.

The test task reaction times in the transfer phase (see Figure 6) were analysed using a 3 (condition) × 8 (block) mixed design analysis of variance. There was a significant effect of block, $F(7,399) = 4.94$, $p<.05$, with a general decline in reaction time as the number of blocks completed increased. There was also a significant interaction between block and condition, $F(14,399) = 2.19$, $p<.05$. This indicates that the rate of improvement in performance as the phase progressed was dependent on condition. Inspection of Figure 10 suggests that the conditions involving the greater amounts of conceptual change (Conditions 2 and 3) improved more than Condition 1, which did not appear to improve at all. No main effect of condition was noted.

To further explore the disruption to the reaction time of the test task problems when the distractor problems were introduced in the transfer phase, *t*-tests were performed on the mean reaction times for the last block of the training phase and the first block of the transfer phase for each condition. Figure 10 shows the performance of the test task problems in both phases, including the changeover from the training phase to the transfer phase where any disruption was expected to commence. No significant difference was found for Condition 1, indicating that there was no major disruption to reaction time performance at the end of the training phase ($M = 1795.88$ ms, $SD = 451.68$ ms) compared to the beginning of the transfer phase ($M = 1950.16$ ms, $SD = 703.56$ ms) as a result of the introduction of the distractor tasks. For Condition 2, mean reaction time at the end of the training phase ($M = 1767.78$ ms, $SD = 519.16$ ms) was significantly faster than the mean reaction time for the beginning of the transfer phase ($M = 2150.20$ ms, $SD = 631.60$ ms), $t(20) = 3.50$, $p<.05$. With Condition 3, mean reaction time at the end of the training phase ($M = 1853.35$ ms, $SD = 487.05$ ms) was significantly faster than the mean reaction time for the beginning of the transfer phase ($M = 2292.75$ ms, $SD = 632.98$ ms), $t(20) = 5.36$, $p<.05$. These results indicate that the

introduction of the distractor tasks disrupted reaction time performance in Conditions 2 and 3. Coupled with the results presented in Figures 7 to 9, it is evident that reaction time performance was disrupted in all three conditions, regardless of whether an initial disruption occurred at the introduction of the distractor tasks in the transfer phase. Even though no initial disruption occurred in Condition 1, it is apparent that, as with the other conditions, performance was sufficiently affected that it did not match the performance predicted by an extrapolation of the power functions that described training phase performance.

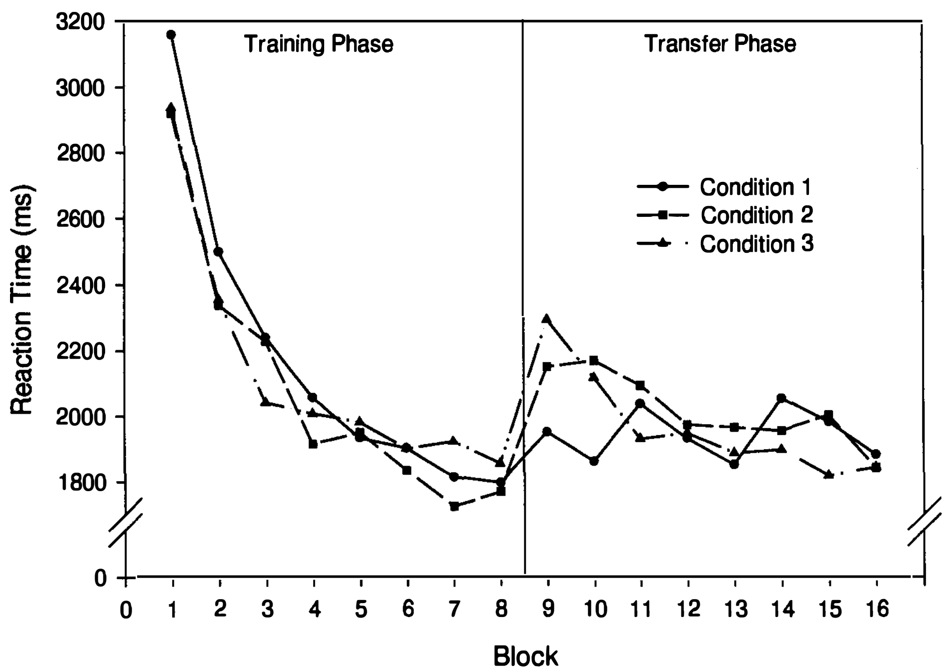

Figure 10. Mean reaction times for each block of test task problems in both phases.

An examination of the extent of the disruptions between the training and transfer phases encountered in each of the conditions was conducted using an analysis of variance. Condition 1 displayed a mean disruption of $M = 154.28$ ms, $SD = 351.38$ ms, Condition 2 displayed a mean disruption of $M = 382.41$ ms, $SD = 489.23$ ms, while Condition 3 displayed a mean disruption of $M = 439.40$ ms, $SD = 367.11$ ms. There was

no significant difference between any of these disruptions, indicating that the extent of the disruption was the same, regardless of condition.

Performance on the distractor tasks (see Figure 11) was analysed using a 3 (condition) × 8 (block) mixed design analysis of variance. There was a significant effect of block, $F(7,399) = 5.93$, $p<.05$, with a general decline in reaction time as the number of blocks completed increased. There was also a significant interaction between block and condition, $F(14,399) = 3.75$, $p<.05$. This indicates that performance improved more as the phase progressed if the conceptual change was greater. That is, the performance improvement across the transfer phase was greater for Condition 3 than Conditions 2 or 1, and the improvement in Condition 2 was greater than the improvement in Condition 1. Condition also had a significant overall effect, $F(2,57) = 39.89$, $p<.05$, with Tukey's HSD post-hoc tests revealing that Condition 1 was significantly faster in terms of reaction time than Conditions 2 and 3, and Condition 2 was significantly faster than Condition 3.

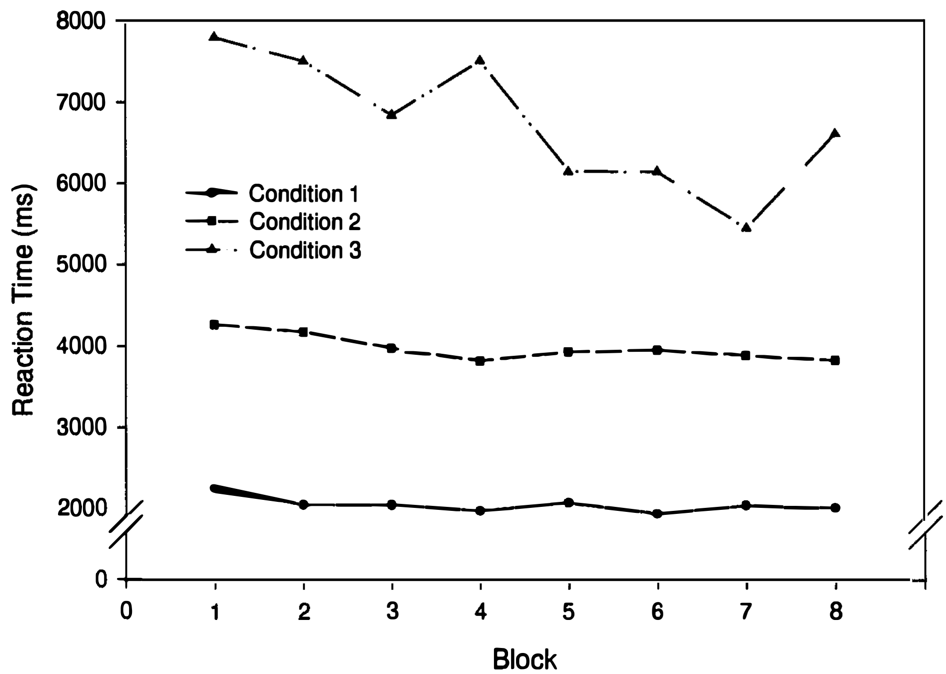

Figure 11. Mean reaction times for blocks of distractor tasks in all conditions.

To examine further the learning that occurred in the distractor tasks during the transfer phase, reaction time performance was analysed in terms of its relationship to a power function. There were moderate to good power function relationships for the distractor tasks in the transfer phase. The R^2 value for Condition 1 was 0.56, while it was 0.80 for Condition 2 and 0.61 for Condition 3. Very little learning was apparent for the distractor tasks, however, since the learning rates for Conditions 1 to 3 were 0.00, –0.07, and –0.11 respectively. Overall, these analyses and Figure 11 indicate that there was very little improvement in Condition 1, with some improvement evident in Condition 2. While more substantial, the performance improvement in Condition 3 was inconsistent.

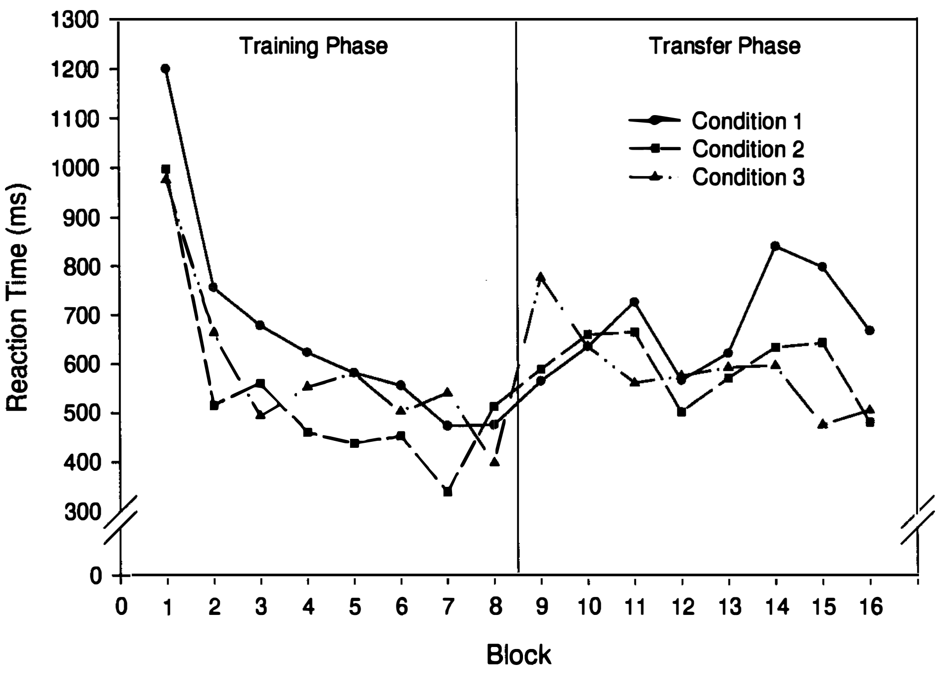

Figure 12. Standard deviations of test task problems in the training and transfer phases.

Figure 12 illustrates the standard deviation of reaction time for the test task problems in both phases of the experiment. In order to determine whether condition affected the variability of participant reaction time performance, standard deviations

were analysed using two 3 (condition) × 8 (block) mixed design analyses of variance, one for each of the training and transfer phases. There was a significant effect of block in the training phase, $F(7,399) = 18.14$, $p<.05$. There was no effect of block in the transfer phase, nor was there an interaction between block and condition in either phase. There was no effect of condition in either phase. *T*-tests were performed on the mean standard deviations for the last block of the training phase and the first block of the transfer phase for each condition. No significant differences were found for either Condition 1 or Condition 2, indicating that there was no major disruption at the end of the training phase compared to the beginning of the transfer phase. In Condition 3, mean standard deviation at the end of the training phase (M = 398.57 ms) was significantly less than the mean standard deviation at the beginning of the transfer phase (M = 776.19 ms), $t(20) = 3.04$, $p<.05$. This result indicates a significant increase in variability of reaction times on the test task at the beginning of the transfer phase. As was the case with reaction time performance (see Figures 7 to 9), Figure 12 indicates that the variability of performance in all conditions is severely disrupted in a prolonged manner, since the clear trend of improvement established in the training phase is no longer apparent in the transfer phase.

Discussion

This experiment sought to determine whether only a change in the conceptual environment could explain the disruption noted by Speelman and Kirsner (under review). Participants were encouraged to conceive of the transfer phase as being different to the training phase in varying degrees. Not only was it the premise that a conceptual change would be sufficient to invoke the disruption found by Speelman and Kirsner, it was proposed that the disruption would be greatest when the conceptual change was greatest.

The results support the specific findings of Speelman and Kirsner (under review) in concluding that skill performance on a task can indeed be disrupted by the presence of a novel task, even when predictions derived from theories such as Anderson's (1993) ACT-R and Logan's (1988) Instance Theory would indicate that performance should continue in accordance with power functions developed from training performance. Not only has their initial disruption again been detected, the results clarify the nature of the disruption by indicating that a change in the conceptual environment is sufficient to affect performance of an established skill.

In addition, the prediction that the initial disruption would be greatest when conceptual change was greatest was also supported, with significant disruptions to performance on the test task problems being found when double-digit additions and large multiplication problems were first introduced to the participants. As well as the predicted initial disruption brought about by the introduction of the distractor tasks in the transfer phase, a continuing, overall disruption to performance on the test task problems was found for all conditions, since performance during the entire transfer phase was disrupted: reaction time performance for two conditions never fell within the range that would be expected by extrapolating the power functions derived from

participants' performance in the training phase. This finding of a continuing disruption is supported by observations regarding the standard deviations of reaction time performance, since these also suffered from a disruption to the improvement trend apparent in the training phase of the experiment.

Prolonged Disruption

In focusing on the disruption noted by Speelman and Kirsner (under review), this study sought to more closely examine the nature of the factors and processes underlying it. Speelman and Kirsner considered that while any change in a task may cause some disruption, an increase in task complexity led to the greatest amount of disruption. In this experiment, there was no influence of extraneous visual presentation factors on the execution of the test task problems. They were presented in precisely the same manner as they were during the training phase. This control enabled the participants to be exposed to subtle, yet distinct, changes in the conceptual environment of the task in terms of what resources and techniques might be required to solve the problems as quickly and accurately as possible. It is apparent from the findings that, even though there was not a consistent initial disruption across conditions when the distractor tasks were introduced, performance in all conditions suffered from a prolonged disruption during the transfer phase. Performance immediately or eventually departed from that which was predicted by an extrapolation of training phase performance. Whether this prolonged disruption is permanent or temporary (as was the case with Speelman and Kirsner's findings), is a point that would be of interest in future research.

Even though the learning rate was low for the test task problems during the training phase, indicating that a well-established skill was being examined, there is nothing to indicate that an absolute asymptote was reached. If it can be assumed that

this was the case, then, since the limits of performance would not have been reached, there could be no influence of floor effects. As such, it may be assumed that the possible influences of the distractor tasks could have been to either slow down or speed up reaction time performance. Given the observed results, it would appear that the influence of the distractor tasks was sufficient to either invoke an immediate disruption to performance that was maintained throughout the transfer phase and prevented further improvements in performance, as was the case with Conditions 2 and 3, or it was sufficient to only prevent further performance improvements that eventually led to a departure from predicted performance, as was the case with Condition 1. Therefore, as predicted, a change in the conceptual environment is sufficient to disrupt performance by slowing down established skills when they are executed in the present of novel, yet similar, tasks.

Perhaps more importantly, if the temporal focus of the influence of the novel tasks is extended beyond the point of their introduction, the results indicate that any change in the conceptual environment is sufficient to disrupt performance. Even though the change may not be sufficient to prompt a significant, immediate deviation to performance, performance in all of the conditions eventually failed to equate to expectations based on an extrapolation of training phase performance. Given that the learning rate was impaired, and that general performance was disrupted in a prolonged manner, it can be inferred that some sort of overhead was added to the entire process by the introduction of the distractor tasks.

As well as accounting for the consistent increase in reaction time within all of the conditions, this overhead would also explain why, even if there was no significant disruption as soon as the distractor tasks were introduced, the observed reaction time eventually failed to match predicted performance. Since there is no reason to include

extra processing steps when determining the correct answer for memory retrieval tasks, it may be the case that the participants introduced some sort of discriminatory or decisional component. This may have been necessary in order to distinguish between the presented problems so as to best decide how to arrive at a result. That is, after realising that memory retrieval strategies were no longer appropriate, and that some other strategy or strategies had to be employed, it would have been necessary for the participants to decide what type of problem they were being presented with in order to invoke the appropriate strategy. This would have changed a fairly simple *stimulus-response* strategy such as that proposed by Campbell (1997) and LeFevre et al. (1996) into a *stimulus-assessment-response* procedure. If this was the only extra processing step required in order to correctly perform the task, it would also explain why there is no differential effect of the distractor tasks on reaction time such that increasing complexity would lead to incrementally larger disruptions.

While this proposal may adequately explain the events associated with Conditions 2 and 3, given that the distractor tasks in Condition 1 still only required memory retrieval, this explanation is problematic. However, the prolonged disruption that occurred in Condition 1, while following the same general form as Conditions 2 and 3, may be due to more subtle factors that would also explain the absence of an immediate disruption. During the training phase it may have been possible for participants to invoke a discrete subset or pool of responses that would suffice when it came to responding to the stimuli presented. In other words, as with the Soar model (1987, cited in Johnson, 1997) (which promotes performance improvements through the progressive chunking of resources), and aspects of Anderson's (1993) ACT-R theory (which simplifies complex processes through a process of composition), they may have been able to quarantine only that chunk or component of single-digit multiplication

knowledge required to perform the training phase test task problems. Indeed, if multiplication tables were learned in discrete sets (where, for example, the Three-Times table is learned separately from the Seven-Times table rather than all of the multiplication table problems being learned in a random fashion), which is probably the case, this would facilitate this strategy. If this were possible, the introduction of the distractor tasks would have forced the participants to load a larger chunk of their available range of multiplication tables. Indeed, this transition may have prompted them to believe that they should now be ready to respond to any of the multiplication tables. Given the limited capacity of working memory (Ericsson & Kintsch, 1995), maintaining this range of possible responses as an encapsulated whole would not have been possible, and there would have had to be more swapping of information in-to and out-of long-term memory. This process may, in turn, have limited the maximum rate at which stimuli could be responded to in this manner, thus leading to a consistent processing overhead in the transfer phase. Moreover, it may not be possible to apply the prior knowledge associated with the training phase in Condition 1 due to its particular use-specificity in this context. Müller (1999) states that an acquired cognitive skill's internal representation cannot be used if a new task requires the same general knowledge to applied differently because the context has changed. Thus, not only would a wider range of multiplication tables have been accessed by the participants, the relative advantage of the already rehearsed Six-Times tables in comparison to these other multiplication tables may have been lost because they would now be playing a different role in the context of all the other information that the participants would have primed for use.

Power Function Aspects

This experiment was also a further test of Speelman and Kirsner's (under review) findings that, contrary to the assumption of many theories of skill acquisition

and transfer, "power functions that describe improvement in old skills during their initial acquisition should predict further improvement on these skills during their execution in new tasks" (p. 32). The results provide support for Speelman and Kirsner's findings that skill performance on old components decreases in the presence of new components on a task. As such, it would appear that the disruption is a legitimate artefact that should be included in any theoretical framework seeking to describe the entire process of skill acquisition and transfer, particularly in settings that do not consider specific skills in isolation to any other factors.

Demonstrating that the disruption could be induced in well-established skills strengthened support for the conclusion that the disruption is a legitimate aspect of skill transfer. Given that research into this area has often examined skills that were developed specifically for the experimental scenario (e.g., Anderson et al., 1999; Blessing & Anderson, 1996; Müller, 1999; Speelman & Kirsner, under review), an argument could be made that any disruption detected might be related to the relative fragility of the skills being examined. That is, the skills may not be robust enough to give a participant confidence to apply them with little or no regard to the circumstances in which they are being evoked. Even though there may have been evidence in prior research that participants were using automatic processing and automatic performance, this fragility and commensurate lack of performance confidence might have been due to the mediating influence of controlled processing (Gopher, Armony, & Greenshpan, 2000; Shiffrin & Schneider, 1977). Because of the manner in which people receive training in the multiplication tables, previous research (e.g., Campbell & Graham, 1985; Pesta et al., 1999) indicates that the only option available to people when performing these skills is memory retrieval. Both Anderson's (1999) ACT-R and Logan's (1988) Instance theories would consider that automatic processing and performance is highly likely in

these circumstances. The fact that participant learning rates for the test task problems were lower than those for the tasks employed by Speelman and Kirsner (under review) is further support for these being well established skills. As such, practicing skills such as these would be expected to add little to overall skill performance. Indeed, it may be the case that much of the improvement in performance noted during the training phase of the experiment was due to participants learning the motor skills required to successfully respond to the tasks as quickly and accurately as possible.

While it is highly likely that improvements in motor skills contributed to the performance improvement demonstrated by the power functions fitted to the observed test task problem data, it is not considered that this aspect would account for any of the changes observed to learning rates. Participant performance with respect only to motor skills would have been a constant influence throughout the experiment, since there were no factors in this regard that changed during either the training or the transfer phases. Consequently, if it were possible to isolate the learning rate that applied to the motor skills component during the experiment, it is highly likely that it would have remained constant. Since the overall learning rate was expected to be a composite of the learning rates applying to the motor skills component and the cognitive processes being examined, a change in the observed learning rates should, by definition, be related directly to test task problem performance and the influence of the distractor tasks.

Not only was the disruption detected in well-established skills, it was also demonstrated that a relatively minor conceptual change was sufficient to induce it. Even though there were differing forms to the initial disruption at the time the distractor tasks were introduced, conceptual change was still able to lead to a prolonged disruption in all conditions. In the case of Condition 1, where the distractor tasks involved simply extending the pool of single-digit multiplication problems, all of which could have been

solved by memory retrieval, a prolonged performance disruption to the very similar test task problems was observed. Even though the distractor tasks in Conditions 2 and 3 required some form of strategic processing, either by employing algorithms or combining algorithms and memory retrieval, the tasks were relatively simple. In the case of Condition 3, the strategy to perform the distractor tasks more than likely included aspects of the same memory retrieval skills that enabled solution of the test task problems, which might be expected to improve performance on the test tasks by providing more practice for the participants. Despite this, performance was disrupted immediately and continually by the introduction of double-digit addition problems and large multiplication problems that extended the scope of the Six-Times table. As such, it appears that not only is the disruption found by Speelman and Kirsner (under review) a legitimate aspect of skill transfer, it is something that may affect skills at any level of expertise since it has been demonstrated that robust skills can still be influenced by relatively minor conceptual changes.

Distractor Tasks and their Influence

It was proposed that the conditions incorporated a logical progression in complexity, ranging from memory retrieval (in Condition 1) to algorithmic processing (in Condition 2), and finally to a combination of both memory retrieval and algorithmic processing (in Condition 3). The backing for this stance was indicated through a preliminary review of the literature, something that was later supported by an analysis of the distractor tasks. Performance in terms of reaction time on the distractor tasks was progressively significantly slower from Conditions 1 to 3. This is a clear indication that Condition 3 required more cognitive processing than Condition 2, which, in turn, required more cognitive processing than Condition 1. In addition, the low learning rates for the distractor tasks in each condition supports their potential to actually disrupt from

the test task problems. If it was difficult for participants to improve their performance, one implication is that much of their cognitive processing at the time of completing the distractor tasks was devoted to generating a solution. This is something on which the participants did not significantly improve during the transfer phase.

As with Speelman and Kirsner (under review), the greater the complexity of the distractor tasks, the greater the disruption. With the current research, the conditions that required more than simply memory retrieval to successfully identify the correct solution both resulted in an immediate disruption to reaction time performance when the distractor tasks were introduced. Despite evidence that the distractor tasks progressively increased in complexity, there was no indication that this had a differential effect on the size of the initial disruption. That is, performance in terms of reaction time was either disrupted by the introduction of the distractor tasks, or it was not. This is also consistent with the findings of Speelman and Kirsner, who found that once a certain degree of complexity is reached a disruption ensues. However, in this experiment this finding appears restricted to only the point at which the distractor tasks were introduced.

The current study extends Speelman and Kirsner's (under review) findings by indicating that this result may be restricted only to the initial appearance of the distractor tasks. The existence of a prolonged disruption is at odds with Speelman and Kirsner's findings that performance returned to normal after only a few blocks, indicating only a temporary disruption. The current findings clearly indicate that performance on the test task problems in the entire transfer phase experienced a considerable disruption. Even though observed performance in Condition 1 did not initially differ from expected performance, by the third block of the transfer phase performance did not match performance predicted by power functions describing test task reaction time in the training phase. Furthermore, even though performance in

Condition 1 was not significantly disrupted at the time the disruptor tasks were introduced, reaction time still slowed. Since transfer performance has often been predicted by extrapolating the improvements indicated by a power function, the fact that performance increased rather than decreased can be interpreted as being indicative of a disruption. Certainly, the *nature* of performance in Condition 1 appeared to be disrupted. This prolonged disruption was also observed throughout the training phase for Conditions 2 and 3. An examination of the standard deviation associated with test task problem performance also supports the existence of a prolonged disruption. As Logan (1988) proposes, as well as reaction time performance, performance standard deviation should also follow a power function. Consequently, if the variation of participant performance is affected by the introduction of distractor tasks, this is further evidence for a disruption. The results clearly indicate a disruption to variation of the reaction time of participants throughout the transfer phase that fails to match the improvements that were noted during the training phase.

Complexity and the Underlying Nature of the Disruption

In general terms, there is no reason to dispute Speelman and Kirsner's (under review) proposal that the disruption noted on the introduction of the distractor tasks is explained in terms of complexity. However, while there may be a complexity threshold that, once exceeded, is sufficient to prompt a significant immediate disruption, the results of this experiment indicate that the introduction of any novel task may be sufficient to prompt a continuing disruption that eventually leads to actual performance differing from predicted performance. Consequently, it is important to consider what might be the underlying process that enables complexity to influence performance. One possibility relates to the participants' view of the overall requirements of the experiment, and how this had been developed during the training phase. Since

participants were very likely to have learned multiplication tables in rote fashion, thus forcing a memory retrieval strategy to be adopted, it is considered that this may have prompted a more fundamental stimulus-response strategy to performing the test task problems in the training phase. Wenger (1999) supports such a possibility when he states that the stimulus interpretation, goal, and implicit response of arithmetic facts can all be encoded as a result of memorisation. That is, all the participant would need to have done in order to arrive at an answer to be compared with the options later presented would have been to attend to the stimulus presented on the screen, and then respond with the answer arising via memory retrieval. This consistency of the sequential characteristics across the training phase would have given participants the opportunity to recognise this and improve their performance accordingly (Wenger & Carlson, 1996). Indeed, in his later work Wenger believes that prior stimuli presented can be used as retrieval cues, all of which might be used to develop an overall strategy. If this scenario was true, then very little, if any, cognitive processing directly related to solving the arithmetic problems would have been required.

However, as soon as a distractor task was first encountered in Conditions 2 and 3, participants would have had to abandon this stimulus-response strategy. The introduction of the distractor tasks may have prompted participants to change their conception of the overall requirements of the experiment, since they may have come to believe that only tasks related to memory retrieval were being examined. As such, as well has having to distinguish between the nature of individual task problem requirements, the initial few distractor task–test task interactions may have been used by participants to develop and decide on the most appropriate response strategy. As Gopher, Weil, and Siegel (1989, p. 151) note, "the voluntary control of attentional resources plays an important role in the development of strategies, as well as the ability

to carry out the performance policies which are dictated by them … the act of shifting strategies is hence also an act of changing the focus of attention." Indeed, it has been noted that any task is comprised of numerous elementary components, each of which may be comprised of further sub-components. The organisation and interaction of these task shells is considered an integral part of task performance since they "specify, establish, and preserve the contextual shell within which the direct perception transformation and response activities operate to carry out goal-directed behaviour" (Gopher et al., 2000, p. 308). Consequently, it is possible that changing the context in which a skill is performed would involve a reconstruction of the conceptual shell that had been developed specifically to deal with the presenting circumstances. This reconstruction of the task shell may have slowed performance on the test task problems until participants developed an acceptable strategy and regained confidence in processing the problems within a new conceptual framework.

Accuracy

Accuracy was not affected by the introduction of the distractor tasks—it remained consistently high throughout the experiment. The gains made in the training phase were maintained throughout the transfer phase. This finding is consistent with Speelman and Kirsner's (under review) results, which also found that performance accuracy was not affected by changes to the task conditions. Given that the test task problems reflected long-standing and well-established skills, this is perhaps not surprising. However, since the distractor tasks were sufficient to evoke prolonged performance speed disruptions, it is further support for Speelman and Kirsner's findings that the disruption may be restricted to performance speed rather than performance accuracy.

Power Law of Practice

Support for the power law of practice was demonstrated by participant performance on the test task problems in the training phase. All conditions strongly conformed to power functions. This degree of conformity was mixed in the transfer phase, and may have been related to recovery from the initial disruption on the introduction of the distractor tasks. That is, once participants had correctly assessed the change in conceptual requirements, they may have been able to recover more rapidly from the conditions that invoked a significant initial disruption, particularly given that the skills being examined are very likely to have been well-established. Interestingly, while conforming moderately to power functions, the learning rates for the distractor tasks were very low. Because of the role that they play in defining the power function itself, as the learning rate approaches zero the power curve becomes flatter. Indeed, a learning rate of zero would define a linear relationship. As such, these learning rates tend to define a more linear relationship than that normally associated with power function curves, which indicates that high correlations with power functions should be interpreted with caution. Given that the distractor items in Conditions 2 and 3 did not contain any repetitions, this indicates that the participants did not learn how to improve their general task performance. In other words, they may not have been able to develop any strategies that enabled them to improve their performance on algorithmic processing or a combination of memory retrieval and algorithmic processing.

Transfer Phase Performance Recovery

The performance associated with the test task problems in the transfer phase indicates that there is a differential rate of recovery from the initial disruption as the transfer phase progresses. That is, where the complexity of the distractor tasks is higher, participants were able to more rapidly improve their performance as the transfer phase

continued. The distractor tasks in Condition 1 were closely related to the test task problems, in that they were drawn from single-digit multiplication tables, and could all be solved using memory retrieval. As such, it might be expected that it would be hard for participants to distinguish between the two types of task, a matter that would not be at issue in Conditions 2 or 3 since the distractor tasks were substantially and obviously different from the test task problems. Since the participants would be able to so easily distinguish between the two types of task in Conditions 2 and 3, they may have been able to treat the overall requirements of the transfer phase as simply performing two distinct tasks. Given that the test tasks and the distractor tasks in Conditions 2 and 3 may not have interfered with each other in this regard, it may have enabled the participants to recover more quickly from the disruption induced by the substantially different distractor tasks.

Future Research

Given that Speelman and Kirsner (under review) have only relatively recently found that established skills can be disrupted in the presence of novel tasks, it can be expected that there is wide scope for further research. Such future research would not only serve to confirm the existence of the disruption, it would also allow the nature and circumstances of the disruption to be better defined. The current study has partially embarked on this path, having provided confirmation of the existence of the disruption as well as indicating that the nature of the disruption may not be restricted only to the period immediately following the introduction of novel tasks.

If the existence of the disruption can now be assumed, then the possibilities for its nature and form include: an initial disruption from which people are able to recover after having incorporated any influence of the conceptual environment on task requirements; a prolonged disruption that amounts to a cognitive processing overhead

being introduced regardless of the initial impact of the novel tasks while a person is performing a combination of the particular skill sets; or some combination of both. Not only is the nature and form of the disruption of interest, the particular cognitive processes to which is applies are also relevant. Both Speelman and Kirsner's (under review) research and the present study have arithmetic skills as their basis. This is but one of a wide range of cognitive functions of which humans are capable. As such, it would be beneficial to examine whether it is possible to detect a disruption to expected performance improvements in such fundamental areas as visual and auditory processing, as well as more complex executive functions such as planning and problem solving.

Conclusion

Since the disruption has now been confirmed by this research, the question arises about what role it might play in the broader picture of skill acquisition and transfer. Presumably, this cognitive component would not have arisen at such a fundamental level if it did not play some useful function. Such benefits may relate to the flexibility that such a cognitive management strategy would provide. As LeFevre et al. (1996) note, cognitive procedures are continuously dynamic, and are refined by an individual's experiences. Indeed, they consider that "it seems entirely reasonable that cognitive systems would be designed so that perfect consistency of retrieval or any other procedure is difficult to obtain" (LeFevre et al., 1996, p. 302). As such, in order for people to be most responsive to changes that occur in the environment in which they must apply their skills, they need the flexibility to re-assess and re-apply their skills and knowledge base.

While the main results of this study have served to confirm that the disruption noted by Speelman and Kirsner (under review) is a legitimate aspect of skill acquisition

and transfer, the design of the experiment has enabled the nature of the disruption to be more closely defined. In this regard, it is apparent that not only is it possible to disrupt performance immediately on the introduction of novel tasks (something that appears to be directly related to a complexity threshold), there may be a prolonged influence of conceptual change that at least results in performance never recovering to previous levels or, if it does, it may take some appreciable time to achieve.

While this finding may not at first glance appear to be of major importance in cognitive psychology, it does have implications for many of the fundamental theories such as Anderson's (1993) ACT-R Theory and Logan's (1988) Instance Theory, along with the array of theories that have been developed in response to their major propositions. While the ability of power functions to describe initial skill acquisition appears to be adequate, their use as a predictive tool for a specific skill without regard to the conceptual framework in which that skill is being applied may need to be examined further. One of the stumbling blocks that these theories may need to address is their reliance on the power law of practice as a major component with which they need to comply and as something that has been extremely influential in their development (e.g., Palmeri, 1999). It is possibly this emphasis on the power law of practice, coupled with its widespread acceptance as a valid account of the development of a skill, that determines its use as a predictive tool with perhaps insufficient regard to other pertinent factors. Consequently, it may be possible for future research to continue to examine the disruption first noted by Speelman and Kirsner (under review) in order to confirm its nature and extent, along with the range of scenarios in which it applies.

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Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Training 7	Training 8	Training 9	Training 10	Training 11
1	2483	3555	2313	1833	3575	2754	4326	4557	2955	3225	1873
2	3595	2594	2774	1832	1833	3525	1633	1993	1763	2103	2033
3	3375			11567		3254	1412	1833	4747	2243	
4	6249	2353	2634	9914	5638	8262	7621	5278	2824	4847	5408
5	3966	2274	3836	4646	1863		4036	4467	2463	2153	6118
6	6860	2033	1952	2003	3235	2574	2704	1953	1772	2203	1803
7	2433	2904		3755	2894	3035	3455	2974	1923	2193	2714
8	1792	1482	1872	1603	2113	1562	1332	1161	932	1843	1021
9	3825	3826	2785	3615	2704	2624	1412	2344	2143		4847
10	2083	1963	1712	1883	1603	1372	2394	1763	1201	2053	1322
11	3865	3075	2985	3135	2704	2494	2163	2193	2364	2013	2193
12	7089	6619	4166	3585		3415	2153	5197	2073	1752	2243
13	2273	1683	1372	1362	2173	2393		1573			2784
14	5618	4437	2464	4566	3365	3134	2934	3465	2313	2373	3775
15	5348	2353	3144	2504	2904	2764	2584	1852	2173	2554	2434
16	3926	4206	2374	2264	2714	3014		2263	2704	2734	2193
17	2864	2794	3695	3075	2474	2313	2774	2514	2093	2603	3185
18	2404	4206	3085	4527	2944	3184	3054	3065	2704	2183	2363
19	3555	3615	6690	2342	4106	3025	2633	2183	1993	2193	2123
20	9213	9604	2473	2504	2053	3685	4066	3775	5107	2343	4296

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 12	Training 13	Training 14	Training 15	Training 16	Training 17	Training 18	Training 19	Training 20	Training 21	Training 22
1	2544	1792	3665	3465	1993	1832	3946	1973	2433	1763	2383
2	2303	1903	1833	1873	1683	1692	1552	1592	1472	1612	1973
3	4026	3505	1522	4816	2504	1442	3035	2073	3195	4656	1252
4	2374	6038	3745	7731	5798	3786	5548	3325	5207	1793	6420
5		2273	2373	3184	6690	2283	2163	2194	2514	1993	2073
6	1922	1913	1952	1683	2023	1642	1763	1772	1292	1222	1372
7	3105	2464	2684	2033	2874	2073	1912	1753	1883	1963	1602
8	901	921	3345	861	891	1602	821	1071	891		3385
9	2974	1592	1252	2313	3274		6670	2533	3615		2503
10	1421	1452	1723	1212		1772	1482	2173	1442	1211	1292
11	2163	2404	2163	2203	2003	1963	2123	2163	1813	1883	1903
12	1683	1462	2354	1442	1993	2313		3866	1652	4576	2233
13	2513	1212		1623	1813	1632	1292	2254	1162	1452	1362
14	3816	2854	3675	3656	1923	2143	5137	2704	2033	2434	1713
15	2814	2193	2113	1953	2343	2484	1923	1842	1603	1753	1722
16	1953	2624	2784	2193	1763	3265	4797	2514	3925	2304	2394
17	2194	2764	1813	1752	2263	1923	1432	1833	1852	2283	1592
18	3485	2143	2473	2023	2153	2103	2304	1952	2744	1843	1883
19	2314	1683	2553		2914	1993	1732	2624	3374	4587	4827
20	2293	4396	2163	2624	2083	1673	1712	1963	3375	2343	3435

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 23	Training 24	Training 25	Training 26	Training 27	Training 28	Training 29	Training 30	Training 31	Training 32	Training 33
1	1762		3274	1993	1702	1983	1732	2834	1492	2053	2274
2	1482	1432	1272	1272	1553	1643	1513	1513	1482	1432	1482
3	1251	4226	3415	6189	1483	3455	1182	1142	1852	2474	1522
4	1492	2233	6760	2483	2584	5048	7541	2073	1832	7241	2594
5	3465	1983	1872	2303	2733	1763	1922	1873	1843	1893	1563
6	1602	1702	1452	1682	1963	1402	1543	2023		2294	2153
7	1712	2744	1472		1952	1522	1723	1853	1161	1833	2292
8	1241	1322	1722	1482	1312	1021	1252	1593	1012	931	1081
9	2874	3936	1912	2664		3615	3104	2584		4257	1993
10	1141	1122	1642	1682	1442	1692	1682	1212	1922	1132	1562
11	1803	1862	1903	1842	2003	1852	2103	1843	2123	1803	1883
12	1712				2484	1121	3305	3074	3455	4045	1372
13	1122	1432	1171	1723	1493	1452	1012		1562		2203
14	2543	2123	2083	2223	4146	1953	1933	2244	1863	1853	7221
15	1722	1763	1683	1602	1852	1532	1572	1602	1492	1542	1512
16	2053	2714	2614	3806	2273	2433	3655	2423	1993	2353	2243
17	1753	1883	1602	1793	1923	1672	1472	1933	1643	1672	1752
18	1872	2233	2354	1763	1362	2113	2183	1672	1793	2854	2785
19	2814	6880	2343	1752	1963	2343	1943	2784	1843	4036	2143
20	1672	2704	1642	3134	1592	2073	1512	2934	2634	1613	1593

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 34	Training 35	Training 36	Training 37	Training 38	Training 39	Training 40	Training 41	Training 42	Training 43	Training 44
1	2072	3115	2083	1412	1312	1572	1872	1332	1712	2073	4166
2	1442	1352	1643	1571	1552	1312	1553	1362	1482	1402	1322
3		1593	1152	3034		2083	1503	8082	1562	1171	3575
4	2153	1923	3145	1822	4046	2113	1913	1833	2013	1732	7040
5	1392	2303	1562	1753	1351	1212	1442	1542	1392	1623	1983
6	1903	1672	1852		1903	1682	1853	2093	2053	1793	1943
7	1392	1573		2073	1332	1121	1212	1733	1231	1372	1522
8	921		2904	1202	851	1081	1041	1352	1091	1452	
9	1602	2784	2433	1682	1833	1762	1532	3194	2233	1693	1953
10	1612	1101	1112	1332	1452	1442	1602	1172		1252	1643
11	1893	2634	2123	1923	1873	2053	1772	1923	2204	2294	1853
12	2373	1933	3585	1662		3145	1912	2914	2323	1993	2473
13	1372	1212	1993	1252	1092	1202	1121	1873	1131	1172	1211
14	2423	2543	1763	1722	2393	2464	1833	2403	1883	2153	1733
15	1332	1412	1362	1883	1652	1652	1322	2103	1522	1803	1472
16	3064	1793	2915	3135	2784	2384	2643	6349	1232	1842	2393
17	1993	1432	1522	1433	1633	2183	1322	1733	1462	1713	1873
18	2274	1803	2233	1962	1913	1842	1693	1923	1923	1703	2002
19	2193	1713	2434	3184	3695	3054	3415	2113	1872	2273	1632
20	1312	1512	1372	1412	2854	1362	1212	1472	2303	3214	2263

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 45	Training 46	Training 47	Training 48	Training 49	Training 50	Training 51	Training 52	Training 53	Training 54	Training 55
1	1953	1763	1993	2023	1171	1953	2163	1372		3455	3585
2	2224	1603	1523	1633	1362	1412	1953	1913	1672	1472	1432
3	1532	4056	1392	2935	1252	1091	1763	2353	1241	3305	1242
4	2744	1812	2163	4617	1843	5087	4526	4657	1732	6239	2433
5	1592	1492	1893	2164	1513	1553	1993	1332	2083	1753	1632
6	1803	1743	2273	1622	1482	1662	1492	1542	1532	1602	1933
7	1362	1001	1121	1312	1442	1362	1282	1332	901	1001	1242
8		2194	1803	2283	991	1092	1002	931	871	1061	1011
9	2443	1843	1402	2634		1161	1182	1132	1011	1212	1291
10	1331	1963	1442	1412	1923	1482	1532	1822	1072	1191	1222
11	1782	1853	1693	1892	2243	1723	1842	1792	1723	1663	1842
12		1682		5158	2513	2584	2324	1872	2013	2203	1712
13		2835	3435	1172	952	1011	1352	1131	1001	1673	1292
14	1853	2153	1812	2694	2153	2073	1863	3104	2133	2153	1983
15	1362	1372	1412	1522	1442	1513	1473	1282	1122	1212	1282
16	2133	1632	2043	1682	1552	2143	3605	2584	1673	1822	1803
17	1833	1332	2704	3214	1983	1432	2033	2313	2233	2243	2003
18	2073	1883	2144	2192	1603	1953	1592	1602	2223	2033	1953
19	1753	2424	1963	2224	2334	2003	1803	1993	2033	1742	2223
20	1552	2614	1482	1172	1562	1352	1362	3566	2514	1352	1212

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 56	Training 57	Training 58	Training 59	Training 60	Training 61	Training 62	Training 63	Training 64	Training 65	Training 66
1	2384	2714	2484	2113	2353	2544	1692	2544	3155	1512	1562
2	1242	1242	1362	1482	1251	1202	1241	1242	1161	1182	1292
3	1332	1973	1382	1242	3425	2834	2664	1242	2353	1732	1402
4	1773	5568	2874	5568	2053	2244	1713	2233	1562	1842	1602
5	1622	1552	1192	1192	1622	1332	1642	1642	1322	1432	1473
6	2143	1803	1632	1602	1382	1432	1362	1472	1502	1482	1482
7	1201	1482	1011	1282	1242	1763	1372	1182	1372	1161	1602
8	972	1342	850	1172	2003	1322	821	2283	1792	1042	1002
9	1683	1913	1172	2434	1041	821	1762	2233	3425	3325	2704
10	1352		2053	1693	1131	1372		1211		1643	1853
11	1823	1862	2123	2002	1743	2042	1813	1642	1752	1863	1893
12	1833		4797	2473	2223	4456	2344	1993	1712	1983	1652
13	1242	1252	1582	1052	972	1221	1042	932	1422	1603	1282
14	1723	2133	1913	2023	2153	2173	1723	2553	1853	2954	2042
15	1302	1392	3775	1732	1573	1392	1512	1632	1572	1572	1282
16	1753	1622	2163	1572	2073	1673	1492	2744	2544	1862	2323
17	1242	1673	1772	1933	1593	2204	1903	1742	1532	1452	1532
18	1392	1472	1833	1883	1682	2063	1963	3555	1653	1833	1582
19	1722	2053	2504	2103	1863	2673	2043	2023	2113	1913	1682
20	1632	1632	1302	1832	1703	1723	1312	1292	1332	2293	1392

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 67	Training 68	Training 69	Training 70	Training 71	Training 72	Transfer 1	Transfer 2	Transfer 3	Transfer 4	Transfer 5
1	2864	1763	2543	2193	1552	2243	1883	1412	1842	1873	2134
2	1482	1683	1402	1162	1281	1212	1232	1241	1212	1121	1132
3	3214	1633	1212	2794	1362	3005	2594	2814	2464	1953	1082
4	7180	3255	6148	1833	1672	1632	6149	5678	8181	1843	4696
5	1492	1502	2103	1672	1122	1212	1392	1602	1712	1582	2033
6	1702	1602	1322	1322	1292	1142	2444	1502	2854	2333	1482
7	1011	1172	1482	1402	1062	1642	1522	1392		1282	1212
8	1081	1252	1331	972	912	1202	851	1292	821	772	
9	1873	1793	2864	2123	1643	2523	2283	3195	1723	1692	2604
10	1302	1122	1662	1212		1963	1432	992		1362	1362
11	1682	1723	1803	1642	1612	1973	2012	1763	1713	2483	2143
12	1843	1723	1792	2323	2363	1953	2083		3064	1783	2784
13	1252		1132	1161	1082	1162	1212		1252	1212	1562
14	1512	2494	1682	3345	2274	1653	1653	1962	2514	1813	1873
15	1121	1212	1332	1312	1292	2463	1162	1532	1161	1593	1122
16	1562	1562	1753	1793	1863	2073	1723	1693	1772	2113	1512
17	1793	1993	1762	1643	2023	1753	1792	1412	1802	1883	1602
18	1452	1682		4477	1753	1792	1863	2103	2263	3655	2113
19	2544	1952	1983	1632	1883	2003	2344	2203	2654	2163	1762
20	1392	1352	2333	1352	2303	1672	3585	1442	2003	1412	1292

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 6	Transfer 7	Transfer 8	Transfer 9	Transfer 10	Transfer 11	Transfer 12	Transfer 13	Transfer 14	Transfer 15	Transfer 16
1	1923	2353	5719	3856	4406	1652	1853	1552	1882	1873	2193
2	1141	1282	1372	1242	1162	1392	1082	1122	1162	1091	1161
3	1101	3375	2915	1312	1712	5608	2223	3535	2865	1552	1051
4	1562	1843	2764	5107	5518	1593	1823	3044	6079	1472	1692
5	1392	1512	1392	1683	1352	2463	1512	1472	1272	1883	1342
6	1682	1452	1562	1893	1432	1522	1232	1953	1331	1482	1743
7	1482	1002	1362	1292	1532	1402	1231	1131	1211	1121	1562
8	1122	1362	1652	1091	1573	1012	811	1081	1032	1052	1212
9	3424	1281			1873	1592	1312	2714		4156	1432
10	1282		1472	1522		1062	1132	1091		1212	1211
11	1843	1882	1843	1842	1923	1722	1652		1772	1923	1682
12	2925	1983	2864	3145	1633	2474		3264	3034	1843	2354
13	991	1482	1031	1282	1402	1453	1132			1132	1352
14	1943	2103	1922	1832	1803	2404	2713	2544	1752	1672	1883
15	1172	1021	962	1482	1132	1161	1191	1200	1292	1242	882
16	2153	1723	1853	4747	5888	1613	2113	2553	2073	2114	1773
17	1362	1753	1633	1733	1752	1912	1803	1322	1723	1603	1723
18	2103	1992	1562	2123	2393	2664	1512	1712	1833	2183	1832
19	2524	2544	2023	2203	1973	1903	2694	2083	1683	2945	2133
20	1552	1392	1372	3885		5228	1442	1612	1412	1993	1202

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 17	Transfer 18	Transfer 19	Transfer 20	Transfer 21	Transfer 22	Transfer 23	Transfer 24	Transfer 25	Transfer 26	Transfer 27
1	2113	1963	3685	5087	2414	1252	3275	2824	4207	1652	3575
2	1162	1242	1522	1542	1162	1593	1102	1082	1172	1542	1322
3	8683	1853	3976		2313	1833	1051	9944	2093	1692	2363
4	1532	1893	10466	1883	2073	3425	4657	3775	3305	10906	1832
5	1562	1211	1552	1672	1712	1522	1592	2193	1472	1332	1482
6	2274	2033	1292	2333	2774	1633	1282	2704	2013	2464	1762
7	1442	1172	1352	1302	1372	1372	1652	1192	1332	1472	1271
8		891	1642	1993	1022	1222	931	991	841	1382	1201
9	1913	1843	1482	1853	1803	1682	1122	2353	3465	2223	1552
10	1122	1001	951	1482	1051	1002	1131	1603	1412	1021	1091
11	2233	1482	1652	1702	1792	2243	1633	1763	1802	1492	1482
12		2403	1883	1562	1673		1633		1933	1712	
13	1793	1101	1091	1202	1141	1172	1041	1442	1212	1922	2073
14	1723	1802	1803	1772	1573	1833	1953	1733	1692	1633	1472
15	1372	1042	1252	1092	1452	1362	1172	1072	1091		2123
16		2153	2193		3615		2744	4207	4847	3335	2304
17	1692	1672	1713	1682	1522	1322	1242	1993	1682	1572	2193
18	1753	2163	4126	2003	2403	2193	2233	2083	1903	2143	1552
19	1612	1643	2274	2674	1783	1893	1752	1392	1702	1873	1512
20	1472	1392	1743	2073	1552	1292	1672	1593	3895	1542	2554

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 28	Transfer 29	Transfer 30	Transfer 31	Transfer 32	Transfer 33	Transfer 34	Transfer 35	Transfer 36	Transfer 37	Transfer 38
1	2744	1232	2914	3245	2003	4206	1692	2233	2874	2374	1492
2	1512	1192	1282	1181	1162	1633	1111	2504	1382	1272	1201
3		1101	3615	5938	4777	1603	2123	1251	1723	1883	2003
4	2594	2443	2113	3815	3745	1763	5879	1793	2644	5477	1693
5	1482	1322	1131	1202	1742	1593	1522	1092	1442	1753	1512
6	1842	1802	1783	1693	1793	2323	1442	1532	1602	2493	2564
7	1552	1212	1472	1292	1402	1132	1131	1202	1532	1653	1332
8	961	811	1092	881	1562	771	862	771	792	982	1682
9	1572	1993	2584	1802	1873	1592	1532		3264	1963	2043
10	1482	1402	1442	1062	1603	1803	1573	1172	1402	1292	1012
11	1492	1492	1332	2043	1462	1563	1763	1562	1622	1542	1533
12	1472	1752	1492	2363	1522	2083	2784	2193	1782	2002	2203
13	1372	1763	1483	1923	1141	1162	1802	1993	1201	1092	1412
14	3495	1683	1912	1963	2433	1522	2273	3265	2514	2323	1832
15	1252	1082		1532	1172	1172	1562	1241	1172	1161	1241
16		3646	2233	5598	2233	2924	2344		2343	1873	2543
17	1472	1722	2033	1532	1853	1592	2213	1712	2193	2003	1542
18	1572	1883	1942	2394	2604	1642	1953	2694	2504	2073	
19	2684	1963	1833	1282	2113	2223	1673	2073	1573	1613	2123
20	2193	2383	1562	1682	1882	1633	4546	3174	2263	1943	1682

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 39	Transfer 40	Transfer 41	Transfer 42	Transfer 43	Transfer 44	Transfer 45	Transfer 46	Transfer 47	Transfer 48	Transfer 49
1		3946	1762		1442	2153	3535	2343	2904	1552	4206
2	991	1001	1082	1593	1242	1222	1433	1873	1913	1282	1372
3	1452	3425	1251	3265	1312	5879	1072	3425	5398	1913	2273
4	1673	1592	1653	7021	2273	1522	3705	2033	9684	9313	3886
5	3124	1562	1302	1592	1432	1492	1592	2183	1252	1312	1081
6	1433	1852	1863	2453	1362	1522	1783	1432	1993	1553	1613
7	1272	1061	1482	1222	1202	1482	1242	1192	1011	1011	1412
8	972	741	981		1081	1833	1052	1442		1102	971
9				3425	2704	1572	1852		1843	1882	
10	1683	1092	1482	2153	1221	1653	1182	1492	1111	1372	1092
11	1402	1442	1502	1412	1492	1442	1292	1222	1342	1482	1282
12	1632	2794		3726	1733	1282	1712	1672	2394		2193
13	1182	1922	1092	1572	1031	1091	1612		1142	1482	1171
14	1563	1753	1993	1883	1583	1512	1672	1723	2153	2784	1963
15	1092	1171	1232	1131	1603	1051	932	1042	1131	1002	1222
16	1622		2394	1913	3354	2984		3956	2374	11747	2704
17	1432	4757	1522	2103	1352	1753	1272	2303	1983	1382	2003
18	3234	1673	1992	1722	1713	1793	1742	1803	1893	1763	2263
19	2053	1392	2033	2113	1412	2334	1543	2834	2494	1843	2113
20	2233	2344	4206	1752	2033	1362	1903	1913	1312	1352	1592

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 50	Transfer 51	Transfer 52	Transfer 53	Transfer 54	Transfer 55	Transfer 56	Transfer 57	Transfer 58	Transfer 59	Transfer 60
1	3345	2734		4336	2583	1672	3655	3936	2113	1993	
2	1553	972	1161	1202	1201	1242	1191	1202	841	1562	1201
3	1803	1522	2323	1993	3025	1452	1482	1952	3375	3775	3906
4	1592	1412	5017	1693	1492	4176	2904	2003	1772	4577	2834
5	1392	1322	1823	1482	1171	1522	1472	1252	1152	1793	3485
6	1473	1362	1342	1562	2684		2564	1803	1662	1492	1492
7	1251	1162	1161	1192	1052	1132	1001	1041	1292	2033	1312
8	841	911	951	831	1021	892		972	891	1161	931
9	5197		5568	1212	1953	3145		3455	2784	1943	3946
10	1302	1102	1492	1382	1492	1332	1222	1052	1612	1562	1322
11	1452	1563	1493	1452	1362	1362	1522	1412	1443	2494	1492
12	1672		2744	1833	1963	1442		1793	1482		
13	1172	1222	1202	2634		1092		1122	2113	1632	2083
14	2153	1712	1913	1472	1692	4697	1592		2353	1752	2204
15	1362	1042	1452	2423	1953	1562	1242	1372	1092	1041	1282
16		3545	2504	1962	1482	1823	1532	1993	15062	1652	4476
17	1292	2354	2264	1443	1953	2854	1913	2003	1713	1843	1892
18	2033	2273	2033	2794	1762	1763	1753	2193	1893	1592	1712
19	1673	1833	1642	2714	1773	1963	2414	1472	2043	1723	1662
20	3996	1352	1661	4977	3174	1111	1041	1632	2854	2854	1872

Blanks indicate incorrect responses

Appendix A

Condition 1 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 61	Transfer 62	Transfer 63	Transfer 64	Transfer 65	Transfer 66	Transfer 67	Transfer 68	Transfer 69	Transfer 70	Transfer 71	Transfer 72
1	1432	4917	4596	6710	1762	1522	2563	1562	2875	2264		3355
2	1271	1292	1131	1251	1172	1042	932	1142	1272	1362	1862	1312
3	2353	1942	1723	1241	1092	3495	1893	1842	7510	4216	2222	4476
4	3535	2324	1442	3776	1512	2624	1392	7261	2864	5989	1762	1432
5	1632	1672	4116	1572	1602	1883	1672	1643	1132		1682	1171
6	2964	1693	2804	1893	1762	1602	1833	1321	1672	1823	1592	1642
7	1242	1062	1352	1101	1202	1251	1131	1713	1092	1082	1442	1092
8	931	901	1012	1132	1292	811	1041	932		981	1692	
9	2433	2354	1282	2094	4637	2234	1212	3345	1883	2874	3766	1472
10	1091	1362	1222		2674	1322	1502	1101	1482	1292	1062	1162
11	1282	1332	1212	1261	1362	1412	1362	1342	1452	1442	2774	1652
12	1211	3105	1732		1533	1652	1692	1322		2303	2384	1562
13	1291	1723	1052	2473	1142	1572	2003	1202	1643	1212	1282	
14	1442	1733	1832	2354	1543	2514	1632	2264	1442	1683	1623	1852
15	1042	1051	1202	1602	1022	1993	2073	1312	1252	1092	1242	1513
16	2183	2503	2043	1762	1592	2233	1612	1593	3806	1833	1882	1532
17	1963	1763	1763	1672	1722	1352	1993	1842	2063	1432	1733	1322
18	1963	2443	1803	1843	1993	1883	1592	1833	2023	1883	1352	1472
19	1882	1762	1993	1723	1692	1592	1912	2654	2834	1532	1803	1863
20	4837	1172	1592	1332	3805	1251	1873	2463	1672	1833	1672	1472

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	**Training 1**	**Training 2**	**Training 3**	**Training 4**	**Training 5**	**Training 6**	**Training 7**	**Training 8**	**Training 9**	**Training 10**	**Training 11**
1	3585	3215	2423	2103	2854	2083	2063	2894	2694	2693	2484
2		3715	2404	2123	2213	1723	1883	1842	1462	1723	2123
3	3465	4086	2113	3675	2594		3505	2473	3024	2393	2243
4	2934	3345	3966	2033	2503	2223	2624	2664	1993		1993
5	2774	2693	3565	1352	1602	1993	2703	2434	1322	1312	1192
6	3605	3415	3365	2274	6079	2243	2674	2383	2193	2203	2714
7	2314	1833	1702	1372	1772	1452	1712	1522	2474	2052	1482
8	4807	4136	4246	6779	2303	7341	5438	8322	6980	2163	7021
9	3074	9113	4495	2013	1832		1923	1893	1532	2473	2233
10	2834	2964	2364	2394	2784	5008	3626	1883	2754	1852	3144
11	2964	3114	2523	1903	1902	3065	2013	2283	2053	2413	2093
12	4276	2664	2153	2304	1953	1272			1442	1442	1432
13		7190		2633	2334	5318	2233	8953	2304	4607	4056
14	2424	3875	5518	4366	2904	2513	3104	2233	1873	2623	2133
15	4877	3295	2663	2193	2924	3986	3965	3695	4967	2073	2584
16	3334	1793	3084	2402	2624	2353	2353	2934	3485	2854	2243
17	4447	2233	2664	2423	2113	2243	1873	1603	1753	1702	1642
18	2514	4176	2554	3054	3695	2664	1822	1963	3124	2143	2433
19	2814	1853	1352	1632	2303	1762	1713	1232	1562	1712	1512
20	3766	3005	2774	4427	2764	2934	2654	2744	2573	3245	2734

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 12	Training 13	Training 14	Training 15	Training 16	Training 17	Training 18	Training 19	Training 20	Training 21	Training 22
1	2193	2364	2233	1852	1823	3215	2694	2073	1753	2083	1963
2	1973	1482	1442	2754	1873	1512	1802	1883	1973	1672	1603
3	1813	2963	1832	2744	1782	2113	2313	2243	1692	2524	2433
4	2073	2183	3055	2534	1983	1763	2714	1462	2073	1792	1522
5	1553	1152	1161		1532	2433	1873	1291	1202	1452	
6	2153	2233	2634	2153	2393	2153	2043	2083	2283	2744	1953
7	1282	1492	1302	1172		1612	1242	1292		2073	1372
8	3555	5588	3986	7540	5598	6629	4617	4616	4446	5278	6319
9	1452	2043	1632	1572	2483	1823	1352		5608	1522	1813
10	1763	2663	4136	3405	1752	1923	1653	1493	1412	2023	3315
11	2552	2554	2503	1963	2884	2043	1963	2023	1913	1722	1953
12	1512	1132	1833			1993	1362	1893	1643	1432	1693
13		4346	5628	2113	1853	1953	2514	5458	4026	3064	
14	2133	2193	2043	2083	1883		2864	2894	1853	1963	2043
15	2474	2543	2434	2544	4286	4156	2073	2293	2203	2043	2343
16	2553	2784	3024	2383	2534	2474	2393	2223	2744	2243	2073
17	1723	1723	1561	1672	1552	1602	2153	1602	1372	1643	1522
18	2884	2754	1912	2754	2734	2553	1983		4847	3065	2314
19	1432	1232	1392	1392	1041	1322	1632	1092	1092		2113
20	2624	2613	2554	3364	2384	2394	2303	2433	2504	2274	2814

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 23	Training 24	Training 25	Training 26	Training 27	Training 28	Training 29	Training 30	Training 31	Training 32	Training 33
1	2033	1793	2423	1993	2033	2324	4796	1793	2073	2063	2263
2	1573	1402	1162	1722	1532	1242	1102	1362	1402	1643	1763
3	1642	1562	1953	2664	2464	1753	1562	1742	1803	1422	
4	1743	1443	1412	1512	1472	2043	1241	1893	1512		2433
5	2163	1162	1352	1212	2373	1081	1042	1332	1362	1091	1162
6	2544	2944	3184	2394	2274	2234	2594	2353	2283	2213	2003
7	1211	1202	1091	1713	2153	1492	1612	1272	1532	1432	1241
8	2384	1952	5959	2743	4717	1983	2664	2223	4577	5068	4146
9	3105	2043	1773	1442	1201	1492	1642	1562	2724	1442	1912
10	1933	3024	1763	1523	1613	1372	1693	1452	1923	1572	1322
11	2073	1862	2063	1782	1963	1752	1652	1843	1933	1622	1452
12	1453	1522	1392	1232	1161	971	1252	1241	1092	1281	1242
13	6499	2273	4717	1532	3134	4456	1412		1843	1732	3545
14		3936	1592	2513	2423	1683	2123	2023	4396	1993	1552
15	3134	3455	2664	2463	2283	2153	3345	1513	1633	1803	2053
16	3185	2233	2153	3094	3134	2794	2223	2183	2193	2243	2233
17	1261	1482	1482	1412	1482	1622	1402	1282	1322	1362	1442
18	2784	2594	2253	2473	2984	3765	1713	2304	1792	2143	2233
19	1302	1593	1612	1712	1242	1132	1442	1442	1613	1351	1282
20	2344	2424	2463	2303	2353	2193	2744	2493	2153	2233	2153

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 34	Training 35	Training 36	Training 37	Training 38	Training 39	Training 40	Training 41	Training 42	Training 43	Training 44
1	2123	2103	2273	2073	1873	1973	2073	2203	2083	1612	1352
2	1181	1282	1332	1282	1422	1252	1763	1502	1682	1481	1932
3	2634	2423	1482	2944	1852	1873		2954	1552	2393	1642
4	1312	1482	1442	1663	1602	1792	2854	1903	1352	1793	1553
5	1041	1202	1082	1001	1001	1252	2303	1011	1272	1011	1242
6	2824	2724	3035	2424	2313	2243	2704	2664	2674	2193	2203
7	1292	1061	1332	1352	1362	1042	1162	1212	1221	1492	1552
8	4977	3355	4376	4606		5949	4486	4807	5357	2514	4166
9	1352	1592	2033	2033	2454	1482	1552	1722	1242	2244	2163
10	3065	1281	1292	1242	1733	1171	1612	1813		3065	1412
11	1492	1522	1322	1692	1502	1412	1643	1562	1281	1492	1322
12		1282	932	1041	1131	932	1072		1211	1212	1051
13	1482	1532	1672	2874	1322	1282	1512	3265	3856	3615	4356
14	1842	1722	1512	2163	1482	1382	2352	1402	1612	1492	1671
15	1852	3405	2103	2043	3605	1853	2204	1843	1472	1983	1763
16	2333	2123	2353	2774	2383	2263	2243	2153	2483	2894	1792
17	1292	1322	1291	1402	1222	1281	1232	1251	1122	1261	1142
18	2984	1762	1752	1963	2744	1692	1742	2043	2353	1913	1683
19	1432	1282	1282	2263	1152	2344	1232	1152	1352	1352	1472
20	2173	2073	2033	2313	2073	2564	2234	2464	2113	2223	2154

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 45	Training 46	Training 47	Training 48	Training 49	Training 50	Training 51	Training 52	Training 53	Training 54	Training 55
1	1492	2153	1993	1372	2033	2504	1452	1362	2264	2304	1792
2	1402	1192	1301	1442	1602	981	1092	1442	1012	1292	1573
3	1372	1442	2704	1643	1443	1603	1723		2604	1532	2203
4	1743	1642	1512	1482	3324	1623	1513	1953	1512	1472	2183
5	932	1172	931	1001	1082	1041	1231	1472	1212	971	1081
6	2294	1853	2003	1762	1732	1883	1802	1963		4016	2554
7	1051	1082	1362	921	1432	1402	1322	1392	2133	1481	1352
8	7531	2744	3294	3535	6519	2754	4126	4486	3024	4126	3995
9	1903	2283	1392	1291	2514	1532	1282	1693	1332	1472	2163
10	1723	1452	1603	1923	4306	1562	2313	2754	2043	1763	1762
11	1312	1523	3085	2243	1692	1432	1442	1362	1372	1472	1402
12	1011	1162	1011	1001	1092	1162	1031	1162	1472	1162	891
13	1592	1352	2264	1683	1121	1853	1563	2474	1091	1522	1122
14	2373	3054	1863	1782	1362	1512	1672	1402	2113	1563	1452
15	1902	2033	1842	2153	2714	1552	1522	1432	1472	1913	1632
16	1883		3295	2723	2975	2103	2303	2023	2203	2003	2073
17	1161	1122	1252	1242	1281	1332	1482	1342	1402	1492	1322
18	1672	1752	1733	1993	1352	2533	1492	2744	2033	1603	1522
19	1272	1783	1782	1432	1913	1282	1362	1472	1542	1422	1593
20	2194	2113	2073	2033	2194	2113	1993	2253	2033	2123	2003

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 56	Training 57	Training 58	Training 59	Training 60	Training 61	Training 62	Training 63	Training 64	Training 65	Training 66
1	2403	1592	1713	1232	1372	1632	2083	2183	2083	1603	1362
2	1202	1041	1142	942	1382	1162	1572	1021	1092	1082	1191
3	1442	2513	2564	3024	1762	1722	2604	1722	1682	1643	1723
4	1392	1332	1482	1752	2143	1903	1412	2033	1632	2033	2744
5	1132	1081	1041	1082	1251	1432	1642	1002	1002	932	1161
6	2163	2153	1952	1843	1962	1893	1792	1963	2083	2083	1863
7	1231	1162	1011		1512	1282	1453	1452	1012	1052	1241
8	5007	3595	3545	2674	3485	2043			3636	3435	3896
9	2163	1412	1483	1442	1522	1212	1422	1242	2003	1402	1312
10	1172	1132	1181	1422	1722	1232	2393	1011	1402	2323	1092
11	1452	1563	1372	1492	1412	1402	1312	1372	1372	1252	1282
12	1051	1162	1732		1362	1171	1092	1081	1672	1011	1212
13	1252	1172	1372		1732	1140	1042	1132	1712	1212	1081
14	1953	2183	1371	2033	1542	1482	1893	1522	1583	1522	1453
15	2914	1442	1432	1752	1552	2433	1793	1762	2564	2203	1963
16	2223	2103	2043	2083	2334	2344	2123	2624	2754	2063	2043
17	1232	1142	1211	1282	1101	1142	1271	1162	1131		5038
18	1412	3936	1792	2123	1852	2804	1692	1953	1592	1893	1583
19	1402	1312	1031	1082	1823		1902	2303	1703	1472	1292
20	2063	2263	1892	2073	1923	2114	2073	1993	2153	2233	2073

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 67	Training 68	Training 69	Training 70	Training 71	Training 72	Transfer 1	Transfer 2	Transfer 3	Transfer 4	Transfer 5
1	1242	1592	1592	1352	1272	1202	1162	1071	2214	2754	2674
2	2163	1492	1152	1202	1372	1191	1092	1082	1402	1132	1122
3	1432	2634	1532	1612	1873	2244	2444		2844	2323	2113
4	3885	1432	1252	1983	1592	1813	1923	3815	1582	2324	2894
5	1062	1172	901		2544	931	2494	1522	1041	1242	1171
6	1803	1622	1813	2113	1843	2474	2944	2473	2133	2434	2253
7	1042	1051	1121	1122	1362	1042	2023	1362	1753	1672	1162
8	4747	2113		4647	2905	2494	3174	3615	1883	3425	2894
9	1132	1301	1682	1172		4537		1412	3855		2464
10	1493	1052	1622	1131		5739	1652	2564	2674	2604	1362
11	1322	1281	1753	1482	1372	1302	2704	1493	1933	1612	1462
12	1482	1131	1001	922		1131	2834	1092	1432	1482	1252
13	2433	1873	1752	1132	1142	1402	4106	1873	1953	3055	1392
14	1643	1292	2494	1442	2354	1442	1562	2003	2794	2113	1753
15	2113	1842	1682	1572	2774	1402		4286		4166	3645
16	2033	2503	1873	2093	2073	2364	3145	2754	2314	2343	2343
17	1453	1773	1562	1412	1382	1442	1843	2073	1693	1552	1803
18	2204	1452	1492	1452	1752	1282	2484	1432	2594	1923	1723
19	1642	1552	1442	1522	1091	1712	3836	1983	1563	1633	1602
20	2073	2003	1992	1993	2113	2103	1913	2314	2243	3145	2844

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 6	Transfer 7	Transfer 8	Transfer 9	Transfer 10	Transfer 11	Transfer 12	Transfer 13	Transfer 14	Transfer 15	Transfer 16
1	2163	2463	1492	2583	3105	1862	2544	2343	2414	2394	3084
2	2133	1802	1362	1091	1833	1342	1082	1092	1322	1703	1432
3	1492	1372	1923	1632	1792	1512	1522	1852		4285	2553
4	3024	1482	2013	4947	2454	1542	1652	3465	1432	2073	2173
5	1092		1282	1552	1402	1251	1873		2164	1882	1112
6	1853	1812	1843	1843	1832	2283	1933	2333	2003	2233	1993
7	1683	1853	1522	1281	1562	1352	1242	1312	1712	1212	1271
8	2633	2153	4416		7091	2904	5688	2744	3625	3825	2574
9	1953	1802	3155	2193	2293	1562	1673	1381	1673	1513	1512
10	1752	1332	3145	1612	1852	2003	1933	1372	2053	1492	4847
11	1612	1572	1963	1632	1933	1602	2313	5057	1673	1662	
12	1312	1532	1983	1021	1212	1882	1312	1162	931	1322	1552
13	1292	1913	2864	1372	1291		3826	3214	1472	1412	3235
14	1872	1643	1603	1592	1912	1572	1883	1813	1852	2383	1913
15	4517	5298	3645	2904	3665	2654	6259	3475	2233	2443	2153
16	2033	1953	2243	2323	2233	2343	2564	2233	3495	1873	2283
17	1753	1602	1462	1512	1642	1382	1513	1402	1672	1472	1372
18	1522	2313	1903		1412	1702	1682	2203	1853	2443	1352
19	1483	1432	1422	2023	2133	2133	1963	1432	1823	1592	2003
20	2534	3185	2153	4596	3255	2503	2253	2584	4807	3055	3255

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 17	Transfer 18	Transfer 19	Transfer 20	Transfer 21	Transfer 22	Transfer 23	Transfer 24	Transfer 25	Transfer 26	Transfer 27
1	1732	3125	1802	9244	2103	2944	2654	2924	2243	2303	1763
2	1823	1612	1843	1933	1062	1322	1382	1733	1823	1692	1813
3	1642	1953	1913	2674	4546	2804	1572	1442	4046	1732	1962
4	1873	1572	1472	1402	1522	1512	1953	1312	1442	2193	3565
5	1332	1082	1472	1052	1192	1091	1122	1122	1762	1272	1011
6	1953	2042	1913	2343	2364	1943	2163	1683	1913	2273	2023
7	1282	1292	1291	1162	1271	1843	1282	1412	1573	1432	1402
8		8242	2674	2864	2865	4036	4387	1913	3335	5078	7962
9	2033	2554	1693	2093	3666	2153	1482	2003	1692	1973	1322
10	1573	2073	5097	2484	1211	2193	1492	1372	3454	1572	2394
11	1562	2013	1482	1452	1723	1492	1762	2043	1732	1562	1452
12	1722	992			1482	961	1522	1552		1492	1713
13	1922	2233	3605	1251	1873	1252	1883	1202	1222	1282	1092
14	3104	3295	2113	1722	2103	2083	2503	2003	2774	3115	1802
15	2554	2243	3014	2574	3695	2644	2463	3303	1833	3385	3866
16	2974	2754	2273	2383	2934	2303	2123	2073	1832	2163	1983
17	1322	1833	2263	1472	1913	1602	1642	1522	1171	1493	1623
18	2033	1643	1793	2924	1442	1602	1722	1482	1611	1833	1672
19	1592	1552	1522	1252	1322	1633	2032	1202	1512	1722	
20	2393	2423	2223	2374	3885	2193	2273	2393	3966	2424	2314

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 28	Transfer 29	Transfer 30	Transfer 31	Transfer 32	Transfer 33	Transfer 34	Transfer 35	Transfer 36	Transfer 37	Transfer 38
1	1952	2854	2584	1823	2384	2003	1823	2364	1783	4617	1942
2	1532	1573	1723	1522	1362	1833	1563	1723	1372	1252	2043
3	3405	2553	3625	1882		1913	3575	2022	1783	1452	2353
4	1352	1312	3885	1693	1432	2234	1793	1592	1432	1272	1242
5	1513	1042	1212	1111	1122	1713	1603	1282	1092	1352	1562
6	2264	2023	2113	1772	1963	1792	1993	1833	1442	2083	
7	1282	1232	1402	1082	1252	1120	1442	1402	1362	1412	1312
8	3144	3255	7721	2563	2984	2934	3224	2514	3836	2623	3165
9	1773	1392	2053	1412	2273	1322	1322	1322	1442	2835	1232
10	1211	4216	2914	1332	3315	2623	1252	1922	1693	1352	1412
11	3395	1562	1612	1483	1553	1612	1502	1682	1612	1842	2864
12	1692	1492	1341	2243	1362	1322	1241		1392	1152	1452
13	1131	1953	1211	1102	1052	1192	1202	1732	1082	931	4126
14	3024	4096	2784	2193	2814	2062	1882	1853	1673	2493	1883
15	2824	2383	2393	2474	2434	2194	1913	2103	3165	2403	2283
16	2304	2263	2313	2244	1983	1753	2143	2012	1952	2264	1922
17	1402	1453	1512	1513	1713	2704	2103	2514	2073	1522	1402
18	1833	2033	2794	1712	1612	1632	2223	1713	2023	1322	1662
19	1312	1442	1392	1442	1282	2063	1241	1312	1232	2624	1392
20	3065	3415	2784	2354	2254	2153	1993	2043	1953	2233	2273

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 39	Transfer 40	Transfer 41	Transfer 42	Transfer 43	Transfer 44	Transfer 45	Transfer 46	Transfer 47	Transfer 48	Transfer 49
1	2103	1512	1833	2143	2734	2624	1392	2063	2143	2303	2394
2	1842	1612	2183	1372	1442	1623	1722	1642	2173	1682	1792
3	1543	2945	1793		1613	2073	1442	1532	1513	1412	1642
4	2063	2103	2154	1492		1763	1502	1773	1492	1372	1473
5	1202	1212	1161	1172		1201	1472	2143	1492	1322	1232
6	2714	2033	2353	1913	3595	2203	2303	1833	2524	1603	2083
7	1241	1231	1292	1121	1132	1332	1502	1091	1202	1292	1122
8	3365	2003	3846	1753	3004	2123	2033	6579	1723		3535
9		1202	1853	1212	1492	1572	1292		2303	2003	2073
10	1412	1201	1322	1132	1131	1212	1672	1182	1482	1792	6079
11	1933	3075	1782	2003	2604	1692	1802	1713	1802	1783	1842
12	1322	1172	1281	1112	1212	1122	1202	1272	1452	1652	1923
13		1282	2864	1432	1663	2264	1403	1212	2664	3205	6029
14	1833	1913	1793	3455	3095	4206	2584		2343	2784	1702
15	2113	1833	2514	2223	3405	2393	3295	2904	1763	2914	2744
16	2324	2033	2894	1973	2433	3184	2484	1843	2183	1953	2204
17	1212	1091	1522			5688	1683	5508	1832	1522	2093
18	2213	4797	3145	3546	1252	1362	1432	1833	1602	1442	1792
19	1442	2313	2433	1432	1553	1432	1703	1523	1352	1232	1673
20	2033	2113	2263	2113	2083	2073	2103	2273	2263	2554	2544

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 50	Transfer 51	Transfer 52	Transfer 53	Transfer 54	Transfer 55	Transfer 56	Transfer 57	Transfer 58	Transfer 59	Transfer 60
1	2194	1593	1553	1592	1953	1902	1472	2183	4837	2914	2384
2	1542	1462	1763	1493	1562	1692	2003	1392	1682	1362	2934
3	2033	1733	2113	1933	1492	2954	1483	1352	1692	3314	1653
4	1112	1602	1833	1191	1783	1723	1462	1553	2194	1553	1202
5	1372	1212	1091	1162	1733	1132	1081	2113	1152	1122	1041
6	2073	1682	1833	2324	1673	1833	2013	1803	1913	2183	1722
7	1252	1142	1763	1141	1052	1222	931	1242	1052	1332	1132
8	1983	2784	2674	6349	4476	2894	4977	3425	1522	3925	7030
9	1442	2674		6099	1883	1812	1683	1252	2133	1842	3225
10	1091	1592	1462	1131	1122	2123	6359	1292	1101	1693	1282
11	1813	1662	1402	1312	1382	1522	1432	1482	1643	1402	3084
12	1072	1332	1122	1262	1122	1272	1102	1282	1392	1171	1051
13	1031	1242	1482	991	1011	1201	1723	1022	2123	1563	932
14		2674	2153	2223	1612	1842	2073	3014	1913	2634	1793
15	1653	1983	3695	2173	1993	3254	1552	1592	1953	2244	2994
16	3615	1682	1803	1632	1712	1852	1963	1833	1792	1553	1893
17	1562	1321	1552	1712	1663	2093	1913	1632	1833	1592	2042
18	1622	1923	1522	1663	1553	1663	1882	2444	1643	1923	1952
19	1472	1633	1682	1412	1281		4036	1873	1802	1712	2503
20	2303	2163	2073	2394	2113	2173	1973	2113	2233	2033	1963

Blanks indicate incorrect responses

Appendix B

Condition 2 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 61	Transfer 62	Transfer 63	Transfer 64	Transfer 65	Transfer 66	Transfer 67	Transfer 68	Transfer 69	Transfer 70	Transfer 71	Transfer 72
1	1472	6229	2363	1953	3645	1553	1473	1512	1643	2504	1682	2734
2	1242	1412	1803	1722	1482	1452		1712	1642	1483	1372	1522
3	1852	1893	1492	2043	1532	1402	1682	1632	1242	1603	1312	2995
4	2313	1883	1172	1051	1292	1071	1352	2383	1332	1623	1523	1110
5	1332	1021	1091	1082	1171	961		1001	1282	1172	1092	1172
6	1833	2463	2023	1802	1993	1842	2073	1762	2003	2673	1633	1703
7	1001	1002	1131	1092	1042	1091	1122	1081	1121	1222	1151	1012
8	4607		7621	2664	3686	3054		5208	2804		9073	6139
9	1702	1993	1793	3635	3154	1953	1372	1282	2284	1352	2393	1482
10	1172	1012	1552	1051	1012	981	1762	971	3195	4096	1362	1102
11	1843	1773	1362	1583	1371	1693	1252	1402	1562	1372	1032	1170
12	1993	2874	1572	1402	1202	1412	1192	1242	1402			1382
13	1281	2193	1122	2073	1202	1111	2003	1392	2203	1242	1171	1091
14	1912	2614	2103	2163	1722	1682	1642	1833	1953	1942	1832	2283
15	1713	2233	2624	1913	2204	1392	1452	2083	2513	1883	2433	1943
16	2043	1993	1833	2073	1633	1612	1582	1883	2063	1913	2393	2043
17	1332	1322		1633	1573	1513	1432	1552	1632	1432	1332	2674
18		3115	2234	2224	3454	2043	1682	1312	2013	1843	1331	1683
19	1482	1943	1432	1431	1632	1512	1702	1522	1802	1883	1752	1823
20	2654	1923	1913	2003	2033	1963	2233	2073	2133	2154	2033	2434

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 1	Training 2	Training 3	Training 4	Training 5	Training 6	Training 7	Training 8	Training 9	Training 10	Training 11
1	3024	2193	2393	2594	2464	2533	2193	1963	3184	2674	2174
2	3895	2784	2514	3265	2634	2754	2684	7350	2073	3895	2374
3	2814	3806	3175	3535	2483	2043	2754	1953	1873	1832	2113
4		3135		4116	6379	2233	1803	1412	1763		3525
5	1643	1903		1722	1412	1632	2273	2073	1822	2614	2203
6	3996	2163	2784	1993	1872	1753	1432	1392	1452	2203	2163
7		6158	8592	3235	9423	2053	2753		2203	2474	2623
8	1712	1953	1993	1653		1952	1392	2193	1793	1352	1292
9	5518	3265		3385	2594	3536	2204	3065	2744	2574	3014
10	2554	1763	1532	1652	1412	1171	1092	1603	1252	1212	1212
11	3365	2754	2544	4737	4737	2233	2033	3024	1562	3615	1352
12	3895	4136	5277	2814	3855	3605	3084	2384	2154	3215	2353
13	7942	3224	5588	2954	5037	2864	3054	3164	2774	2824	2774
14	3064	3896	2364	2444	3064	3104	2674	2674	3045	2703	2053
15	3925	3685	2474	2744	2544	2643	2354	2224	2113		2825
16	2854	3184	2163	3074	2714	2593	1993	2824	4005	1763	1793
17		5818	4677	3685	3304	2263	2464	6760	2474	2554	1772
18	3125	2594	1873	2744	1963	1832		1772	2033	1712	1642
19	7664	2172	2407	1854	3517	4622	2013	2527	2486	3039	2527
20	3536	3856	3093	2393	3425	1953	4967	2594	3304	2624	3114

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 12	Training 13	Training 14	Training 15	Training 16	Training 17	Training 18	Training 19	Training 20	Training 21	Training 22
1	2544	3585	2273	2243	1963	1953	2113	2133	2474	2513	1953
2	2153	2243	2664	1963	3105	1792	3735	2664	2183	1772	3385
3	1802	2093	2153	2123	2754	2163	1703	1593	1913	1752	1713
4	2854	4035	1703	1402	2904	4016	2143	1633	1872	3074	1272
5	1802	2143		6029	4406	1572	1752	1913	1312	1152	1282
6	1582	1732	1192	1793	2473	1833	1331	1522	1252	1312	1753
7	5658	2484	2324		5257	2273	9574	3865	1813	2003	2283
8		1652	2273	1352		2574	1522	2874		1212	1322
9	2203	2233	2784	2103	2043	3475	2333	1873	1733	2343	2944
10	991	982	1092		1582	1252	1132	1131	1122	1081	1051
11	1563	1912	1713	1833	1081	1512	1923	3495	1462	2083	1712
12	2674	2072	2043	1652	2433	1492	1803	2144	2193	1793	1762
13	3735	2944	2664	2734	2914	3225	2204	3015	2764	4356	2674
14	2433	1833	1842	2043	2223	1842	2073	1602	1702	1602	1943
15	2083	2424	2033	2003	2183	2703	2514	2143	2424	1983	2103
16	1882	2073	1963	2033	2043	1883	2404	2573	2113	1652	1612
17	2664	2113	2033	2774	1953	4317	2424	2704	3405	2303	1923
18	1632	1713	1603	1883	1993	2123	1593	2314	1443	1633	1272
19	1936	1810	2130	2289	2485	2842	2645	2014	1774	2171	1816
20	3345	2904	1933	2253	3495	4717	2023	3615	2444	2794	2093

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 23	Training 24	Training 25	Training 26	Training 27	Training 28	Training 29	Training 30	Training 31	Training 32	Training 33
1	3054	1993	2073	1893	2964	1883	2644	3305	2013	5648	2624
2	1872	1793	1633	2194	2204	1563	2244	1713	1592	1732	2313
3	1593	2273	1682	1602	1782	1713	1743	1442	1832	1913	1773
4	1432	1352	3205	2473	1112	1983	2243	1312	2073	1242	1412
5	1362	1012	1012	1201	1322	1171	3265	1402	2534	1252	1803
6	1251	1603	1522	1282	1242	1312	1192	1161	1752	1442	1322
7	4355	1813	2244	1723	2674	2234	1953	2203	2594	2003	3375
8		1693	2154	1523	2864	1372	1202	1653	1532	1251	1212
9	1882	2003	2043	2073	2274	1793	2073	1903	1462	2774	1732
10	1362	931	971	1953	1472	1131	1372	2413	1132	1052	1492
11	1402	1602	1442	5558	1932	1923	1281	1522	1112	1542	2864
12	1803	1853	1432	1912	1883	2022	2113	1562	5838	3535	1773
13	2513	3065	3295	4396	4326	3174	2464	2854	2464	2744	2124
14	1802	1813	1793	1592	1752	1833	1842	1793	1993	1873	1483
15	2123	2033	2133	2083	2143	2163	1963	1952	1943	1942	2494
16		2193	1823	1402	2223	2083	2223	1412	2083	1963	1712
17	2403	2654	2704	1552	1682	3035	1843	1752	2103	1712	2484
18	1592	1693	1402	1312	2333	1212	2173	1412	1693	1052	1492
19	2131	1932	1497	2289	2129	2092	1772	1894	1576	3054	1759
20	3415	1872	1963	4126	1653	2985	2494	2584	2384	2623	2333

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 34	Training 35	Training 36	Training 37	Training 38	Training 39	Training 40	Training 41	Training 42	Training 43	Training 44
1	2424	2353	2163	1692	2233	2073	1832	1973	2914	3144	2113
2	1933	1792	1893	1472	1883	1532	2053	1693	1642	1392	1573
3	1682	1522	1412	1963	1482	1653	1613	1683	1762	1602	1482
4	1873	1673	1433	3185		4517	2063	1322	5358	2975	1953
5	1442	1972	1292	1953	1162	2233	1422	1632	1562	1442	1532
6	1352	1052	1422	1151	1272	1081	1762	1152	1291	2784	2213
7	1852		2584		2824	3195			1873		2123
8	1482	1322	1212	1201	1252	1141	1152	1252	1512		1443
9	2133	2994	1402	3455	1552	1492	1993	2584	1242	1722	2664
10		2133	1192	1251	1642	1292	1051	1012	1763	2243	1051
11	1563	1092	1973	1162	4767	2514	2123	1121	1482	1402	1131
12	1322	1883	2274	2704	2303	2484	2623	1512	1362	2513	1652
13	9694	2504	7000	10125	2964	2463	2313	3305	3155	2383	4196
14	1643	1553	1613	1542	1672	1963	1643	1703	1602	1602	1632
15	1992	1873	2073	1923	1953	2403	1953	1793	2113	1753	2033
16	2273	1532	1943	1352	1352	1332	1392	1322	1332	2003	1912
17	1943	2313	1923	2113	1983	1943	1552		2263	3685	1952
18	1292	1122	1563	1453	1332	1001	1122	1011	1121	1262	1432
19	1973	2128	1697	1654	2328	1895	2013	2389	2169	2131	2014
20	3055	2063	1913	1952	2754	2143	2784	1952	1953	2664	2143

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 45	Training 46	Training 47	Training 48	Training 49	Training 50	Training 51	Training 52	Training 53	Training 54	Training 55
1	2674	2003	1923	2002	2434	1683	2413	2013	4016	2323	1622
2	1933	2293	1893	1732	1442	1642	2233	2443	1682	1723	1493
3	1572	1332	1442	1472	1492	1522	1773	1743	1522	1442	1583
4	1272	1201	2664	2473	1392	1512	1812	1442	2824	1512	2934
5	1211	2033	1352	1402	1292	2564	1302	2624	1162	1081	1202
6	1282	1682	1872	1422	1272	1522	1231	1192	1171	1082	1473
7	3945	1853		2764	1883	1642	2694	3384	2163	3195	1813
8	1142	1231	1482	1883	1171	1332	2483	1492	1202	1563	1563
9	1522	1612	1492	1912	2354	1723	2103	2714	2574	3225	1722
10	1202	1282	1362	1212	1422	1112	1182	1092	1963	1402	
11	1132	1092	4406	1692	3245	2875	1412	1172	5588	1372	1723
12	1372	1402	1682	1302	1692	1452	2203	1002	1001	1041	1633
13	2433	2083	3144	2674	2233	2383	3725	2223	2704	3144	3375
14	1562	1362	1402	1523	1482	1402	1502	1292	1452	1352	1432
15	2073	1843	1752	1913	1913	1953	1902	1953	2383	1953	1963
16	1412	1322	2884	1632	2383	1392	1522	1412	1573	1603	1453
17	2384	2464	4676	2113	1793	2063	1983	2103	1992	1753	2364
18	1432	1563	1172	1462	1272	1122	1061	1252	1201	2444	1362
19	2130	2250	3397	2289	2621	2369	2093	2014	1656	1934	2170
20	1793	2343	2193	2914	1712	1712	1712	2484	1482	2113	1673

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 56	Training 57	Training 58	Training 59	Training 60	Training 61	Training 62	Training 63	Training 64	Training 65	Training 66
1	2043	2824	2133	1762	2433	1923	2543	1803	2083	2684	1953
2	1693	1482	2554	1893	1503	1643	2234	2204	1412	1803	2194
3	1682	1342	1452	1372	1602	1692	1482	1442	1482	1802	1482
4	1282	1923	1252	3115	2083	1332	1753	1492	1933		2974
5	1442	1832	961	871		2083	2073	1252	1002	1102	891
6	1883	1532	1362		2233	1232	2434	2363	1562	1242	1723
7	4657	4807	1813	1282	2474	1402	3355	1802	2924	2123	2393
8	1312	1062	2314	1332	1402		1632	1372	1392	1752	1312
9	3215	2424	2543	2053	2243	2193	2053	1843	2393	2714	1642
10	1051	2053	1231	1963	1312	2083	1492	1302	2914	1051	1332
11	1723	1412	2604	1452	4226	3164	1893	1382	1402	2053	1322
12	3405	2433	3295	2944	1842	1562	1683	1643	2003	2233	2113
13	5699	2424	2083	2504	1832	1793	2623	3745	3095	2033	2193
14	2423	1743	1733	1442	1562	1472	1502	1543	1683	1402	1803
15	2003	1712	1923	1793	1802	2193	1803	1833	2053	1923	1793
16	1412	1472	1312	1291	1472	1542	1332	1322	1593	1322	1512
17	5437	1813	1552	1361	1913	2363	3094	1793	2794	1993	3575
18	981	1182	1041	971	941	891	982	1112	881	921	1131
19	1914	2013	2091	3201	2250	1877	2567	1734	2014	2012	1814
20	2023	1653	1713	1642	2834	1713	1682	2123	1832	1953	2423

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Training 67	Training 68	Training 69	Training 70	Training 71	Training 72	Transfer 1	Transfer 2	Transfer 3	Transfer 4	Transfer 5
1	1923	3185	1913	2053	2363	2003	4146	2353	2113	3966	1923
2	1513	1372	1773	1793	1332	1563	1782	2383	1522	4226	1772
3	1392	1392	1522	1432	1412	1813	3064	2033	1913	1673	1673
4	1913	2384	1532	1331	2153	1642	2153	4096	1782		2894
5	1662	941	931	972	1052	1402	1172	1372	1132	1522	1362
6	1482	1172	1232	2224	1633	1622	1693	1632	4997	1572	1472
7	2043	3905	2313	1402	2083	3154	2964	2123	2874	1853	2754
8	1241	1232	1252		1442		1683	1773	1382	1672	1211
9	3515	2463	2784	2073	1952	2073	4226	2924	3064	2784	1642
10	2433	1682	1222	1412	1693	1452	2323	992	3315	1002	1532
11	1172	1292	1022	981	1832	2003	2523	1162	3345	1883	1792
12	1392	1922	2704	1712	1642	1633	2174	1903	1472	1342	2924
13	4006	2153	3275	3425	4867	2224	5558	2995	3255	3105	2754
14	1512	1632	1672	1542	1442	1562	2003	1842	1773	1883	1672
15	1763	2734	2003	1883	1923	1873	2193	2443	2384	2153	2193
16	1282	1452	1321	1913	1292	1563	1512	3646	3114	2073	1602
17	1842	1823	3685	1632	1772	1552	5318	3335	2985	1913	2894
18	1132	1712	1332	1092	1131	1062	942	1161	1011	1993	1312
19	2326	2645	2011	1934	2206	1991	3508	1970	2132	1577	1814
20	2193	1993	2194	1953	2153	1893	2483	5007	1702	2163	1793

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 6	Transfer 7	Transfer 8	Transfer 9	Transfer 10	Transfer 11	Transfer 12	Transfer 13	Transfer 14	Transfer 15	Transfer 16
1	2153	2203	2874	2744	1713	2314	2163	3455	1853	2113	2203
2	1522	1822	1453	1763	1823	1632	1572	1572	1512	1692	1362
3	1552	1492	1612	1713	1913	1843	1722	1603	2073	1713	1532
4	3565	3966	2153	3886	2554	3415	1753	1662	1702	1432	3104
5		1452	1251	2003	2003	2824	5208	1402	1713	1802	1412
6	2273	1452	3104	1392	1091	1282	1171	1202	1212	1593	1051
7	1693	2513	2043	2033	2644	2303	2634	1301		1532	2003
8	1672	1122	1322	1873	1202	1993	971	1061	1092	1181	2473
9	2313	1762	2694	2714	3224	3345		1452	3015	3345	2043
10	1322	1732			1833	1372	2133	1572		1893	3154
11	5087	1782	1172	2693	2354	2033	1132	1212	1612	1322	1532
12	2733	2233	2503	2083	1953	2284	2023	1833	5438	2794	1592
13	6890	3024	3505	2012	3175	3495	2664	2423	3255	5408	2464
14	1753	2153	1953	1712	1242	1602	1522	1412	2343	1593	1682
15	2464	1953	2153	2133	1993	2704	2284	2233	2193	2193	3655
16	1852	1813	1472		3345		1742	2995	2824		
17	2664	2273	2673	3525	4967	2343	1873	2533	1472	1562	3165
18	1212	1572	1512	1472	1281	1011	1843	1280	1292	1212	1272
19	3005	2288	1540	1501	2808	2171	1816	3318	2171	1538	1581
20	2423	9624	2343	2463	2874	2233	3255	5407	2624	2063	2053

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 17	Transfer 18	Transfer 19	Transfer 20	Transfer 21	Transfer 22	Transfer 23	Transfer 24	Transfer 25	Transfer 26	Transfer 27
1	3264	2213	2193	1833	2323	2433	2173	1963	2344	2063	2383
2	1632	2063	1512	1242	1291	1693	1613	1592	1372	1802	1733
3	1572	1682	1462	1682	1482	1472	1682	1752	1632	1673	1592
4	1352	1722	5898	1532	4136	3465	1682	1322	3254	1603	1432
5	1332	2904	1592	1312	2444	1362	1493	1232	1132	1172	1012
6	1362	1982	1362		1312	1492	1482	1833	1952	1072	1593
7	2374	1693	1812	2314	1321	1542	2833	2123	2203	2794	1632
8	1382	1150	1152	2433	1311		1322	1012	1052	1202	1292
9	2133	4126	1843	1732	3345	2194	1873	2344	2003	3385	1613
10	2363	2523	1573	4035	1371	1573	1693	1212	1212	1412	1683
11	1131	1682	3315	2153	1332	1512	991		3154	1853	1812
12	1913	2033	1803	4646	1993	1853	1612	1713	1663	1522	2023
13	2433	3405	2674	3094	2714	2824	4196	2273	2123	2073	2594
14	1763	1513	1593	1672	1913	1592	2033	1833	1632	2424	2113
15	2113	2144	2083	2153	2073	1793	2444	1642	1833	2073	2083
16		1683	3385	1602	1492	1412	2914	1402	1523	3805	1572
17	1652	3455	3646	1903	2483	1813	1612	1882	1712	2544	2554
18	1413	1172	1572	1672	1312	1011	1292	1022	981	971	881
19	1972	2092	2808	2072	1657	1579	1500	1501	2092	2210	1619
20	2083	1972	2043	1692	1692	1603	2164	2324	2344	1832	2623

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 28	Transfer 29	Transfer 30	Transfer 31	Transfer 32	Transfer 33	Transfer 34	Transfer 35	Transfer 36	Transfer 37	Transfer 38
1	1752	2204	1943	1863	1732	1953	1912	2474	1923	1952	2093
2	1563	1652	1923	2003	1653	1812	5398	1753	1492	3855	1592
3	1492	1442	2263	1973	1753	1442	1472	1432	1533	1993	1672
4	2394	2514	3304	2704	1402	2774	2103	1312	1712	1602	1793
5	931	961	1092	2423	1081	771	1072	982	1011	891	1752
6	1863	1212	1653	2223	1122	1673	1231	2033	1292	1572	1602
7	2764	3034	1882	2243	3305	1583	2354	1883	3585		
8	931	1122	1321	922	1262	2123	1873	1552	1022		1212
9	2233	1643	1902	2714	2113	3605	2564	3064	1643	1993	1922
10	1242	1211	1181	1953	2604	1292	1222	1842	1643	1913	1482
11	1682	1462	1753	1892	1452	1081	2363	1853	1201	1082	2083
12	4717	1532	1413	2153	3375	3254	1492	1372	2393	1612	2443
13	3646	2114	3175	2474	4216	2624	4366	3185	2744	8892	3185
14	1833	2063	1532	1622	1492	1913	1923	1492	1572	2003	1683
15	1583	3475	1983	1863	2955	3185	1733	2233		1792	2534
16	1272	1162	1362	1382		1953		1072	1332	1331	1923
17	1752	1883	1833	1392	2153	1993	1753	1912	4166	1733	1953
18	1963	1562	1122	1382	1202	1282	1552	1252	1242	1432	1280
19	1597	1282	1830	1857	1856	1973	5100	1620	1776	1398	1341
20	1873	1712	1652	3295	3455	1592	1923	1552	1953	2073	1432

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 39	Transfer 40	Transfer 41	Transfer 42	Transfer 43	Transfer 44	Transfer 45	Transfer 46	Transfer 47	Transfer 48	Transfer 49
1	1723	1683	3585	1652	2193	1762	1873	1953	2083	1922	2684
2	1873	1532	1752	2003	1352	1552	1582	1591	1913	1792	1332
3	1722	1402	1493	1533	1803	1522	1482	1422	1322	1763	1452
4	3405	1642	1642	5178	2733	2674	2113	1342		2143	1412
5	1853		1282	2904	1292	1012	1081	1242	1092	981	972
6	1272	1312	1913	1412	1512	2342	1332	1161	1673	2423	5257
7	1562	2433	1743	1992	2314	1643	3896		2043	1843	1842
8	1562	971	1092			2073	1162	1161	1602	1172	
9	2444	1953	2935	3876	1612	2163	1612	1452	1212	2834	2083
10	1653	1202	1522	1532	2273	1382	1192	1332	1532	1723	1413
11	3035	1242	1292	1692	2504	1402	1282	1202	1091	1692	1332
12	1913	1923	1412	1802	1652	1653	1412	2193	1612	1522	1792
13	2984	3375	3094	2714	2984	2433	2634	3024	2343	3025	3405
14	1552	1722	1492	1362	1603	1613	1392	1292	1772	1993	1842
15	2153	2544	2393	1803	1853	1803	1642	2173	1933	1633	1913
16	3505	1392	1532	2344	1593	1843	1653	1391	1472	1562	1311
17	1352	1873	1913	2494	2714	1632	1532	2473	1942	3365	1963
18	1492	1362	1282	1362	1222	1162	1412	1122	1362	1081	1252
19	1497	1261	1617	1977	1380	1695	1658	1459	2529	2369	2604
20	2073	1843	1512	1482	1482	1552	1533	1442	2223		4456

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 50	Transfer 51	Transfer 52	Transfer 53	Transfer 54	Transfer 55	Transfer 56	Transfer 57	Transfer 58	Transfer 59	Transfer 60
1	2654	2794	1682	2854	1792	1772	1953	1883	1833	1632	1883
2	1712	3695	2093	3274	2153	1673	1772	3034	3275	1553	1713
3	1362	1482	1322	1973	1493	1573	1563	1482	1402	1873	1372
4	4997	1682	2073	2915	1963	2073	1392	1292	1872	1602	1793
5	942	1041	1682	1082	1091		1402	1202	1051	1071	1242
6	1512	2143	2003	2744	3055	1412	1352	1722	2183	1282	1512
7	1773		1682	1923	2164		2003	1762	1302	2323	1452
8	932	861	861	1232	1052	1202	1171	1042	932	1031	1132
9	1482	2524	2784	1492	1702	3385	3385	1692	2243	3735	2474
10	1913	2934	1212	1683	1452	1252	1412	1612	1242	1633	1532
11	6038	1252	1642	1492	1172	2203	1092	1212	1492	1102	1201
12	1753	1382	2103	1492	1432	1612	1873	2234	1281	1752	2103
13	2083	2314	2143	3335	4256	2624	2714	1993	2434	2984	3815
14	1492	1482	1282	1602	1572	1772	1592	1642	1682	1803	1632
15	1772	1773	1922	1753	1683	2032	3215	2033	1763	1803	2544
16	1372	1412	3024	1882	3265	2083	1563	1852	1212	1292	1332
17	1322	2153	1903	2584	1772	1743	2103	1673	2244	1883	1923
18	1432	1212	1412	1472	1172	1332	1292	1101	951	1002	1332
19	2173	1498	1660	1815	1577	1896	1719	1617	1617	1777	1595
20	2584	2203	1793	1953	1633	1593	1563	1642	1722	3545	1582

Blanks indicate incorrect responses

Appendix C

Condition 3 Training and Transfer Phases Test Task Problem Data (ms)

Participant	Transfer 61	Transfer 62	Transfer 63	Transfer 64	Transfer 65	Transfer 66	Transfer 67	Transfer 68	Transfer 69	Transfer 70	Transfer 71	Transfer 72
1	1782	2344	1753	1632	1953	1762	1973	3194	1873	1883	1803	1753
2	2985	1562	5078	4005	1572	1412	3855	2083		6159	2344	2033
3	1321	1603	1362	1483	1322	1241	1422	1482	1873	1843	1262	1402
4	1422	1372	3695	2542	2344	1402	4186	1562	2033	1652	3225	1963
5	1442	1362	1722	1122			1352	1472	1131	1011	1172	1252
6	2343	1372	1282	1201	1442	1442	1442	1282	2073	1803	1802	2144
7	1602		1532	1362	2083	1402	1292		1672	2193	2123	
8	881		962		1212		1272	1292	972	932	1221	961
9	1442	5488	2353	1482	1953	1963	2874	2203	1442	1522		2003
10	1852	1423		1302	1392	2323	2404	2003	1412	3746	1392	2644
11	1132	1492	1151	1202	1061	1282	1211	1402	1282	1131	931	1282
12	2994	1913	2073	1492	1652	1653	1412	1282	1432	1252	1252	1372
13	2083	2714	1803	4026	2153	2344	1872	2784	2043	3885	2073	2473
14	1592	1312	1673	1813	1842	1753	1672	1552	1392	1472	1362	1361
15	1802	3455	1663	2083	1953	2043	1963	2975		3184	1923	2344
16	1082	2053	2935	1202	1632	2343	1712	1162			1242	1903
17	2143	2073	1963	1953	1833	1763	2223	2514	2303	1983	1613	1793
18	1302	1242	1091	1792	1241	1372	1252	1372	1292	1181	1172	1202
19	2510	1856	2765	1659	1618	2605	2056	1680	1659	2727	2746	1618
20	1412	1192	2954	6320	2263	1402	1392	1832	2504	1683	1813	1633

Blanks indicate incorrect responses

Appendix D

Condition 1 Distractor Task Problems Data (ms)

Participant	Transfer 1	Transfer 2	Transfer 3	Transfer 4	Transfer 5	Transfer 6	Transfer 7	Transfer 8	Transfer 9	Transfer 10	Transfer 11
1	2584	3114	3375	1482	1702	3816	1963	5518	2523	1472	2244
2	1322	1573	1232	1292	1201	1312	1152	1172	1201	1362	1152
3	7641	1372	2193	3936	2754	4577	1231	1953	1492	1052	2403
4	8773	4236	5007	3385	1923	2834	1713	2073	1932	1963	3855
5	3175	1762	2023	1873	2353	1432	1632	1882	2694	1562	2513
6	4907	2724	2995	2083	1623	1652	2714	2504	2083	1553	2184
7	1242	1292	1442	1592	1993	1632	1683	1332	1552	1473	1392
8	4817	1673	1722	1171	2394	1122	2433	1021	1612		1321
9		1472		1752	1161	3495	1172	1241	1763	1843	1652
10	1692	1512	1482	1462		1583		1723	2694	1643	1573
11	2303	2123	2544	1973	1762	1763	1762	1722	2063	1722	1853
12	3825	3094	1793	2213	2033	2053		1993		4166	1753
13	2624	1512	1131	1472	1121	1282	1482	1642	1252	1432	1172
14	2503	1983	2463	2624	1813	2714	2584	2824	2464	1832	2514
15	1132	1532	1242	1292	1412	1332	2704	1523	1411	1162	1141
16	2304	6299	2484	2123	1812	2093	3975		11627	3145	1753
17	1472	2183	1732	2103	1892	1582	1752	1593	1942	2684	1683
18	2303	1833	2463	3535	2554	2513	1492	1722	1903	3505	1993
19	2664	2884	2253	3044	2153	1873	2153	1843	2664	1922	1912
20	1642	1392	3485	2043	2544	1522	1883	1872	1712	1883	1892

Blanks indicate incorrect responses

Appendix D

Condition 1 Distractor Task Problems Data (ms)

Participant	Transfer 12	Transfer 13	Transfer 14	Transfer 15	Transfer 16	Transfer 17	Transfer 18	Transfer 19	Transfer 20	Transfer 21	Transfer 22
1	1943	2364	1602	1912		1943	4847	1432	2243	4536	5588
2	1322	1182	1402	1201	1192	1191	1202	1282	1172	1322	1122
3	1011			2123	2394	2203	1081	1502	3856	2384	1322
4	1682	1572	5528	1583	2032	2784	1563	1372	2394	4807	1512
5	2934	1432	1432	1913	1532	2864	1742	1492	1983	1473	1352
6	1843	1612	1542	2283	1793	1682	1301	1632	1923	2233	1953
7	1562	1302	1583	1352	1472	1282	1893	1252	1593	1362	1462
8	1131	1362	1021	3385	1052	1281	1292	3065	1703	1402	691
9	1773	1802		1872	1472	3355	2194	2915	3125	1282	1202
10	1473	2564	1722	1522	972	1282	1532		1713	1051	1222
11	1762	2834	2554	2263	1642	1442	2073	1563	1482	1562	2804
12	2664		5087				1993	2984		2274	1262
13	1282	1572	1933	1292	1272	1553		1362	1171	1202	1241
14	2153	1802	3535	1963	1712	1773	1803	3805	1442	1482	2003
15	1322	1122	1402	1122	1292	1102	1162	1512	1602	1132	1161
16	1922	4136	2313	2123	7500	2984	5909	6379	2274	2304	3145
17	2524	1792	1883	2384	2033	1462	1733	1803	1522	1432	1752
18	2884	2583	1873	3335	2694	1773	2554	2844	1592	2383	2353
19	4176	2584	1693	2153	1653	1902	1572	2663	1993	2463	1933
20	3425	1883	1713	3154	2354	1922	3995	2534	1833	1763	2123

Blanks indicate incorrect responses

Appendix D

Condition 1 Distractor Task Problems Data (ms)

Participant	Transfer 23	Transfer 24	Transfer 25	Transfer 26	Transfer 27	Transfer 28	Transfer 29	Transfer 30	Transfer 31	Transfer 32	Transfer 33
1	3886	3645	1802	3265	2003	1372	1613	2794	3685	2423	1432
2	1162	1252	1092	1392	1172	1242	1122	1192	1021	1342	1202
3	1833	4617	1172	2123	1002	1331	2273	2464	1762	1552	1842
4	1432	1873	2143	3215	1713		1992	1752	3145	5839	5879
5	1913	1803	1412	1241	1252	2003	1282	1833	1473	1402	2644
6	1692	1292	2314	1292	1623	1502	2904	2975	1492	1743	2444
7	1212	2944	1092	2033	1592	1442	1352	1272	1633	2063	1302
8	891	1533	1553	922	1012	1011	1502	841	1082	1632	1132
9		3134		2864	4497	1082	2023	2033	1021	2003	
10	1252	1532		1332		1913	1212	1692	1361	1683	1893
11	1773	1642	1402	2714	1562	1483	1513	1562	1422	1493	1422
12		2634	3776	2113	2204	2153		1603		1883	1722
13	1442	1252	1321	1171	1152	1211	2874	1321	2554	1092	2113
14	2344	1562	3625	6149	2274	1773	1602	2233	2824	1883	1482
15	1712	1172	3345	1573	2073	1192	1762	1522	1412	1141	1322
16		2203	2544	2714	4806	2253	2053	1853	2354	5258	2934
17	1642	1833	1722	1562	1793	1873	1251	1593	1643	1362	2643
18	2283	2123	2544	1452	1723	1763	2143	2373	1643	2153	2153
19	1743	2503	3215	1913	1682	1512	1842	1793	1642	2183	2234
20	2584	1753	2383	3034	1723	1852	3996	2113	1672	2163	1452

Blanks indicate incorrect responses

Appendix D

Condition 1 Distractor Task Problems Data (ms)

Participant	Transfer 34	Transfer 35	Transfer 36	Transfer 37	Transfer 38	Transfer 39	Transfer 40	Transfer 41	Transfer 42	Transfer 43	Transfer 44
1	1272	2193	1332	1533	4246	1512	2794	2133	5548	4687	5468
2	1041	921	1222	1202	1162	1091	1202	1722	1252	1242	961
3	7531	1322	5518	4106	1532	2153	2925	3906	2043	941	1222
4	1993	2885	3545	2193	5478	3064	2013	11096	3495	3144	5398
5	1612	1903	1272	1512	1522	1752	1472	1482	1523	1252	1312
6	1712	1723	1512	1953	1672	2363	1442	2003	1993	1762	1282
7	2394	1311	1813	1052	1171	1052	1703	1162	1202	1172	1242
8		2854	1122	1112	1442	1642	1601	1011	931		1492
9	1842	2043			1652	2524	2434			2444	1772
10	1462	1482	1412	1482	1211	1261	1172	2253		1733	1772
11	1362	1442	1442	1412	1642	1522	1482	1532	1642	1482	1322
12	3145	2244	2854			2123	2263	2704		2834	2123
13	1482	1362	1052	1252		1452	1602	1122		1983	2714
14	1752	1422	1893	2414	1552	2483	1562	1433	4637	4417	2914
15	2854	2003	3044	1352	1212	1271	891	1012	892	962	961
16	2083	2594	2313	2283	3065	1953	5157	2393	2824	2604	3334
17	2934	2854	1883	1893	1963	3104	1633	1482	1682	1832	1633
18	1793	2264	2253	1813	1512	3955	1632	1492	3335	3094	2113
19	1672	1752	2704	1953	1752	1802	1953	2444	1733	2523	2263
20	1642	3145	2013	1803	2434	1392	2404	1362	1843	1472	2023

Blanks indicate incorrect responses

Appendix D

Condition 1 Distractor Task Problems Data (ms)

Participant	Transfer 45	Transfer 46	Transfer 47	Transfer 48	Transfer 49	Transfer 50	Transfer 51	Transfer 52	Transfer 53	Transfer 54	Transfer 55
1	2664	1432	2394	3866	3255	1993	4016	2183	1642	2043	3886
2	961	1032	1432	1122	1122	1182	1452	2033	1362	1212	1552
3	2684	1632	1171	1402	1042	1522	1251	1292	1652	2865	1282
4		6069	1332	2002	1292	1913	3715	2032	1412	2553	17876
5	1352	1752	2373	1282	1412	1152	1472	1793	1913	1753	1882
6	1873	1342	1712	2734	1492	1723	1763	2624	1662	3826	1953
7	1642	1292	1352	1242	1172	1051	1042	1912	1112	1241	1202
8	1241	1602	771	891	921	1011	1933	1061	2203	1643	892
9	1843	1392	1603	2464	1692	1792	2544		1993		2784
10	1783	1322	1322	1061	1082	1322	1021	1202	922	1242	1040
11	1462	1372	1362	1322	1372	1281	1302	1762	2233	1452	1763
12	2304	2664	2694	1673				1913	1653	1673	
13	1332	1482	2353	1272	1483	1132	1212	1252	1252	1162	2373
14	2964	2173	2614	1382	1632	2644	3215	2032	1442	2644	3214
15	1763	2324	1352	2193	1252	1092	1162	1191	1702	1803	2073
16	1783	3825	3595	9374		3465	3655	3465	1712	1913	4727
17	1873	1673	2794	1692	1603	2234	2153	2383	1732	1553	1652
18	3024	4877	2153	1993	3044	2744	1923	1953	1773	2353	2624
19	1833	2133	1833	1793	1892	1912	2764	1572	2083	2214	1452
20	1322	1482	1633	1512	1902	1613	1192	3645	4827	1372	3095

Blanks indicate incorrect responses

Appendix D

Condition 1 Distractor Task Problems Data (ms)

Participant	Transfer 56	Transfer 57	Transfer 58	Transfer 59	Transfer 60	Transfer 61	Transfer 62	Transfer 63	Transfer 64	Transfer 65	Transfer 66
1	1392	1572	1202	2243	4035	2464	1913	4417	2824	3796	2154
2	1242	1161	1242	1122	1071	1162	1713	1241	1593	1081	1172
3	3435	2043	1723	1081	1633	6430	3385	4176	1592	1132	3505
4	2273	3555	5197	1883	1492	1553	2394	2244	1533	1553	3265
5	1482	1272	2263	1482	1492	1482	1271		1633	2434	1422
6	2684	1602	2874	2363	1662	1362	2073	3585	2674	1552	1542
7	1613	1182	1732	1292	1132	1532	1402	1212	1362	1092	1001
8	1242	1091	1052	932	1242	1052	1242	1001	1472	961	1282
9	2594	1712	1692	1622	4055	4397	1753		2543	1773	
10	931	1302	1212	1332	1813		1733		1443	1092	1483
11	1332	1322	1322	1482	1422	1142	1322	1322	1302	1442	1172
12	1572	1793	1883		1603	1612	1842		1242	1372	2374
13	1462	1402	1121		1602	1241	1432	1803	1312	1142	1041
14	1763	1473	2243	2474	3114	2473	2624	2233	1893	1733	1653
15	1512	1042	971	1201	1683	1091	1522	1081	1723		2123
16	1833	1492	2733	2273	2573	1402	2484	2153	4156	5388	
17	1993	1722	3034	1533	2043	1212	2153	1762	1673	2504	1872
18	2664	1903	2113	2243	1832	1692	1772	2073	2484	1792	1592
19	1943	1832	2504	1673	1923	1662	1372	1492	1792	2624	1953
20	1562	4557	1593	2343	2814	1412	6830	2494	3846	1592	2513

Blanks indicate incorrect responses

Appendix D

Condition 1 Distractor Task Problems Data (ms)

Participant	Transfer 67	Transfer 68	Transfer 69	Transfer 70	Transfer 71	Transfer 72
1	3926	3335	1643	1833	3184	4667
2	1482	1191	1282	1362	2343	1282
3	2384	4697	4126	1392	4487	
4	1472	2694	1732	2754	12778	1442
5	1672	1722	1592	1963	1412	1472
6	1482	1693	2073	1613	1522	2433
7	1833	1041	1652	1282	1142	1041
8	1062	852	1442	791	1132	2143
9	3024	4447	1352	1723		4406
10	1282	1241	962	1322	1602	2003
11	1341	1242	1983	1332	1322	1483
12			1552	1763	2193	
13	1132	1161	1442	1533	1362	2032
14	2153	1522	1582	2073	2052	1092
15	1762	1452	3455	1442	1372	1132
16	4837	2303	2433	1913	1853	1712
17	1712	1843	1332	2053	1753	1803
18	1983	1722	1712	1842	1903	2003
19	1883	3445	2073	1752	2624	1523
20	3505	1442	2754	1212	1502	1642

Blanks indicate incorrect responses

Appendix E

Condition 2 Distractor Task Problems Data (ms)

Participant	Transfer 1	Transfer 2	Transfer 3	Transfer 4	Transfer 5	Transfer 6	Transfer 7	Transfer 8	Transfer 9	Transfer 10	Transfer 11
1	7000	4987	5228	1993	1942	2313	5638	7841	3575	4356	5909
2	3155	3035	3184	4977	2203	2874	1292	4386	4937	2734	2834
3	4466	4276	5598	4447		8412		4777	3505	3414	3475
4		2393	4196	2393	2984	4076	3085	3405	2493	2033	2073
5	3134	4126	1242	1712	1913	2553	1833	2103		2594	
6	3585	2473	3755	3906	3104	6579	3255	4316	3184	2834	4666
7		2504	2634	2584	1652	2353	3735	2073	2804	2113	2544
8		7861		5328	11096	9874	3856	6460	8753	5268	3655
9	7321	4537	4967	3155		10395	2032	2324	3625	4016	2233
10		1853	2243	10004	2394	8773	7791	2203		9914	
11	7390	4256	2884	2834	4887	2163	6239	2905	7812		5168
12	3024	1592	1482	2033	1753	2423		2233	2554	2633	2704
13	8091	2713	1923	1802		6460	2393	4096	2183	3315	4256
14	3926	4636	3034	3295	3886	2604	3374		5237	2273	2253
15	9894	7631	4857	3725	2704	4797	4125	4196	6580	4116	5268
16	6018	5008	4286	8072	6270	5518	8182	3975	2694	4166	5508
17	5868	3174	3034	2383	2794	3314	2884	2473	2354	2784	2884
18	4677	5168	2174	2925	4716	2984	2744	10195	4356	5999	5107
19	6179	5729		3055	2573	2814	5758	3996	3495	5608	3755
20	8161	3415	11617	9494	6149	3064	3285	3765	4476	4667	5999

Blanks indicate incorrect responses

Appendix E

Condition 2 Distractor Task Problems Data (ms)

Participant	Transfer 12	Transfer 13	Transfer 14	Transfer 15	Transfer 16	Transfer 17	Transfer 18	Transfer 19	Transfer 20	Transfer 21	Transfer 22
1	12608	4316	4637	5068	3925	2424	3656	4727	2944	5738	
2	2834	2393	3144	5979	2874	2994	3194	2273	2824	3005	1922
3	5007	4767	8101	4106		4025	10385		6640	11156	5468
4	3926	2473		3104	2584	1953	2113	1472	1913	2043	2984
5	2343	2794	2384	2343	3254	2143	1613				3885
6	3686	5318	4296	4716	2614	2634	6069	3465	3395	5388	7260
7	1833	2623	4256	2584	2123	3265	3215	4816	2073	1632	5267
8	8493	6850		4406	4757	5437	6930	2874	3495	3215	6700
9	2784	1893	4467	2824	5438	2944	2564	2193	2113	3225	1933
10	3264	8422	8723			4806	3936	7000	8152		7340
11	3946	3705	4096	6760	4176	5048	5368	5788	2824	2714	3235
12		1752	2424	2163				1593	1322		
13	1763		6580	1782	5058		5638	2113		8763	3575
14	3866	4527	2854	4316	4286	4206		5358	4877	4717	6940
15	7751		10606	5208	7010	4246	4426	8632	5398	3695	4286
16	11907	5628	9653	3215	7440	5148	4837	7049	3335	8272	
17	4015	2394	2304	2133	2474	2975	2354	2204	3585	3115	2013
18	2664	4727	7321	2303	4166	1843	4096	10775	3395	5237	2183
19	3985	2494	3945	3165	2394	3606	2574	3896	2464	3525	4387
20	3706	5508	3225	3966	4466	5078	3535	3575	3605	4276	3895

Blanks indicate incorrect responses

Appendix E

Condition 2 Distractor Task Problems Data (ms)

Participant	Transfer 23	Transfer 24	Transfer 25	Transfer 26	Transfer 27	Transfer 28	Transfer 29	Transfer 30	Transfer 31	Transfer 32	Transfer 33
1	6970	8632	3896	3825	3135	2493	3145	3926	6068	4336	1872
2	2804	2895		2964	2834	1883	2043	2413	1842	2955	2864
3	2965	2825	6149		4566		4767		6179		6119
4	3365	2013	1953	2113		2383	3886	1923	3124	2504	3345
5		2774		1553		2183	2654	2744	2854	1221	2554
6	2954	3545	3225	2554	4807	3775	3775	2754	3535	6700	2824
7		2033	1642	5097	2083	3015	8933	3656	2474	2523	1252
8	4426		5278	3925	2854	2454	4807		2363	4977	3925
9	1602	4957	4506	3385	1652	5407	2384	1361	2233	2043	3364
10	2944	2634	2073	1962	3225	2073				7430	1813
11	6840	4186	5608	2673	4566	2604	3985	2784	5858	3084	2674
12		1753	2784				2424				
13	2944	5017	3415	5268	2623	4016	2714	3335		4006	2504
14	7611	3375	2744	5869	3586	6539	5518	2684	4887	2463	2273
15	8923		6460	3365	2914	5438	10455	6259	4927	5237	4556
16	8151	5287	6850	4586	3565	4236	7931	5278	9694	3975	3986
17	2905	2824	3064		2944			2444	1993	2033	3495
18	6599	2784	8722	2584	4646	3726	1953	2433	3425	2033	3034
19	2784	4877	4376	3995	4887	2814	1922	2574	3886	3525	2303
20	3105	3685	3345	5307	3335	3344	3014	3325	3625	3775	4757

Blanks indicate incorrect responses

Appendix E

Condition 2 Distractor Task Problems Data (ms)

Participant	Transfer 34	Transfer 35	Transfer 36	Transfer 37	Transfer 38	Transfer 39	Transfer 40	Transfer 41	Transfer 42	Transfer 43	Transfer 44
1	6770	4526	7951	8352	4496	5068	5578	2533	5007	10525	3325
2	2434	1963	2153	2684	4466	3746	2364	4426	3545	2323	2794
3	11166	8502	10986	4266	5658	3225	4807		1653	2523	8402
4	1362	2343	2303	2834	5167	1832	1953	2233			2904
5	2984		4156		2904	4836	2714	3175	4477	2914	3465
6	3305	4847	2694	3775	5138	2754	5077	3103	3455	3976	2473
7	2073	4637	6619	3084	2183	2043	4026	2974	3906	3735	3184
8			5558	2464	3495		6109	5729	6940	3545	6159
9	4296	3505	3655	2233	4016	1792	2123	2794	1883	1643	6169
10	4426					9523	7871	7230	4697		11907
11	3665	5247	4627	5168	4116	1833	3184	2594	2833	3004	1953
12	2383			1943		1683	2043		2073	2614	1833
13	2955	3495	2704	2203	3255	7811		4367	5128	10255	3615
14	2744	2624	4677	5388	3025	3335	1952	2845	3716	6340	4447
15	3055	4065	5277		3855	3174	6760	5868	4636	3365	2974
16	7010	5228	3385	4607	8442	6569	4296	4957	5949	5158	3896
17	2233	3094	4126	3265	2514	1952	3065	2384	1993	3926	2113
18		5378	5979	2724	2193	2283	4837	2493	4406	2704	1962
19	2794	2574	2663	2033	1823	2213	2544	2774	3765	2774	2944
20	3975	3254	5528	4557	2484	3465	2274	5028	2884	3214	2744

Blanks indicate incorrect responses

Appendix E

Condition 2 Distractor Task Problems Data (ms)

Participant	Transfer 45	Transfer 46	Transfer 47	Transfer 48	Transfer 49	Transfer 50	Transfer 51	Transfer 52	Transfer 53	Transfer 54	Transfer 55
1	3284	10054	4287	4276	3405	5798	2714	6970	3054	3875	1763
2	2904	2233	2193	2403	3115	3435	1993	2493		2513	3736
3	7421	4606	17866	3515	18907	3195	8452	4567	4907	11977	5077
4	3455	2063	3465	3455	2433	3775	4236	4466	3325	3425	4957
5				4627	3815	3626	3776	3845	4196	5387	3535
6	3295	4256	6069	1682	4667	2433	3655	2554	3334	3495	4576
7	1933	4907	4637	2904	2744	3344	2664	1893	2583	2624	1412
8	4046	2764	6930	4085	3435	4436	2774	3795	4596	8012	6209
9	2243	2313	2113	4657	2233	2254	2744	3305	2684	3706	2233
10		3705	5658	8142		3665		2965	2193	4887	
11	2914	5217	4336	3184	7361	3515	3125	4016	2914	3164	2634
12	2183	2194	2143	2193	3304	1572	2304	2313	1672		2143
13	2994	2784	2304	2304			2553	6239	2784	2473	6029
14	3325	3545	4947	8663	3335	7090	2994	5989	3816	7521	8792
15	3966	4477	3955	5147	3855	5067	3064	4607	2283		6380
16	9223	4877	7441	4617	4126	7520	2654	3965	3545	10996	3715
17	3255	2153	4046	2343	2193	2033	3345	2083	2995	3285	1913
18	6530	3265	4366	2704	3344	2794	1712		3325	2384	7991
19	2534	3024	2223	2534	2364	2684	4507	2804	2854	2373	2373
20	3765	4105	4095	5498	2544	2264	3846	3965	3555	4136	3254

Blanks indicate incorrect responses

Appendix E

Condition 2 Distractor Task Problems Data (ms)

Participant	Transfer 56	Transfer 57	Transfer 58	Transfer 59	Transfer 60	Transfer 61	Transfer 62	Transfer 63	Transfer 64	Transfer 65	Transfer 66
1	3606	3936	4476	2993	1722	2514	4367	3586	4356		4407
2	1933	4066	2794	4696	4026	2664	2774	2363	3425	3074	4136
3	11206	8021	11657	4306		5238	4968	3786	5528	3625	4026
4	1972	2884	2213	3806	2744	1943	2062	2854	2194	1903	2072
5				2233	7161	1713	2303	3595			2354
6	2323	3495	3254	4446	3785	2594	2974	4426	4366	7841	2093
7	3856	1912	2634	1752	1603	5138	1562	4186	4407	3215	2744
8	5318	4476	4877	2032	2904		4055	3215	6830	5317	3956
9		4056	2444	3395	2494	4136	2473	3605	2834	3425	2033
10	7871	7331	4266	5808	7841	3165	8462			3465	
11	3665	6409	2393	3264	3515	2924	3825	5168	3995	3635	3545
12		1332	1712	1792		2464		1723	2945	1542	2423
13	8782	2624	1512	10225		10084		3004	2003	4206	3806
14	5989	4387	2393	2433	4637	3976	2403	3335	2433	4046	3265
15	3375	3084	4917	5007	5558	4116	5207	4146	4576	2754	3846
16	5988	7490	3495	5899	10646	3465	3565	3445	8352	2623	4836
17	2274	2043	2474	2013	1953	2323	1932	1813	3535		3265
18	3284	3035	2974	2393		7120	2233	4336	2373	2534	2824
19	2103	2774	2293	3085	2884	2193	2614	2884	2584	3194	2664
20	3525	3135	3805	2463	3265	3475	4096	3545	2424	3405	4677

Blanks indicate incorrect responses

Appendix E

Condition 2 Distractor Task Problems Data (ms)

Participant	Transfer 67	Transfer 68	Transfer 69	Transfer 70	Transfer 71	Transfer 72
1	3094	10135	3655	4987	4556	3565
2	2634	3275	2704	2593	3063	3215
3	6469	5888	3976		8852	
4		4006	2043	2183	2584	2103
5	3254	2975	6339	7430	1993	2263
6	6439	3525	3335	3455	3254	3455
7	3625	2604	2523	2634	4086	3034
8	4106	5939	5247	4807	4606	5438
9	2784	3675	2333	2554	2133	1953
10	7861	6990			6119	2393
11	2313	3355	2784	4426	2564	3505
12	1642		1913		2373	3114
13	3094	6689	3585	1682	2003	8312
14	2273	3826	3144	7531	2874	5117
15	3976	3966	2834	5278	3465	10595
16	7331	8793	5388	3546	8362	6769
17	1853	1722	2273	4316	2043	1953
18	3255	4477	3254	3785	1723	3546
19	2804	2734	2243	2643	3125	2453
20	3805	3645	2864	2985	2394	5317

Blanks indicate incorrect responses

Appendix F

Condition 3 Distractor Task Problems Data (ms)

Participant	Transfer 1	Transfer 2	Transfer 3	Transfer 4	Transfer 5	Transfer 6	Transfer 7	Transfer 8	Transfer 9	Transfer 10	Transfer 11
1	17285	3705		8282	8252	7701	7390	14981	2273	2864	15973
2	5458	2353	5598	3385	3335	1853	14281	3545	3065	1962	3746
3	3145	3495	4337	3826	2694	3025	4096		3485		5658
4		14481	10014	15462	14200	7331		7752	14752	10004	
5		5317	8642	12247	11607	4686		6699		10545	5989
6	3645	2464						3275		8192	
7	9424	7842	3796			3705	5759		3384	3595	5378
8	5618	4056	2583		3335		3575		2464		2063
9				10225			14391	3495		15903	9604
10	4887	3465		3926	3064	1812	3535	4597		7271	1883
11	10244	8883	2864		11407	10665	3385	3695	11386	4957	7491
12		17665	17776	1612		11396	9464	20720	8653		6590
13		8742	12588	8312	13570	10965	9574	7481	26668	12768	6579
14	6069	4287	4797	7200	5829	2815	5558	7090	2784	6119	4787
15		5508		12498	7371	8282	8392	4567	6670	7651	9414
16	6199	5168		2464	6920	4366	3495	2354			6269
17	11947	5307	8342	7440	16043	14741	9874		17545	19909	8573
18		4166	6619	5158	5028		7991	4166	3765	7050	5568
19	24568		12142	13763	10005	29675		12142	11034	7035	8109
20	19258	8312	7521		15082	10015	11957	2744	10826	6500	

Blanks indicate incorrect responses

Appendix F

Condition 3 Distractor Task Problems Data (ms)

Participant	Transfer 12	Transfer 13	Transfer 14	Transfer 15	Transfer 16	Transfer 17	Transfer 18	Transfer 19	Transfer 20	Transfer 21	Transfer 22
1	12728	4807	13710	5838	9434	6910	17845	4767	7501	6760	2513
2	2864	4686	4407	8973	3495	4737	6420	4867	9844	4336	3575
3	3505		5127	3104	5568		3345	4386	5328	6710	
4	7441	21501	5037	14300	13009	13149	21641	15222	14511	9174	10445
5	16794		9714	1873	10736	23253	35311	7751	8312	13720	4957
6	2935		8212	5238	5598	4186	6179	5678			4587
7	4396	3184							8572		2553
8	2003			2083		4577	1682	1492		1202	
9	11536	8091	5758	9223	8262	2464	11837	6759		11977	
10	3465	3856	2434	2834	3866	4857	3114	2905	2434	2033	4175
11	6870	8002	12277	6660		8262	7571	4766	4296	7011	8683
12		5228	2433	8111	7911	25116	8291	6269	17946	6419	
13	21971	18377	11867	12067	8942	13019	7511	10916	7721	8833	12508
14	2153	7571	3916	3455	5628	5428	3505	2033	5197	3765	4166
15			7421	5167	5718	8713	10375	8993	4397	5969	2594
16	2804		1913	6629		4766		5588	3905	7201	4235
17	5038	4767	10705	11847	13289	11617	4907	19858	6299		11376
18	2384	4497	6699	4957	1322	3515	6338	4827	6890	11196	4367
19	8938	3872	6523	8439	4388	6324	9691	9885	5456	13249	3989
20	18346	7141	6299	7531	9844	6359	17916	3415	4767	8162	7792

Blanks indicate incorrect responses

Appendix F

Condition 3 Distractor Task Problems Data (ms)

Participant	Transfer 23	Transfer 24	Transfer 25	Transfer 26	Transfer 27	Transfer 28	Transfer 29	Transfer 30	Transfer 31	Transfer 32	Transfer 33
1	3455	10986	7821	3826	2894	24966	3275	3665	8332	7010	8913
2	4226	5288	3976	5648	3114	6229	5007	5759	5769	4377	6659
3	5297	3235	2834	3935			7100		7931	7991	
4	16724	11507		7771	5638	5188	7010	7101	13049		15262
5	6779	6740	6259	11176	8813	24856	6189	7811	16323	7020	8802
6	3174	1802	6469	6459	2534	4998	4357	5238	4246	5939	7251
7	6039	1843		4997	5168	3666	6239	6199		3115	2314
8	1643	1803	1091	1523			981	1001		801	
9	1932	9143	5518	7271	9754		11066	3045		8262	5038
10	5959	5358	2374	3044	2775	2484	2724	3906	6279	2674	3815
11	5438	8242	10936	8682	5448	8121	13199	12839	5318	6589	8672
12		9223			12308	7171	9194	6530	4857	3255	7060
13	9664	17425	10205	18036		15292	11076	9534	8543	14631	
14	2874	3024	3976	2584	2273	3686	7921	5247	8242	3455	4356
15	5237	10485	5307	4287	7380	4887	4547	6659	5128	4276	3926
16	5247	7300	5158	6580	5978	10645	3846		11156	5197	7611
17	11887		16594	10074		26699	8082	8552		22703	11076
18		2273	5558	7070	6018			8682	8903	7561	7501
19	8145	13254	12936	9751	9094	7514	5137	7592	12004	8068	18259
20	7891	11236	4837	5858	15152	18557	2163	14981	4206	7681	7361

Blanks indicate incorrect responses

Appendix F

Condition 3 Distractor Task Problems Data (ms)

Participant	Transfer 34	Transfer 35	Transfer 36	Transfer 37	Transfer 38	Transfer 39	Transfer 40	Transfer 41	Transfer 42	Transfer 43	Transfer 44
1	9033	4957	8902	5318	7621	9473	5368	14712	4767	7781	8413
2	6720	7100	5317	8122	3505	2874	5518	5888	9984	4016	9254
3	3395	1873	6860	2954	3145	3976	5047	5468	5878	1753	2464
4	8743	7911	13079	10756		5738	5067	5037	4477	5158	5148
5		6749	5758	9824		4967	6589		7130	5207	17465
6	3685	3184	6179	3936	4176	4766	7201		2734		7611
7	4656	4587		2834	2323						
8				901			2504	1592	1612		
9		7280		8912	3575	6920	6118		7701	6829	5208
10	4156	2243	1482	6879	4056	3005	3225	4416	1802	2684	4176
11	6480	8332		26248	6320	7141	3144	16073	4576	17104	2944
12	6289	12147	13129	6539			2124	13409		3104	1842
13		27660	9965	15472	6819	9103	4406	9893	9774	6078	11206
14	11516	2593	4757	2985	4557	4296	1902	2904	2624	1613	4276
15	8082		6028	6109	3585	3775	6800	3725	4005	3906	2904
16		10566	7902	6018	7040	7851	2663	5959	4786	8162	
17	11046	5928	16543	5157		6459	16984	9223	10045	4537	12217
18	6499	5077	4326	5248	6630	5548	1833	9463	6299	2784	4366
19	13100	11789	8920	7828	5453	4407		8386	10881	13968	7949
20	7711	6339	5548	10365	4206	6970	7301	4517	7521	12749	5588

Blanks indicate incorrect responses

Appendix F

Condition 3 Distractor Task Problems Data (ms)

Participant	Transfer 45	Transfer 46	Transfer 47	Transfer 48	Transfer 49	Transfer 50	Transfer 51	Transfer 52	Transfer 53	Transfer 54	Transfer 55
1	9724	8742	2153	4276	7861	4306	4767	4456	7250	7491	4096
2	6980	6319	3615	4426	5127	3655	9363	2834	3495	8111	4727
3	8192	2113	1833	5598	3035	5999	3164	5457	4967		3805
4	7731	5298		8993	9654	6259	8632	7561	14601	11807	9623
5	12338	10375	8092			5638	3975	4356	9033	10255	3154
6	5108	6229	5448	4757	6058	2844	6269	2814	2494	3255	4597
7			3736	2083				2584			
8	1782		821	1722		922	781	812	1282	1392	1963
9	6009	6409	7882		6990				8021	5298	7481
10	3465	1543	1413	2443	5227	4647	3935	3826	4626	3445	2834
11		23094	15091	5708	5328	7641	5238	4487	5609	4446	4016
12		7782	9855	4156			5368	12778	6379	11006	
13	5267	5789	6740	12097	11837	7751	7520	11266	3615	4286	8562
14	7421	3175	4006	3144	9494	4536	2563	4377	3495	5318	3736
15	5508	2083	5758	4146	6730	3966	3646	3655	5408	4396	6149
16		3294	4336	4587	3545	13690	1433	3966	2854	6850	3335
17			13128	14221	10945	16093	9964	12969	10015	6599	8572
18	4246		10044		7691		5739	18537	5348		3275
19	13017	4109	7042	2961	17926	6682	5220	3754	6724	5813	7177
20		5188		13550	5778	2824	3375	3395	6459	9614	6930

Blanks indicate incorrect responses

Appendix F

Condition 3 Distractor Task Problems Data (ms)

Participant	Transfer 56	Transfer 57	Transfer 58	Transfer 59	Transfer 60	Transfer 61	Transfer 62	Transfer 63	Transfer 64	Transfer 65	Transfer 66
1	4927	4096	2473	8091	6579	4957	2704	2384	4156	4376	1762
2	3175	4887	2083	3415	3074	4526	3425	2794	6149	8673	16053
3	2874	2524	5328		3956	2554	6870	4847	4627	7531	4006
4		8082	8192	6219	5337	3105	7020	6189	6019	10495	9614
5	4206	1042		6199	1442		6469	4626	2894	18256	5598
6	3846	5077	5278	4387	2944	3745		6139	5568	3495	3255
7				2984		2003	2824	5017		3875	
8	862	901		781	721	1121					1162
9		10315	7321			4146		6439			
10	4176	2443	3385	1913	3716	4026	1602	1763	5407	4737	4066
11	4526	6259	2503	6199	3815	4977	4286	5909	5087	7230	6229
12	5939	18587	2173	6559	10004	7751	4897	10996	19728	8863	3535
13	2554	9864	9213	3735	7711	5818	8702	8152	8622	9584	8673
14	3916	5147	5037	4877	2984	3144	5408	3074	4646	3455	1793
15	5278	7862	3024	2594	2424	4206	3345	4437	9063	5788	3926
16		4527	11637	4206	5738	5768		2935	1312	10174	3584
17	8583	11055	13049		21031	7481	11647	9173	9173	30394	20259
18	9814	4156	4596	3906	1552	3565	4176	14871	6610	1713	9183
19	12422	7158	7434	13453	6445	16778	7100	5337	8899	6089	4982
20	6059	7481	2944	6579	7591	5228	11867		4587	7280	9383

Blanks indicate incorrect responses

Appendix F

Condition 3 Distractor Task Problems Data (ms)

Participant	Transfer 67	Transfer 68	Transfer 69	Transfer 70	Transfer 71	Transfer 72
1	7932	6389	2874	7341	1912	5829
2	5708	3976	4456	5408	4967	13179
3	5508	1582	7380	7701	9484	
4	9493	6920		14220	6149	
5	7480	3976	7641	1762	4667	
6	7060	5076	2253	3405	2654	3265
7		4967			1953	3986
8					2424	1482
9					9613	10906
10	6910		5478	4577	4978	
11	6740	4286	8732	4697	3695	11226
12	5759	17355	1833	6139	9534	9583
13	11746	10145	13008	7190	14450	7331
14	4006	4126	5077	4005	4917	2394
15		3616	3565	13048	2193	5628
16	4086		2863	3886	2824	3185
17	1903	7981	15011	10555	18046	2474
18		6850	1402	7561	3375	4717
19	8742	5773	10128	16000	13255	5855
20	3505	10655	4286	7510	11176	5078

Blanks indicate incorrect responses

Appendix G
Practice, Test, and Distractor Task Problems

Practice Task Problems:

5×1	5×2	5×3
5×4	5×5	5×6
5×7	5×8	5×9

Test Task Problems:

6×2	6×3	6×4
6×7	6×8	6×9

Condition 1 Distractor Task Problems:

2×3	2×4	2×6
2×7	2×8	2×9
3×2	3×4	3×6
3×7	3×8	3×9
4×2	4×3	4×6
4×7	4×8	4×9
7×2	7×3	7×4
7×6	7×8	7×9
8×2	8×3	8×4
8×6	8×7	8×9
9×2	9×3	9×4
9×6	9×7	9×8

Condition 2 Distractor Task Problems:

10 + 38	14 + 85	17 + 55
18 + 76	20 + 30	23 + 99
24 + 20	24 + 45	24 + 88
26 + 74	31 + 17	32 + 62
32 + 97	35 + 12	35 + 13
35 + 92	36 + 79	39 + 59
40 + 41	40 + 96	41 + 55
43 + 12	44 + 75	48 + 60
49 + 15	49 + 65	50 + 24
50 + 69	50 + 70	50 + 95
51 + 91	52 + 15	52 + 44
53 + 50	53 + 90	56 + 15
58 + 28	59 + 70	60 + 25
60 + 35	61 + 24	61 + 45
63 + 91	65 + 24	65 + 65
67 + 35	69 + 16	69 + 40
70 + 50	70 + 92	73 + 14
73 + 15	73 + 41	73 + 79

Appendix G
Practice, Test, and Distractor Task Problems

Condition 2 Distractor Task Problems, continued:

75 + 50	75 + 89	77 + 86
78 + 46	81 + 68	83 + 89
86 + 43	86 + 79	86 + 80
88 + 67	88 + 73	88 + 99
89 + 68	90 + 36	91 + 34
94 + 28	96 + 42	96 + 69

Condition 3 Distractor Task Problems:

6×13	6×14	6×15
6×16	6×17	6×19
6×20	6×21	6×22
6×23	6×24	6×25
6×26	6×27	6×28
6×29	6×30	6×31
6×32	6×33	6×34
6×35	6×36	6×37
6×38	6×41	6×42
6×43	6×44	6×45
6×46	6×47	6×48
6×49	6×50	6×53
6×54	6×55	6×56
6×57	6×58	6×59
6×60	6×61	6×62
6×63	6×65	6×66
6×68	6×69	6×70
6×71	6×74	6×75
6×77	6×78	6×79
6×82	6×84	6×85
6×86	6×87	6×88
6×89	6×90	6×91
6×93	6×95	6×96
6×97	6×98	6×99